State of Oregon Department of Environmental Quality

Example applications of the Waste Impact Calculator

Martin J. Brown, Martin.Brown@state.or.us

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Introduction

The Waste Impact Calculator (WIC) is a framework for estimating the life cycle environmental impacts of solid waste streams, and projecting the life cycle impacts associated with different solid waste management scenarios. See *Technical Overview of the Waste Impact Calculator* for general background.

The WIC framework can be exercised in many ways. This document shows several examples that use the R language.

- First, there is a realistic but simple WIC analysis, based on a real-world solid waste management question. This is fully coded, documented, and interpreted in R Markdown. This demonstrates many of the mechanics involved with working with WIC's tables and producing results.
- Second, there are screenshots from an interactive web app created with R's "shiny" package. This is a more extensive expression of the WIC idea, with multiple scenarios and diverse types of graphics available for a large number of Oregon counties. The goal of this app is to increase the user's understanding of the life cycle impacts associated with solid waste.

Example WIC analysis using R Markdown

by Martin Brown, Martin.Brown@state.or.us

Introduction

This R Markdown document provides an example application of the Waste Impact Calculator (WIC) framework. Using an actual real-world waste management question from an Oregon city (here renamed Anytown), it demonstrates the basic steps involved in nearly any WIC analysis.

You, the reader, play the part of a waste manager or sustainability analyst from Anytown. You will:

- convert a waste management question into waste streams linked to scenario labels in a ***massProfiles*** table;
- combine your ***massProfiles*** with the ***impactFactors*** table provided by WIC, and filter and summarize the results for each of your scenarios, in multiple impact categories (GHGs, water use, etc.);
- delve into the reasons the scenarios differ – or perhaps, fail to differ much; and finally,
- reflect on what WIC has and hasn't told you.

Along the way, you'll find pointers on how to properly combine, filter, and summarize WIC's data tables, so that the final results actually represent the scenarios you want to evaluate.

Intended audience

This document is oriented towards more technical users: those familiar with statistical or database operations. This document assumes a beginning-to-intermediate familiarity with the R language, especially the packages "base," "dplyr", "rmarkdown", and "ggplot2". Though R is used here, R is not specifically required to create results using WIC. No matter what computer setup is involved, the elementary steps will be the same – and you are responsible for your own work! :)

Before using this document, or WIC in general, as the basis for new analyses, you should have a clear understanding of:

- how WIC calculates impacts for individual life cycle stages (see "Prerequisites", below); and
- how file structures and joining commands (for example *left_join* and *full_join* in R's dplyr package) can create sets of impacts that represent the phases of the materials life cycle.

Prerequisites

- Read "Technical overview of the Waste Impact Calculator". This describes the the purpose, limitations, and basic operation of WIC. It also documents the meaning of all the fields in each of WIC's data tables – information that will, for the most part, not be repeated here.
- Have experience with R as described above.

Conventions

- the words "table" and "data frame" are used interchangeably. The latter refers to a specific data structure in R, but it is equivalent to a table.

- the words “mass” and “weight” are used interchangeably. The distinction between these terms is important in other fields, but not in Earthbound waste management.
- the term “impact category” is used to describe quantities such as global warming potentials, which are technically “LCIA profiles”, as well as quantities like water use summaries, which are technically “inventory metrics.”
- weights are in short tons

Anytown’s situation and your expectations of WIC

You work for Anytown’s sustainability department and are concerned about the environmental impacts of Anytown’s municipal food waste.

In particular you are considering implementing a food waste composting scheme, but don’t know if it is worth the effort it would require. You feel that composting food waste is likely to be better on an environmental impact basis than simply landfilling it, but it is unclear how big the improvement would be. Another option is the idea of trying to reduce the sheer generation of food waste through a public education campaign – which would have its own difficulties, but, as an “upstream” strategy, might be more powerful than the “downstream” one of composting.

You will use WIC to compare Anytown’s current treatment of food waste (the “baseline” scenario) with two scenarios for increasing composting of food waste, and two scenarios for reducing food waste generation.

You expect that WIC will estimate life cycle impacts for each scenario, in enough detail that the reasons for differences between scenarios can be understood. At the same time, you understand that WIC is about environmental impacts only – it will not specifically output other relevant information such as the cost of infrastructure or staff.

Therefore WIC is unlikely to be the only basis for Anytown’s final decision about how to proceed. But its environmental impact numbers should play an important part.

Defining baseline and alternative scenarios

Currently, none of the food waste Anytown collects is composted. Instead, food waste is included in general trash collection and taken to a landfill 178 miles away. However, Anytown’s municipal waste service includes a separate collection of yard debris, which is taken to a site 4 miles away and composted aerobically.

It has been proposed to allow Anytowners to throw food waste in their yard debris bins, so that the materials can be composted together. However, there is a complication: the nearby composting site cannot accept food waste, because it is too close to an airport, and birds attracted to the waste could present a danger to aircraft. The yard debris/food waste mixture will need to be taken to a different site for composting, 77 miles away.

Accordingly, your analysis is really about two materials: yard debris and food waste. Food waste can’t be considered on its own because food waste treatment can affect yard debris’ impacts. Management scenarios will differ in amounts of those two materials going to two end-of-life dispositions (landfilling and composting), as well as end-of-life transport distances.

To establish the tonnages linked to the baseline situation, you must do a a bit of estimating. Anytown knows how many tons of yard debris it picks up and composts each year (9000 tons), but not how much food waste it disposes as part of regular garbage disposal. Anytown does not do its own “waste sort” of disposed materials. However, Anytown is part of a larger metropolitan region, which has information for both food waste and yard debris. Based on the metropolitan region’s studies, you estimate that for every 9000 tons of yard debris composted by Anytown’s system, there are 7669 tons of food waste generated and landfilled as part of Anytown’s garbage.

Accordingly,

- the “baseline” scenario in your ***massProfiles*** is defined by 9000 tons of yard debris going 4 miles to composting, and 7669 tons of food debris going 178 miles to landfill.

To represent the proposed addition of food waste to yard debris, you define two more scenarios:

- “compostFW585”: where 585 tons of food waste are added to yard debris and all composting happens at the new site, 77 miles away; the remainder of food waste is landfilled as usual.
- “compostFW1000”: where 1000 tons food waste are added to yard debris and all composting happens at a new site, 77 miles away; the remainder of food waste is landfilled as usual.

You do not create a scenario where *all* food waste is included with yard debris. You consider it unlikely that all homes and businesses contributing to Anytown’s garbage collection will have the interest and ability to put all their food waste in with yard debris. In fact the compostFW585 scenario is considered most realistic, as it is based on the observed mixture of food waste and yard debris in a nearby city that collects food waste and yard debris together.

As an alternative to increased composting, you also create scenarios representing successful efforts to reduce the generation of food waste. Though this “upstream” solution is potentially powerful, anecdotal experience suggests that reducing food waste generation is not easy. An optimistic example is provided by the comprehensive WRAP progam in the UK, which reduced household food waste by 6% over 3 years. Half of that, a 3 percent reduction might be more realistic for Anytown.

The food waste reduction scenarios are:

- “reduceFW03”: no change in management sites or methods, but generation of food waste is reduced by 3 percent to 7439 tons; and
- “reduceFW06”: no change in management sites or method, but generation of food waste is reduced by 6 percent to 7209 tons.

You want to know:

- which scenario is associated with the lowest life cycle impacts, in multiple impact categories?
- in general, what are the reasons that scenarios perform the way they do?
- for example, which materials and life cycle stages represent the biggest part of this system’s associated life cycle impacts?
- and, does the necessity of adding transport distance undermine the benefits of composting?

Outline of the analysis

Your analysis will proceed in this order:

- preparing the R workspace

- loading in the two source data frames, ***massProfiles*** and ***impactFactors***
- calculating impacts and creating the master results data table, ***impactsInDetail***
- checking for internal consistency of ***impactsInDetail***
- creating summary statistics and graphics using both weight and impact perspectives

Preparing the R workspace

```
# checking working directory
getwd()

## [1] "C:/Users/mbrown2/Documents/Local repositories/wic3/wic-base/exampleAn
alysis"

# loading packages useful for the analysis
library(tidyverse)  # many useful functions for data management

## -- Attaching packages --------------------------------------- tidyverse 1.
3.0 --

## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.6     v dplyr   1.0.4
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflict
s() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(ggthemes)   # some themes for plotting
library(scales)     # useful functions for labeling charts

##
## Attaching package: 'scales'

## The following object is masked from 'package:purrr':
##
##     discard

## The following object is masked from 'package:readr':
##
##     col_factor

library(knitr)      # helps generate formatted output of various kinds
library(rmarkdown)  # converts RMarkdown documents to other formats
library(viridis)    # nice & accessible color schemes

## Loading required package: viridisLite

##
## Attaching package: 'viridis'
```

```
## The following object is masked from 'package:scales':
##
##     viridis_pal

library(svglite)    # helps write charts to SVG files
```

Loading *massProfiles* and *impactFactors*

As you recall from *Technical overview of the Waste Impact Calculator*, the ***massProfiles*** table describes waste management scenarios by listing, in detail, the mass of each waste material going to specific end-of-life dispositions (e.g. landfilling, recycling), from areas of interest ("wastesheds"), as well as (optionally) setting transport distances for those end-of-life treatments. Different waste management ideas, or "scenarios", are expressed as different numbers of tons going to different dispositions, and (optionally) different transport distances.

You have prepared a ***massProfiles*** table representing your five scenarios in a CSV file. Here you load it in to an R data frame, and print it out in a formatted table.

```
# loading the mass profile data into an R data frame
massProfiles <-
  read.csv(
    file = "massProfiles.csv",
    header = TRUE,
    stringsAsFactors = FALSE
  )
# a formatted printout
kable(
  massProfiles,
  caption="massProfiles for Anytown's analysis of food waste"
)
```

massProfiles for Anytown's analysis of food waste

scenario	wasteshed	material	disposition	umbDisp	tons	miles
baseline	Anytown	FoodWaste	landfilling	disposal	7669	178
baseline	Anytown	YardDebris	composting	recovery	9000	4
compostFW585	Anytown	FoodWaste	composting	recovery	585	77
compostFW585	Anytown	FoodWaste	landfilling	disposal	7084	77
compostFW585	Anytown	YardDebris	composting	recovery	9000	77
compostFW1000	Anytown	FoodWaste	composting	recovery	1000	77
compostFW1000	Anytown	FoodWaste	landfilling	disposal	6669	178
compostFW1000	Anytown	YardDebris	composting	recovery	9000	77
reduceFW03	Anytown	FoodWaste	landfilling	disposal	7439	178
reduceFW03	Anytown	YardDebris	composting	recovery	9000	4
reduceFW06	Anytown	FoodWaste	landfilling	disposal	7209	178
reduceFW06	Anytown	YardDebris	composting	recovery	9000	4

Notice how the ***massProfiles*** table, in its compact way, provides ALL the details of the management scenarios you defined earlier. The ***massProfiles*** table is the main place you provide input to the WIC system.

Here you list the fields in ***massProfiles***:

```
str(massProfiles)

## 'data.frame':    12 obs. of  7 variables:
##  $ scenario   : chr  "baseline" "baseline" "compostFW585" "compostFW585" .
..
##  $ wasteshed  : chr  "Anytown" "Anytown" "Anytown" "Anytown" ...
##  $ material   : chr  "FoodWaste" "YardDebris" "FoodWaste" "FoodWaste" ...
##  $ disposition: chr  "landfilling" "composting" "composting" "landfilling"
...
##  $ umbDisp    : chr  "disposal" "recovery" "recovery" "disposal" ...
##  $ tons       : int  7669 9000 585 7084 9000 1000 6669 9000 7439 9000 ...
##  $ miles      : int  178 4 77 77 77 77 178 77 178 4 ...
```

As you recall, *tons* is the critical variable. This is a mass of some waste material, in short tons. All the other variables serve to identify or qualify where the *tons* came from, which disposition is being used, etc.

Note that the technical disposition of the material (landfilling or composting) is recorded independently of its legal classification (recovery or disposal) in the field umbDisp. The umbDisp field is provided as a convenience, so that you can calculate weight-based statistics such as diversion rates. However, impacts are always calculated based on the disposition name. The legal classification should have no effect on impact results.

Here are a few weight-based waste statistics for each scenario from ***massProfiles***: the tons of waste generated, the tons of waste recovered, and the weight-based recovery rate, as a fraction.

```
massProfiles %>%
  group_by(scenario) %>%
  summarize(
    tonsGenerated=sum(tons),
    recoveredTons=sum(ifelse(umbDisp=="recovery",tons,0))
    ) %>%
  mutate(
    weightBasedRecoveryRate=round(recoveredTons/tonsGenerated,2)
    ) %>%
  kable()
```

scenario	tonsGenerated	recoveredTons	weightBasedRecoveryRate
baseline	16669	9000	0.54
compostFW1000	16669	10000	0.60
compostFW585	16669	9585	0.58
reduceFW03	16439	9000	0.55
reduceFW06	16209	9000	0.56

It appears that the scenario compostFW1000 has the highest weight-based recovery rate. You are interested in finding out – does that mean compostFW1000 will also represent the smallest life cycle impact? Stay tuned!

WIC's other source data table is ***impactFactors***. It contains environmental impact magnitudes for standard weights of solid waste materials, classified by disposition and life cycle stage.

Here you load the complete "impactFactors.csv" file, provided with WIC, into an R data frame, which you name ***impactFactorsAll***. Since it is thousands of records long, you print out only a small sample of it to see what it looks like…

```
impactFactorsAll <-
  read.csv(
    file = "../impactFactors/distributable/impactFactors.csv",
    header = TRUE,
    stringsAsFactors = FALSE  #
  )
kable(impactFactorsAll %>% head(20))
```

material	LCstage	disposition	corporateSource	impactCategory	impactUnits	impliedMiles	impactCategoryLong	impactFactor	gabiExportDate	wicImportDate
AcceptedOtherSteel	endOfLife	incinerationNoER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	85.14568	2020-11-06	2021-02-11
AcceptedOtherSteel	endOfLife	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	39.36742	2020-11-06	2021-02-11
AcceptedOtherSteel	endOfLife	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	-1455.27759	2020-11-06	2021-02-11
AcceptedOtherSteel	endOfLifeTransport	incinerationNoER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
AcceptedOtherSteel	endOfLifeTransport	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
AcceptedOtherSteel	endOfLifeTransport	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
AcceptedOtherSteel	production	production	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	2213.56286	2020-11-06	2021-02-11
Aluminum	endOfLife	incinerationNoER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	142.37133	2020-11-06	2021-02-11
Aluminum	endOfLife	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	39.36742	2020-11-06	2021-02-11
Aluminum	endOfLife	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	-2267.13376	2020-11-06	2021-02-11
Aluminum	endOfLifeTransport	incinerationNoER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
Aluminum	endOfLifeTransport	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
Aluminum	endOfLifeTransport	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01883	2020-11-06	2021-02-11
Aluminum	production	production	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	4724.99869	2020-11-06	2021-02-11
AsepticContainers	endOfLife	incinerationER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	210.11534	2020-11-06	2021-02-11
AsepticContainers	endOfLife	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	388.83016	2020-11-06	2021-02-11
AsepticContainers	endOfLife	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	-578.46351	2020-11-06	2021-02-11
AsepticContainers	endOfLifeTransport	incinerationER	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01006	2020-11-06	2021-02-11
AsepticContainers	endOfLifeTransport	landfilling	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01006	2020-11-06	2021-02-11
AsepticContainers	endOfLifeTransport	recyclingGeneric	IPCC AR5	GWP 100	kg CO2 eq.	180	GWP100, excl biogenic carbon	41.01006	2020-11-06	2021-02-11

Many of these records, and some of the diagnostic fields such as *corporateSource* and *gabiExportDate*, are unnecessary for the current analysis. You cut ***impactFactorsAll*** down to a manageable size – using only the materials and dispositions and impact categories that you need – and save the result as ***impactFactors***.

```
# learning the materials in the massProfiles table and
# saving them as a vector of string values
materialNamesToUse <-
  massProfiles %>%
  select(material) %>%
  distinct() %>%
  pull(material)

# doing the same thing for disposition names
dispositionNamesToUse <-
  massProfiles %>%
  select(disposition) %>%
  distinct() %>%
  pull(disposition)
# need to keep production impacts too
dispositionNamesToUse <-
  c("production",dispositionNamesToUse)

# creating a list of impactCategories to use
allImpactCategories <-
  impactFactorsAll %>% select(impactCategory) %>% distinct %>% pull()
impactCategoriesToUse <-
  setdiff(
    allImpactCategories,
    # what follow are the categories to NOT use
    c(
#      "GWP 100",
#      "GWP 100 (EpaFcs)",
      "GWP 100 (Slash)",
      "GWP 20 (Slash)",
      "GWP 20 (EpaFcs)",
      "GWP 20",
#      "Human health particulate air",
      "Human toxicity, non-cancer",
      "Human toxicity, cancer"
      )
  )

# for the sake of brevity in printouts for this
# example analysis,
# limiting the impactFactors to the materials and
# dispositions in massProfiles, and ten impact
# categories.  In regular usage there is no
```

```r
# need to do such filtering -- the impactFactors
# data frame may be left complete.
impactFactors <-
  impactFactorsAll %>%
  filter(
    material %in% materialNamesToUse &
      disposition %in% dispositionNamesToUse &
      impactCategory %in% impactCategoriesToUse
  ) %>%
  # there are also several diagnostic columns that may be
  # removed for the sake of this example analysis.. see
  # Technical Overview of the Waste Impact Calculator
  # for their meaning.
  select(
    -corporateSource, -impactCategoryLong,
    -gabiExportDate, -wicImportDate
  ) %>%
  # sorting it for easier reading
  arrange(impactCategory, material, LCstage, disposition)
# a formatted printout of 20 random lines
kable(
  impactFactors %>% sample_n(20),
  caption="20 random lines of Anytown's impactFactors table"
)
```

20 random lines of Anytown's impactFactors table

material	LCstage	disposition	impactCategory	impactUnits	impliedMiles	impactFactor
YardDebris	endOfLifeTransport	composting	Energy demand	MJ	180	603.4704492
FoodWaste	endOfLife	landfilling	Water consumption	kg	180	-250.7538380
FoodWaste	endOfLifeTransport	landfilling	GWP 100	kg CO2 eq.	180	41.0188344
YardDebris	production	production	Eutrophication	kg N eq.	180	0.0327298
FoodWaste	endOfLife	landfilling	Eutrophication	kg N eq.	180	1.5840044
YardDebris	endOfLifeTransport	composting	GWP 100 (EpaFcs)	kg CO2 eq.	180	40.8536951
FoodWaste	endOfLife	landfilling	Ecotoxicity	CTUe	180	3.7735100
YardDebris	endOfLifeTransport	composting	Ozone depletion	kg CFC 11 eq.	180	0.0000000
YardDebris	endOfLife	landfilling	GWP 100 (EpaFcs)	kg CO2 eq.	180	819.0801850
FoodWaste	endOfLife	landfilling	GWP 100	kg CO2 eq.	180	343.6771280
YardDebris	production	production	Energy demand	MJ	180	258.3278333
FoodWaste	endOfLifeTransport	composting	Energy demand	MJ	180	603.4704492
FoodWaste	endOfLifeTransport	landfilling	Human health particulate air	kg PM2.5 eq.	180	0.0048426
FoodWaste	endOfLife	composting	Smog air	kg O3 eq.	180	1.9381548
YardDebris	endOfLifeTransport	composting	GWP 100	kg CO2 eq.	180	41.0188344
FoodWaste	endOfLifeTransport	landfilling	Energy demand	MJ	180	603.4704492
YardDebris	endOfLifeTransport	landfilling	GWP 100 (EpaFcs)	kg CO2 eq.	180	40.8449565
FoodWaste	endOfLifeTransport	landfilling	Eutrophication	kg N eq.	180	0.0120146
YardDebris	endOfLife	landfilling	Water consumption	kg	180	-507.7033219
YardDebris	endOfLife	composting	Acidification	kg SO2 eq.	180	0.9002805

As you recall from *Technical overview of the Waste Impact Calculator*, the critical field in this table is *impactFactor*. This number expresses an environmental impact for a particular mass 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.

The ***impactFactors*** data frame should have EXACTLY one record for each combination of material, life cycle stage, disposition, and impactCategory of interest. Though ***impactFactors*** tables provided by Oregon DEQ should have this characteristic, you can check it if you desire, for example like this:

```
# checking for rows of impactFactors that might be duplicates
# and printing a summary sentence
print(
  paste(
    "There are ",
    impactFactors %>%
      group_by(material, LCstage, disposition, impactCategory) %>%
      summarise(myCount=n()) %>% # number of rows in each group
      filter(myCount != 1) %>% # keep only rows where count <> 1
      nrow(),
    " rows in impactFactors that need to be inspected for duplicates.",
    sep=""
  )
)

## `summarise()` has grouped output by 'material', 'LCstage', 'disposition'.
You can override using the `.groups` argument.

## [1] "There are 0 rows in impactFactors that need to be inspected for dupli
cates."
```

Merging the two tables to produce *impactsInDetail*.

You must merge ***massProfiles*** and ***impactFactors*** to calculate impacts, but before you do that you must address a limitation of ***massProfiles***. So far ***massProfiles*** only includes tons of materials handled at the end-of-life phase of the life cycle. You must also account for the tons of those materials that are handled at two other life cycle stages: end-of-life transport and production.

You will add tonnages representing production here using a simple copy- and append operation. In the following code, all the cases from ***massProfiles*** are copied, labeled with a *disposition* (and *umbDisp*) of "production," and then added back to ***massProfiles***, creating a new data frame, ***massProfilesPlus***.

```
# copy end-of-life tons and label them as production tons
tempProductionMasses <-
  massProfiles %>%
  mutate(
    disposition="production",
```

```
    umbDisp="production",
    miles=NA
  )
# add the production tons to the end-of-life tons
massProfilesPlus <-
  bind_rows(
    massProfiles,
    tempProductionMasses
  ) %>%
  # sort the new, larger table
  arrange(
    scenario, wasteshed, material, disposition
  )
rm(tempProductionMasses) # remove temporary table
```

The resulting table, ***massProfilesPlus***, should have exactly twice the total tonnage of ***massProfiles***. Moreover, within each *scenario*, production tons should have the same sum as end-of-life tons. This too you can check...

```
print(
  paste(
    "Total tonnage in massProfiles is ",
    sum(massProfiles$tons),
    ".",
    sep=""
  )
)

## [1] "Total tonnage in massProfiles is 82655."

print(
  paste(
    "Total tonnage in massProfilesPlus is ",
    sum(massProfilesPlus$tons),
    ".",
    sep=""
  )
)

## [1] "Total tonnage in massProfilesPlus is 165310."

massProfilesPlus %>%
  group_by(scenario) %>%
  summarise(
    prodTons=sum(ifelse(umbDisp=="production",tons,0)),
    eolTons=sum(ifelse(umbDisp!="production",tons,0))
  ) %>%
  print()

## # A tibble: 5 x 3
##   scenario      prodTons eolTons
```

```
## * <chr>            <dbl>   <dbl>
## 1 baseline         16669   16669
## 2 compostFW1000    16669   16669
## 3 compostFW585     16669   16669
## 4 reduceFW03       16439   16439
## 5 reduceFW06       16209   16209
```

The tonnages associated with end-of-life transport are still missing, but you will generate them during the following merge of ***massProfiles*** and ***impactFactors***.

The merge is made on unique combinations of *material* and *disposition* name. However, since ***impactFactors*** has *two* life cycle stages (endOfLifeTransport and endOfLife) in the field *LCstage* for each *disposition* name, records will effectively be added to represent endOfLifeTransport tons.

The merged file has both tons (from the ***massProfiles*** table) and *impactFactor* scaled to tons (from the ***impactFactors*** table), which can then be multiplied to get an impact in units of *impactUnits*.

Like so:

```
impactsInDetail <-
  # joining all impact factors relevant to massProfiles
  left_join(  # important: use left_join not full_join
    massProfilesPlus,
    impactFactors,
    by = c("material", "disposition")
  ) %>%
  # calculating impacts with special considerations
  # for end-of-life transport impacts
  mutate(
    # if miles is missing replace it with default value
    miles = ifelse(is.na(miles), impliedMiles, miles),
    # calculate impact
    impact =
      case_when(
        LCstage != "endOfLifeTransport" ~ tons*impactFactor,
        LCstage == "endOfLifeTransport" ~
          tons*(miles/impliedMiles)*impactFactor
      )
  ) %>%
  arrange(impactCategory, scenario, material, LCstage, disposition)
```

This creates a data frame, ***impactsInDetail***, with records for each combination of *scenario, wasteshed, material, LCstage, disposition,* and *impactCategory*. A printout of this table is very lengthy, so as a visual check, you print out only the records associated with a single *impactCategory*:

```
kable(
  impactsInDetail %>%
```

```
    filter(impactCategory==sample(impactCategoriesToUse, 1)),
  caption="impactsInDetail for a single impactCategory"
)
```

impactsInDetail for a single impactCategory

scenario	wasteshed	material	disposition	umbDisp	tons	miles	LCstage	impactCategory	impactUnits	impliedMiles
baseline	Anytown	FoodWaste	landfilling	disposal	7669	178	endOfLife	Acidification	kg SO2 eq.	180
baseline	Anytown	FoodWaste	landfilling	disposal	7669	178	endOfLifeTransport	Acidification	kg SO2 eq.	180
baseline	Anytown	FoodWaste	production	production	7669	180	production	Acidification	kg SO2 eq.	180
baseline	Anytown	YardDebris	composting	recovery	9000	4	endOfLife	Acidification	kg SO2 eq.	180
baseline	Anytown	YardDebris	composting	recovery	9000	4	endOfLifeTransport	Acidification	kg SO2 eq.	180
baseline	Anytown	YardDebris	production	production	9000	180	production	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	composting	recovery	1000	77	endOfLife	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	landfilling	disposal	6669	178	endOfLife	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	composting	recovery	1000	77	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	landfilling	disposal	6669	178	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	production	production	1000	180	production	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	FoodWaste	production	production	6669	180	production	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	YardDebris	composting	recovery	9000	77	endOfLife	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	YardDebris	composting	recovery	9000	77	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW1000	Anytown	YardDebris	production	production	9000	180	production	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	composting	recovery	585	77	endOfLife	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	landfilling	disposal	7084	77	endOfLife	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	composting	recovery	585	77	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	landfilling	disposal	7084	77	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	production	production	585	180	production	Acidification	kg SO2 eq.	180
compostFW585	Anytown	FoodWaste	production	production	7084	180	production	Acidification	kg SO2 eq.	180
compostFW585	Anytown	YardDebris	composting	recovery	9000	77	endOfLife	Acidification	kg SO2 eq.	180
compostFW585	Anytown	YardDebris	composting	recovery	9000	77	endOfLifeTransport	Acidification	kg SO2 eq.	180
compostFW585	Anytown	YardDebris	production	production	9000	180	production	Acidification	kg SO2 eq.	180

reduceFW03	Anytown	FoodWaste	landfilling	disposal	7439	178	endOfLife	Acidification	kg SO2 eq.	180	3.0183015	22453.14481
reduceFW03	Anytown	FoodWaste	landfilling	disposal	7439	178	endOfLifeTransport	Acidification	kg SO2 eq.	180	0.0881314	648.32461
reduceFW03	Anytown	FoodWaste	production	production	7439	180	production	Acidification	kg SO2 eq.	180	15.8027864	117556.92828
reduceFW03	Anytown	YardDebris	composting	recovery	9000	4	endOfLife	Acidification	kg SO2 eq.	180	0.9002805	8102.52432
reduceFW03	Anytown	YardDebris	composting	recovery	9000	4	endOfLifeTransport	Acidification	kg SO2 eq.	180	0.0881314	17.62627
reduceFW03	Anytown	YardDebris	production	production	9000	180	production	Acidification	kg SO2 eq.	180	0.0629918	566.92620
reduceFW06	Anytown	FoodWaste	landfilling	disposal	7209	178	endOfLife	Acidification	kg SO2 eq.	180	3.0183015	21758.93547
reduceFW06	Anytown	FoodWaste	landfilling	disposal	7209	178	endOfLifeTransport	Acidification	kg SO2 eq.	180	0.0881314	628.27962
reduceFW06	Anytown	FoodWaste	production	production	7209	180	production	Acidification	kg SO2 eq.	180	15.8027864	113922.28740
reduceFW06	Anytown	YardDebris	composting	recovery	9000	4	endOfLife	Acidification	kg SO2 eq.	180	0.9002805	8102.52432
reduceFW06	Anytown	YardDebris	composting	recovery	9000	4	endOfLifeTransport	Acidification	kg SO2 eq.	180	0.0881314	17.62627
reduceFW06	Anytown	YardDebris	production	production	9000	180	production	Acidification	kg SO2 eq.	180	0.0629918	566.92620

Note that each line is labeled with the *umbDisp* from ***massProfiles***, so distinctions can be made between recovery and disposal impacts or tonnages if desired.

Checking the internal consistency of *impactsInDetail*

Before using the ***impactsInDetail*** table to calculate results, some basic quality checks should be performed.

For example, tonnages associated with all life cycles should have the same value within each scenario. That is, within each scenario, tons for "production" should be the same as tons for "endOfLifeTransport" and "endOfLife". You use code like the following to confirm that:

```
impactsInDetail %>%
  group_by(LCstage, scenario) %>%
  summarise(tons=sum(tons)) %>%
  arrange(scenario, LCstage) %>%
  kable()

## `summarise()` has grouped output by 'LCstage'. You can override using the
`.groups` argument.
```

LCstage	scenario	tons
endOfLife	baseline	166690
endOfLifeTransport	baseline	166690
production	baseline	166690
endOfLife	compostFW1000	166690
endOfLifeTransport	compostFW1000	166690
production	compostFW1000	166690
endOfLife	compostFW585	166690
endOfLifeTransport	compostFW585	166690
production	compostFW585	166690
endOfLife	reduceFW03	164390
endOfLifeTransport	reduceFW03	164390
production	reduceFW03	164390
endOfLife	reduceFW06	162090
endOfLifeTransport	reduceFW06	162090
production	reduceFW06	162090

You note that tonnages in the table above are not identical to tonnages summarized earlier for the the ***massProfiles*** table. Besides the recent addition of production-related tons, and end-of-life transport tons, ***impactsInDetail*** has a complete set of tons for every *impactCategory* in use.

You also check that every record has a value in the *impactFactor* field. No impact factors should be missing, and any impact factors that are exactly zero should be viewed with suspicion (because impact factors of exactly zero are unlikely, and may represent a computation error or lazy assumption). In addition, *impact* and *tons* may be zero but should not be missing. These things can be checked with code like this:

```
impactsInDetail %>%
  filter(is.na(impactFactor) | impactFactor==0) %>%
  nrow()

## [1] 0

impactsInDetail %>%
  filter(is.na(impact)) %>%
  nrow()

## [1] 0

impactsInDetail %>%
  filter(is.na(tons)) %>%
  nrow()

## [1] 0
```

In each of these cases, your nrow() call has output 0. This means that your ***impactsInDetail*** table has passed these particular quality checks. If nrow() output >1, then it would be necessary to backtrack and correct something.

When ***impactsInDetail*** fails such simple internal-consistency checks, it is likely to be the result of mismatches between the ***massProfiles*** and ***impactFactors*** tables. Spellings of *material* and *disposition* names must match exactly, and every field in every table (with the exception of the *miles* field) must be filled in with a reasonable value.

Creating tabular and graphical output

Guidelines

The ***impactsInDetail*** data frame is the source of all future output from your analysis. Most results of interest – for example, the total waste tonnages and total impacts linked to each scenario – are the result of simple filter, group, and summation operations on tons or impacts in ***impactsInDetail***.

When creating results from ***impactsInDetail***, you recall that:

- there is much redundancy in this data table now: records representing every combination of scenario, wasteshed, material, LCstage, disposition, and impactCategory. So data must be filtered down to the desired specific content to avoid miscalculation.
- when tons are summed, they should be restricted to tons marked with the “endOfLife” LCstage. The tons that appear in other LCstages are redundant and only serve for the calculation of the impacts of those stages.
- furthermore, when tons are summed, they should be restricted to a single impact category (it should not matter which) – as the complete set of tonnages has been repeated for every impact category.
- impacts should be summed only within a single impactCategory – unless you are willing to create, program, and defend a method for normalizing and/or summarizing across multiple impact categories.

Some utility objects

For the purpose of creating charts and tables, a few miscellaneous objects could be useful:

- a plaintext list of material names, sorted in descending order of abundance. (While the current example analysis has only 2 materials, many WIC analyses will be considerably more involved.)

- a table of likely impact category labels. (Impact categories like “Energy demand” do not currently include physical units, such as “MJ” for megajoules. An impact category label would merge those for use on chart axes.)
- a graphical theme for charts
- an ordered list of scenario names

Creating those things…

```
# most abundant materials in the wastestream, in order
materialSortOrder <-
  massProfiles %>%
  group_by(material) %>%
  summarise(tons=sum(tons)) %>%
  arrange(desc(tons)) %>%
  pull(material)
# a table of impact categories combined with units
# (for use in chart labels)
impactLabels <-
  impactFactors %>%
  select(impactCategory, impactUnits) %>%
  distinct() %>%
  mutate(
    impactLabel =
      paste(
        impactCategory,
        " (",
        impactUnits,
        ")",
        sep=""
      )
  )
# a custom graphic theme for charts, inspired by
# the fivethirtyeight theme
theme_539 <- function() {
  theme_fivethirtyeight() +
  theme(
    rect=element_rect(fill="transparent"),
    panel.grid = element_blank(),
    axis.ticks = element_line()
  )
}

# making an ordered list of scenarios, where "baseline" is first
scenarioOrder <-
  c(
    "baseline",
    setdiff(
        massProfiles %>%
        select(scenario) %>%
        distinct() %>%
        pull(scenario),
```

```
      "baseline")
  )
```

Weights of waste in each of the scenarios

Your analysis starts with a review of the weights handled in each scenario. It's a good way to assure yourself your ***massProfiles*** have been entered accurately.

You recall that when weights are summed, only the "endOfLife" *LCstage* is used, and only a single *impactCategory* is used.

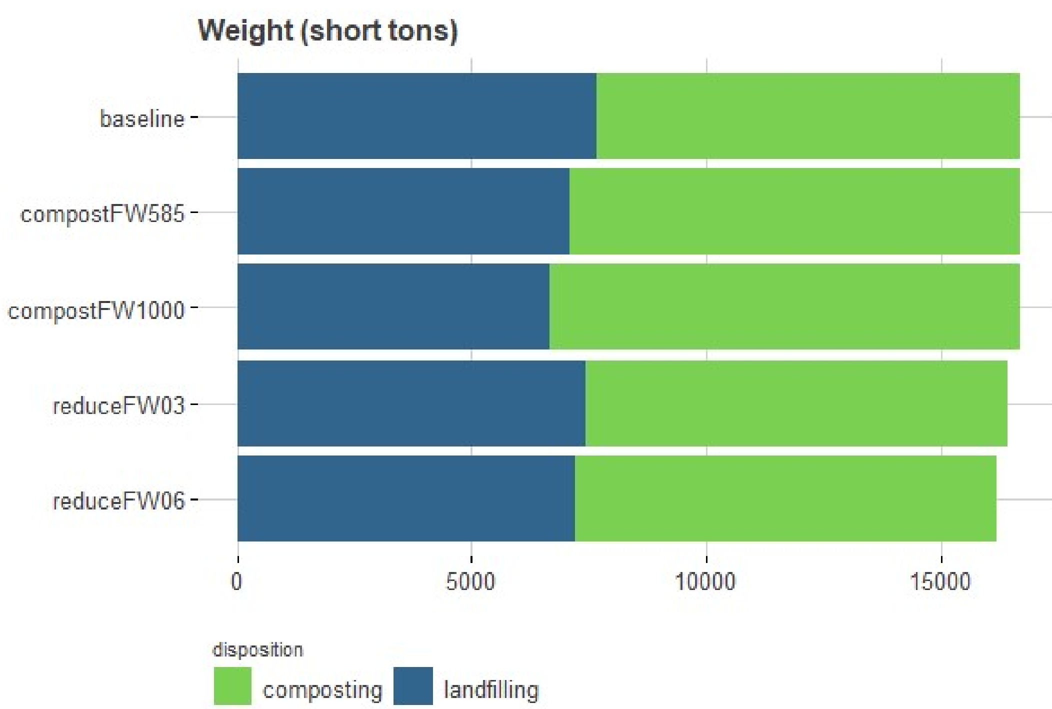
```
# summing weights by disposition for each scenario
tempWeightData1 <-
  impactsInDetail %>%
  filter(
    LCstage == "endOfLife" &
      impactCategory==sample(impactCategoriesToUse,1)
    ) %>%
  group_by(scenario, disposition) %>%
  summarise(tons=sum(tons)) %>%
  ungroup() %>%
  filter(tons != 0) %>%
  mutate(scenario= factor(scenario, levels=rev(scenarioOrder)))

## `summarise()` has grouped output by 'scenario'. You can override using the
`.groups` argument.

kable(tempWeightData1)
```

scenario	disposition	tons
baseline	composting	9000
baseline	landfilling	7669
compostFW1000	composting	10000
compostFW1000	landfilling	6669
compostFW585	composting	9585
compostFW585	landfilling	7084
reduceFW03	composting	9000
reduceFW03	landfilling	7439
reduceFW06	composting	9000
reduceFW06	landfilling	7209

You make that weight data into a chart…

```
tempWeightChart1 <-
  ggplot()+
  ggtitle("Weight (short tons)")+
  theme_539()+
  geom_bar(
    data = tempWeightData1,
    aes(x = scenario, y= tons, fill= disposition),
    color=NA,
```

```
    stat="identity"
  )+
  scale_fill_viridis(begin=0.32, end=0.8, discrete = TRUE,
                     direction = -1)+
  coord_flip()+
  guides(fill=guide_legend(ncol=2, title.position = "top"))+
  theme(
    rect=element_rect(fill="transparent"),
    plot.title = element_text(size=12),
    legend.position="bottom",
    legend.title = element_text(size=8),
    legend.justification="left"
    )
# printing the chart to the current device
tempWeightChart1
```




```
# saving the chart as external files
ggsave("chart_output/weights.png")

## Saving 6.5 x 4.5 in image

ggsave("chart_output/weights.svg")

## Saving 6.5 x 4.5 in image
```

That chart shows you that most of the scenarios are similar in terms of total weight, and management changes between scenarios are modest.

With a bit more coding, you can produce the same chart with individual materials separated.

```
# summing weights by disposition for each scenario and material
tempWeightData2 <-
  impactsInDetail %>%
  filter(
    LCstage == "endOfLife" &
      impactCategory==sample(impactCategoriesToUse, 1)
    ) %>% # correct set for weight calculations
  group_by(scenario, material, disposition) %>%
  summarise(tons=sum(tons)) %>%
  ungroup() %>%
  filter(tons != 0) %>%
  mutate(scenario= factor(scenario, levels=scenarioOrder))
```

```
## `summarise()` has grouped output by 'scenario', 'material'. You can overri
de using the `.groups` argument.
```

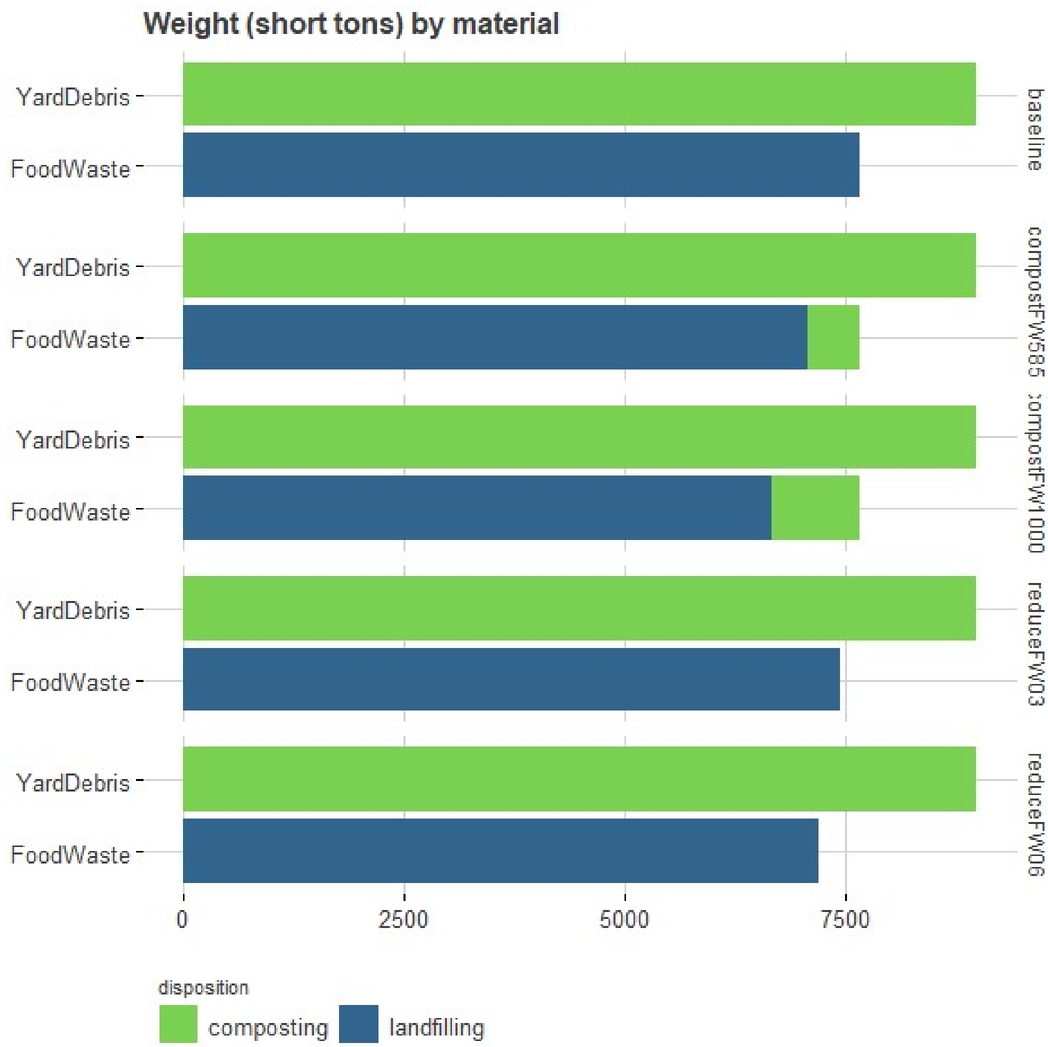
```
kable(tempWeightData2)
```

scenario	material	disposition	tons
baseline	FoodWaste	landfilling	7669
baseline	YardDebris	composting	9000
compostFW1000	FoodWaste	composting	1000
compostFW1000	FoodWaste	landfilling	6669
compostFW1000	YardDebris	composting	9000
compostFW585	FoodWaste	composting	585
compostFW585	FoodWaste	landfilling	7084
compostFW585	YardDebris	composting	9000
reduceFW03	FoodWaste	landfilling	7439
reduceFW03	YardDebris	composting	9000
reduceFW06	FoodWaste	landfilling	7209
reduceFW06	YardDebris	composting	9000

Making a weight chart with materials separated:

```
tempWeightChart2 <-
  ggplot()+
  ggtitle("Weight (short tons) by material")+
  theme_539()+
  geom_bar(
    data = tempWeightData2,
    aes(x = material, y= tons, fill= disposition),
    color=NA,
    stat="identity"
  )+
  scale_fill_viridis(begin=0.32, end=0.8, discrete = TRUE,
                     direction = -1)+
  coord_flip()+
```

```
  facet_grid(scenario~.)+
  guides(fill=guide_legend(ncol=2, title.position = "top"))+
  theme(
    rect=element_rect(fill="transparent"),
    plot.title = element_text(size=12),
    legend.position="bottom",
    legend.title = element_text(size=8),
    legend.justification="left",
    strip.text=element_text(size=9)
    )
# printing the chart to the current device
tempWeightChart2
```




```
# saving the chart as external files
ggsave("chart_output/weightsInd.png")

## Saving 6.5 x 6.5 in image
```

```
ggsave("chart_output/weightsInd.svg")

## Saving 6.5 x 6.5 in image
```

This chart shows you your ***massProfiles*** have described your scenarios fairly. Yard debris does not change its weight throughout all scenarios, while the treatment of food waste varies somewhat.

Life cycle impacts for waste in each scenario

Now for comparison, you look at the impacts associated with those scenarios. But here, output will be voluminous, since you have a large number of impact categories to consider. All your choices are in this list: GWP 100, GWP 100 (EpaFcs), Acidification, Ecotoxicity, Eutrophication, Human health particulate air, Ozone depletion, Smog air, Energy demand, Water consumption.

You start by summing up the impacts in similar detail to the first weight chart:

```
tempImpactData1 <-
  impactsInDetail %>%
  group_by(scenario, impactCategory, impactUnits) %>%
  summarise(impact=sum(impact)) %>%
  ungroup() %>%
  mutate(
    scenario = factor(scenario, levels = rev(scenarioOrder)),
    impactLabel =
      paste(
        impactCategory,
        " (",
        impactUnits,
        ")",
        sep=""
      )
  )

## `summarise()` has grouped output by 'scenario', 'impactCategory'. You can
override using the `.groups` argument.

kable(
  tempImpactData1,
  caption="summed impacts for each scenario and impactCategory"
)
```

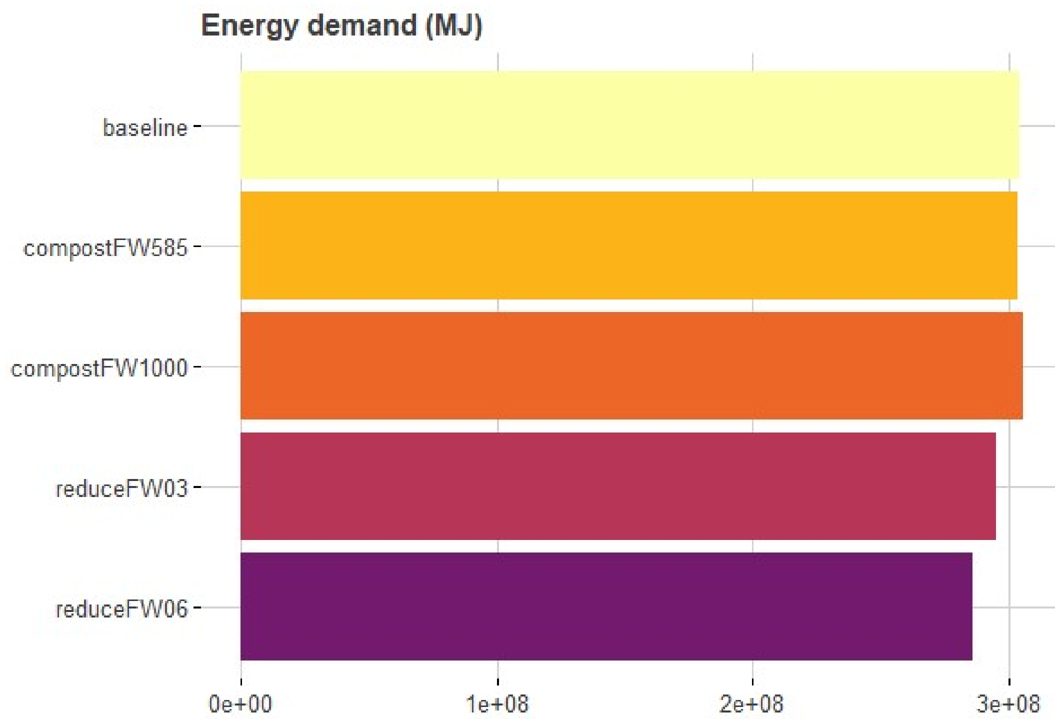
summed impacts for each scenario and impactCategory

scenario	impactCategory	impactUnits	impact	impactLabel
baseline	Acidification	kg SO2 eq.	1.536944e+05	Acidification (kg SO2 eq.)
baseline	Ecotoxicity	CTUe	1.171997e+08	Ecotoxicity (CTUe)
baseline	Energy demand	MJ	3.040130e+08	Energy demand (MJ)
baseline	Eutrophication	kg N eq.	1.387923e+05	Eutrophication (kg N eq.)
baseline	GWP 100	kg CO2 eq.	1.601632e+07	GWP 100 (kg CO2 eq.)

baseline	GWP 100 (EpaFcs)	kg CO2 eq.	1.059028e+07	GWP 100 (EpaFcs) (kg CO2 eq.)
baseline	Human health particulate air	kg PM2.5 eq.	1.584823e+04	Human health particulate air (kg PM2.5 eq.)
baseline	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)
baseline	Smog air	kg O3 eq.	7.646943e+05	Smog air (kg O3 eq.)
baseline	Water consumption	kg	1.004051e+09	Water consumption (kg)
compostFW1000	Acidification	kg SO2 eq.	1.518486e+05	Acidification (kg SO2 eq.)
compostFW1000	Ecotoxicity	CTUe	1.193495e+08	Ecotoxicity (CTUe)
compostFW1000	Energy demand	MJ	3.050143e+08	Energy demand (MJ)
compostFW1000	Eutrophication	kg N eq.	1.373021e+05	Eutrophication (kg N eq.)
compostFW1000	GWP 100	kg CO2 eq.	1.572895e+07	GWP 100 (kg CO2 eq.)
compostFW1000	GWP 100 (EpaFcs)	kg CO2 eq.	1.063685e+07	GWP 100 (EpaFcs) (kg CO2 eq.)
compostFW1000	Human health particulate air	kg PM2.5 eq.	1.585763e+04	Human health particulate air (kg PM2.5 eq.)
compostFW1000	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)
compostFW1000	Smog air	kg O3 eq.	7.664987e+05	Smog air (kg O3 eq.)
compostFW1000	Water consumption	kg	1.004794e+09	Water consumption (kg)
compostFW585	Acidification	kg SO2 eq.	1.523978e+05	Acidification (kg SO2 eq.)
compostFW585	Ecotoxicity	CTUe	1.184438e+08	Ecotoxicity (CTUe)
compostFW585	Energy demand	MJ	3.031141e+08	Energy demand (MJ)
compostFW585	Eutrophication	kg N eq.	1.378910e+05	Eutrophication (kg N eq.)
compostFW585	GWP 100	kg CO2 eq.	1.574730e+07	GWP 100 (kg CO2 eq.)
compostFW585	GWP 100 (EpaFcs)	kg CO2 eq.	1.051702e+07	GWP 100 (EpaFcs) (kg CO2 eq.)
compostFW585	Human health particulate air	kg PM2.5 eq.	1.584181e+04	Human health particulate air (kg PM2.5 eq.)
compostFW585	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)
compostFW585	Smog air	kg O3 eq.	7.609366e+05	Smog air (kg O3 eq.)
compostFW585	Water consumption	kg	1.004219e+09	Water consumption (kg)
reduceFW03	Acidification	kg SO2 eq.	1.493455e+05	Acidification (kg SO2 eq.)
reduceFW03	Ecotoxicity	CTUe	1.142750e+08	Ecotoxicity (CTUe)
reduceFW03	Energy demand	MJ	2.948222e+08	Energy demand (MJ)
reduceFW03	Eutrophication	kg N eq.	1.346540e+05	Eutrophication (kg N eq.)
reduceFW03	GWP 100	kg CO2 eq.	1.552105e+07	GWP 100 (kg CO2 eq.)
reduceFW03	GWP 100 (EpaFcs)	kg CO2 eq.	1.038519e+07	GWP 100 (EpaFcs) (kg CO2 eq.)
reduceFW03	Human health particulate air	kg PM2.5 eq.	1.538281e+04	Human health particulate air (kg PM2.5 eq.)
reduceFW03	Ozone depletion	kg CFC 11 eq.	7.051661e-01	Ozone depletion (kg CFC 11 eq.)
reduceFW03	Smog air	kg O3 eq.	7.425039e+05	Smog air (kg O3 eq.)
reduceFW03	Water consumption	kg	9.736875e+08	Water consumption (kg)
reduceFW06	Acidification	kg SO2 eq.	1.449966e+05	Acidification (kg SO2 eq.)
reduceFW06	Ecotoxicity	CTUe	1.113503e+08	Ecotoxicity (CTUe)
reduceFW06	Energy demand	MJ	2.856313e+08	Energy demand (MJ)
reduceFW06	Eutrophication	kg N eq.	1.305157e+05	Eutrophication (kg N eq.)
reduceFW06	GWP 100	kg CO2 eq.	1.502578e+07	GWP 100 (kg CO2 eq.)
reduceFW06	GWP 100 (EpaFcs)	kg CO2 eq.	1.018009e+07	GWP 100 (EpaFcs) (kg CO2 eq.)
reduceFW06	Human health particulate air	kg PM2.5 eq.	1.491739e+04	Human health particulate air (kg PM2.5 eq.)
reduceFW06	Ozone depletion	kg CFC 11 eq.	6.847034e-01	Ozone depletion (kg CFC 11 eq.)
reduceFW06	Smog air	kg O3 eq.	7.203135e+05	Smog air (kg O3 eq.)
reduceFW06	Water consumption	kg	9.433244e+08	Water consumption (kg)

Then you examine total impact results for a single impact category chosen at random – by making an impact chart similar in form to the to the previous weight charts:

```
# chose a single impactCategory at random
tempImpactCat0 <-
  impactLabels %>% sample_n(1)
tempImpactCat <-
  tempImpactCat0 %>% pull(impactCategory)
tempImpactLabel <-
  tempImpactCat0 %>% pull(impactLabel)

# get the impacts for that category
tempImpactChart1 <-
  ggplot()+
  ggtitle(tempImpactLabel)+
  theme_539()+
  geom_bar(
    data =
      tempImpactData1 %>%
        filter(impactCategory==tempImpactCat),
    aes(x = scenario, y= impact, fill=scenario),
    color=NA,
    stat="identity"
  )+
  scale_fill_viridis(begin=0.32, end=1, discrete = TRUE, option="B")+
  coord_flip()+
  guides(fill=guide_legend(ncol=2, title.position = "top"))+
  theme(
    rect=element_rect(fill="transparent"),
    plot.title = element_text(size=12),
    legend.position="none",
    legend.title = element_text(size=8),
    legend.justification="left"
    )
tempImpactChart1
```



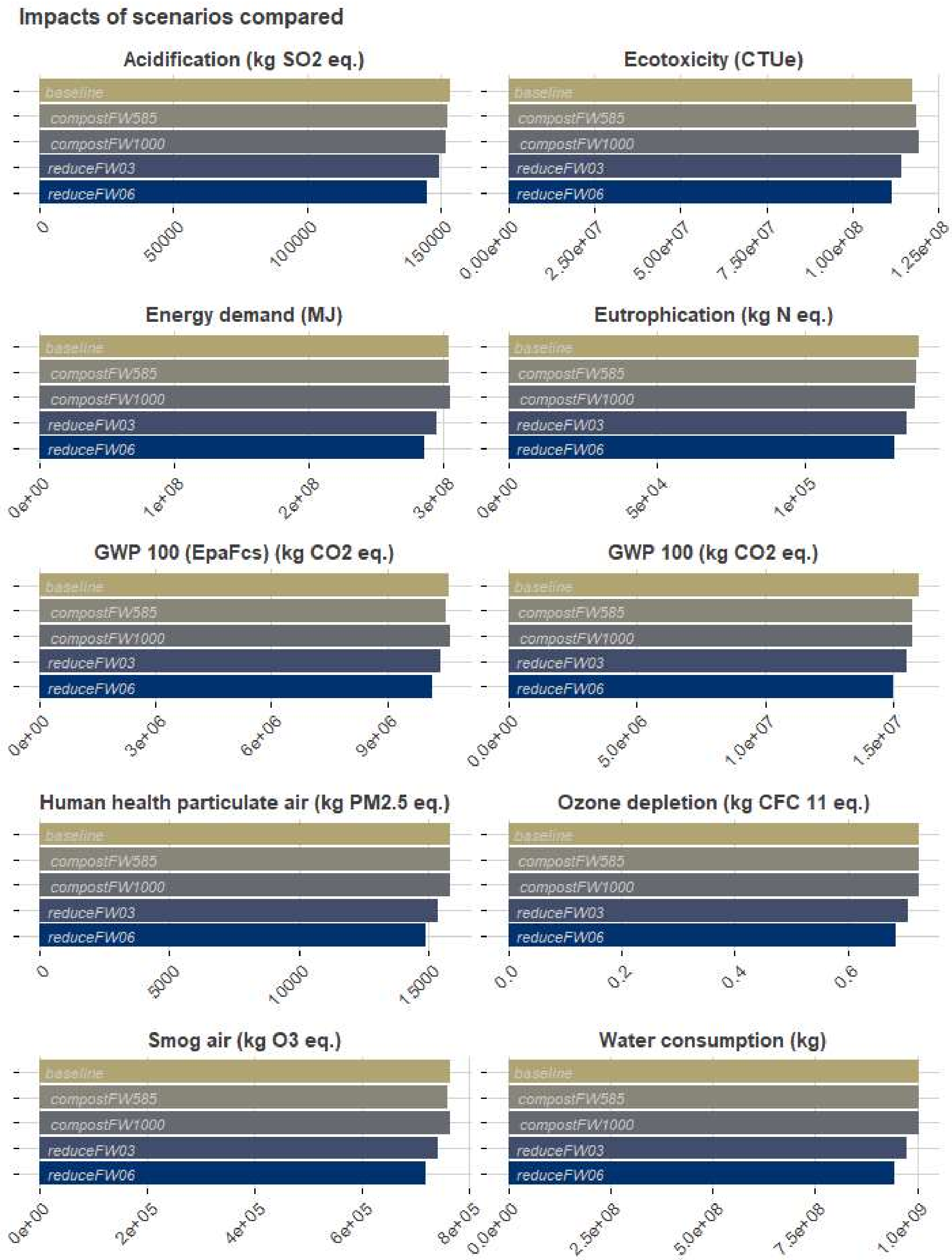

```
ggsave("chart_output/impacts1.png")

## Saving 6.5 x 4.5 in image

ggsave("chart_output/impacts1.svg")

## Saving 6.5 x 4.5 in image
```

These are the net life cycle impacts for Anytown's combined food waste and yard debris in the impact category Energy demand. All scenarios have similar results, but reducing food waste represents a bigger reduction in impact, compared to baseline, than composting.

But this is only for a single impact category. You make a bigger display to calculate the results for all impact categories on a single 8.5x11 page (with 1 inch margins).

```
tempImpactChart1a <-
  ggplot()+
  ggtitle("Impacts of scenarios compared")+
  theme_539()+
  geom_bar(
    data = tempImpactData1,
    aes(x = scenario, y= impact, fill=scenario),
    color=NA,
    # size=2,
    stat="identity"
  )+
  geom_text(
    data=tempImpactData1,
```

```
    aes(x=scenario, y=0, label=scenario),
    color="gray80",
    size=3,
    fontface="italic",
    hjust=-0.1
  )+
  facet_wrap(~impactLabel, ncol=2, scales="free")+
  scale_fill_viridis(
    begin=0.1, end=0.7, discrete = TRUE, option="cividis"
  )+
  coord_flip()+
#  guides(fill=guide_legend(ncol=2, title.position = "top"))+
  theme(
    rect=element_rect(fill="transparent"),
    plot.title = element_text(size=12),
    legend.position="none",
    axis.text.x=element_text(angle=45, hjust=1),
    axis.text.y=element_blank(),
    strip.text = element_text(size=11, face="bold")
    )
tempImpactChart1a
```




```
ggsave("chart_output/impacts2.png")

## Saving 7.5 x 10 in image

ggsave("chart_output/impacts2.svg")
```

```
## Saving 7.5 x 10 in image
```

These results are somewhat repetitive. In most or all impact categories, total impacts do not differ much between scenarios. Composting food waste sometimes adds a bit to, and sometimes subtracts a bit from, the baseline impacts. Reducing food waste tends to reduce impacts in all categories, by a somewhat larger but not breathtaking quantity.

You go for a more space-efficient expression of the same set of results, using a "heatmap" where all impacts are expressed in percents, where the baseline scenario is defined as 100%.

```
tempImpactData3 <-
  tempImpactData1 %>%
  filter(scenario=="baseline") %>%
  select(impactLabel, impact) %>%
  rename(baselineImpact=impact)
tempImpactData3a <-
  left_join(
    tempImpactData1,
    tempImpactData3,
    by= c("impactLabel")
  ) %>%
  mutate(
    pctBaselineImpact=impact/baselineImpact
  )
kable(tempImpactData3a, caption="heatmap data set")
```

heatmap data set

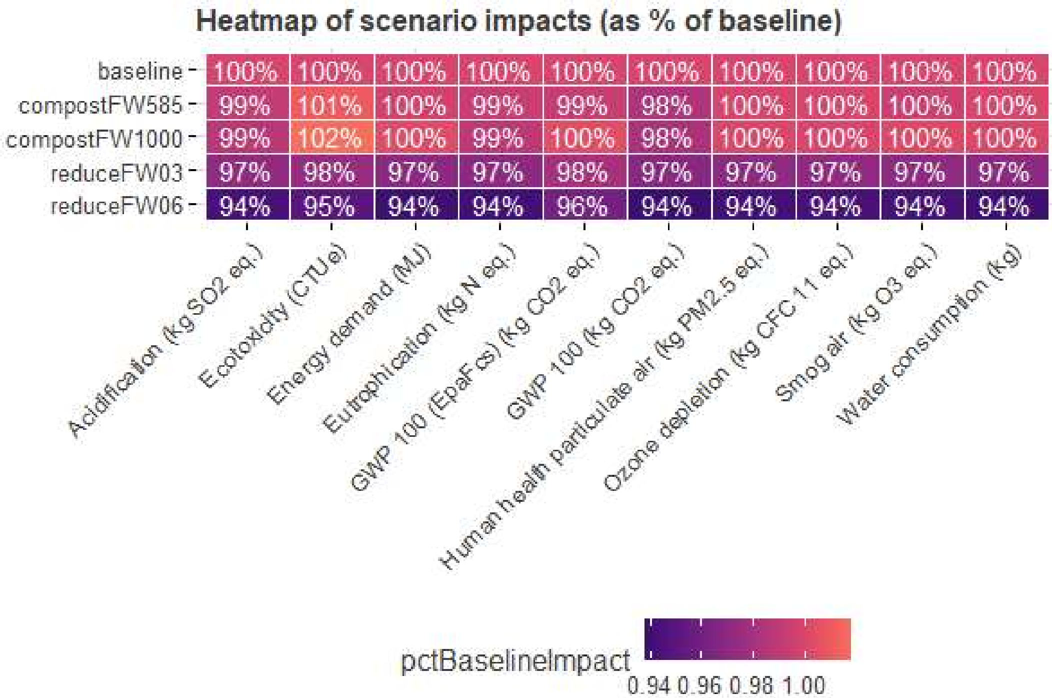
scenario	impactCategory	impactUnits	impact	impactLabel	baselineImpact	pctBaselineImpact
baseline	Acidification	kg SO2 eq.	1.536944e+05	Acidification (kg SO2 eq.)	1.536944e+05	1.0000000
baseline	Ecotoxicity	CTUe	1.171997e+08	Ecotoxicity (CTUe)	1.171997e+08	1.0000000
baseline	Energy demand	MJ	3.040130e+08	Energy demand (MJ)	3.040130e+08	1.0000000
baseline	Eutrophication	kg N eq.	1.387923e+05	Eutrophication (kg N eq.)	1.387923e+05	1.0000000
baseline	GWP 100	kg CO2 eq.	1.601632e+07	GWP 100 (kg CO2 eq.)	1.601632e+07	1.0000000
baseline	GWP 100 (EpaFcs)	kg CO2 eq.	1.059028e+07	GWP 100 (EpaFcs) (kg CO2 eq.)	1.059028e+07	1.0000000
baseline	Human health particulate air	kg PM2.5 eq.	1.584823e+04	Human health particulate air (kg PM2.5 eq.)	1.584823e+04	1.0000000
baseline	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)	7.256287e-01	1.0000000
baseline	Smog air	kg O3 eq.	7.646943e+05	Smog air (kg O3 eq.)	7.646943e+05	1.0000000
baseline	Water consumption	kg	1.004051e+09	Water consumption (kg)	1.004051e+09	1.0000000
compostFW1000	Acidification	kg SO2 eq.	1.518486e+05	Acidification (kg SO2 eq.)	1.536944e+05	0.9879905
compostFW1000	Ecotoxicity	CTUe	1.193495e+08	Ecotoxicity (CTUe)	1.171997e+08	1.0183437

compostFW1000	Energy demand	MJ	3.050143e+08	Energy demand (MJ)	3.040130e+08	1.0032936
compostFW1000	Eutrophication	kg N eq.	1.373021e+05	Eutrophication (kg N eq.)	1.387923e+05	0.9892625
compostFW1000	GWP 100	kg CO2 eq.	1.572895e+07	GWP 100 (kg CO2 eq.)	1.601632e+07	0.9820582
compostFW1000	GWP 100 (EpaFcs)	kg CO2 eq.	1.063685e+07	GWP 100 (EpaFcs) (kg CO2 eq.)	1.059028e+07	1.0043972
compostFW1000	Human health particulate air	kg PM2.5 eq.	1.585763e+04	Human health particulate air (kg PM2.5 eq.)	1.584823e+04	1.0005930
compostFW1000	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)	7.256287e-01	1.0000000
compostFW1000	Smog air	kg O3 eq.	7.664987e+05	Smog air (kg O3 eq.)	7.646943e+05	1.0023596
compostFW1000	Water consumption	kg	1.004794e+09	Water consumption (kg)	1.004051e+09	1.0007408
compostFW585	Acidification	kg SO2 eq.	1.523978e+05	Acidification (kg SO2 eq.)	1.536944e+05	0.9915637
compostFW585	Ecotoxicity	CTUe	1.184438e+08	Ecotoxicity (CTUe)	1.171997e+08	1.0106151
compostFW585	Energy demand	MJ	3.031141e+08	Energy demand (MJ)	3.040130e+08	0.9970433
compostFW585	Eutrophication	kg N eq.	1.378910e+05	Eutrophication (kg N eq.)	1.387923e+05	0.9935056
compostFW585	GWP 100	kg CO2 eq.	1.574730e+07	GWP 100 (kg CO2 eq.)	1.601632e+07	0.9832034
compostFW585	GWP 100 (EpaFcs)	kg CO2 eq.	1.051702e+07	GWP 100 (EpaFcs) (kg CO2 eq.)	1.059028e+07	0.9930819
compostFW585	Human health particulate air	kg PM2.5 eq.	1.584181e+04	Human health particulate air (kg PM2.5 eq.)	1.584823e+04	0.9995951
compostFW585	Ozone depletion	kg CFC 11 eq.	7.256287e-01	Ozone depletion (kg CFC 11 eq.)	7.256287e-01	1.0000000
compostFW585	Smog air	kg O3 eq.	7.609366e+05	Smog air (kg O3 eq.)	7.646943e+05	0.9950860
compostFW585	Water consumption	kg	1.004219e+09	Water consumption (kg)	1.004051e+09	1.0001680
reduceFW03	Acidification	kg SO2 eq.	1.493455e+05	Acidification (kg SO2 eq.)	1.536944e+05	0.9717043
reduceFW03	Ecotoxicity	CTUe	1.142750e+08	Ecotoxicity (CTUe)	1.171997e+08	0.9750455
reduceFW03	Energy demand	MJ	2.948222e+08	Energy demand (MJ)	3.040130e+08	0.9697682
reduceFW03	Eutrophication	kg N eq.	1.346540e+05	Eutrophication (kg N eq.)	1.387923e+05	0.9701834
reduceFW03	GWP 100	kg CO2 eq.	1.552105e+07	GWP 100 (kg CO2 eq.)	1.601632e+07	0.9690773
reduceFW03	GWP 100 (EpaFcs)	kg CO2 eq.	1.038519e+07	GWP 100 (EpaFcs) (kg CO2 eq.)	1.059028e+07	0.9806335
reduceFW03	Human health particulate air	kg PM2.5 eq.	1.538281e+04	Human health particulate air (kg PM2.5 eq.)	1.584823e+04	0.9706328
reduceFW03	Ozone depletion	kg CFC 11 eq.	7.051661e-01	Ozone depletion (kg CFC 11 eq.)	7.256287e-01	0.9718001
reduceFW03	Smog air	kg O3 eq.	7.425039e+05	Smog air (kg O3 eq.)	7.646943e+05	0.9709813
reduceFW03	Water consumption	kg	9.736875e+08	Water consumption (kg)	1.004051e+09	0.9697594

reduceFW06	Acidification	kg SO2 eq.	1.449966e+05	Acidification (kg SO2 eq.)	1.536944e+05	0.9434085
reduceFW06	Ecotoxicity	CTUe	1.113503e+08	Ecotoxicity (CTUe)	1.171997e+08	0.9500909
reduceFW06	Energy demand	MJ	2.856313e+08	Energy demand (MJ)	3.040130e+08	0.9395364
reduceFW06	Eutrophication	kg N eq.	1.305157e+05	Eutrophication (kg N eq.)	1.387923e+05	0.9403668
reduceFW06	GWP 100	kg CO2 eq.	1.502578e+07	GWP 100 (kg CO2 eq.)	1.601632e+07	0.9381547
reduceFW06	GWP 100 (EpaFcs)	kg CO2 eq.	1.018009e+07	GWP 100 (EpaFcs) (kg CO2 eq.)	1.059028e+07	0.9612670
reduceFW06	Human health particulate air	kg PM2.5 eq.	1.491739e+04	Human health particulate air (kg PM2.5 eq.)	1.584823e+04	0.9412655
reduceFW06	Ozone depletion	kg CFC 11 eq.	6.847034e-01	Ozone depletion (kg CFC 11 eq.)	7.256287e-01	0.9436003
reduceFW06	Smog air	kg O3 eq.	7.203135e+05	Smog air (kg O3 eq.)	7.646943e+05	0.9419627
reduceFW06	Water consumption	kg	9.433244e+08	Water consumption (kg)	1.004051e+09	0.9395188

now, to make that into a chart:

```
tempImpactChart3 <-
  ggplot()+
  ggtitle("Heatmap of scenario impacts (as % of baseline)")+
  theme_539()+
  geom_tile(
    data=tempImpactData3a,
    aes(y=scenario, x=impactLabel, fill=pctBaselineImpact),
    color="white"
  )+
  geom_text(
    data=tempImpactData3a,
    aes(
      y=scenario, x=impactLabel, label=percent(pctBaselineImpact,1)
    ),
    color="white"
  )+
  scale_fill_viridis(begin=0.2, end=0.7, option="A")+
  theme(
    plot.title = element_text(size=12),
    rect=element_rect(fill="transparent"),
    panel.grid = element_blank(),
    axis.ticks = element_line(),
    axis.text.x = element_text(hjust=1, angle=45)
  )
tempImpactChart3
```




```
ggsave("chart_output/impacts4.png")

## Saving 6.5 x 4.5 in image

ggsave("chart_output/impacts4.svg")

## Saving 6.5 x 4.5 in image
```

This display shows you that for many impact categories, baseline, compostFW585 and compostFW1000 have very similar impacts. The exceptions are the two GWP categories, which represent 1-2% decreases in impact through composting, and ecotoxicity, where impacts actually go up through additional composting.

Meanwhile, the reduceFW03 and reduceFW06 scenarios show declines in impact, compared to baseline, that are very similar to the amounts of food waste reduced – 3 and 6 percent respectively.

This suggests that food waste generation is dominating the impacts of the whole system. To check this, you display the impacts of materials and life cycle stages individually.

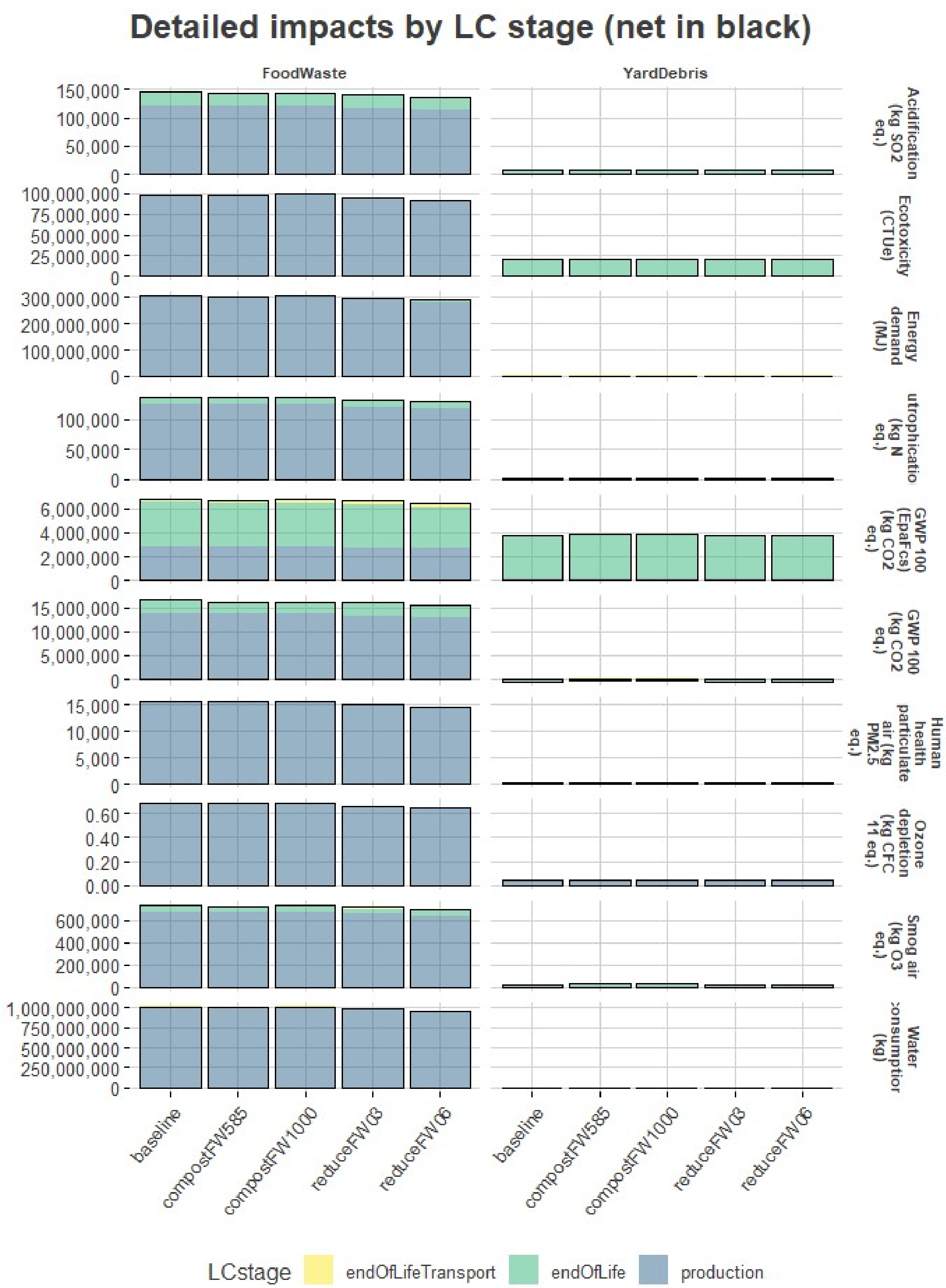
```
# calculating detailed impacts by scenario, material, and LCstage
tempImpactData5 <-
  impactsInDetail %>%
  group_by(
    scenario, material, LCstage, impactCategory, impactUnits
  ) %>%
  summarise(impact=sum(impact)) %>%
  ungroup() %>%
```

```
  mutate(
    scenario = factor(scenario, levels = (scenarioOrder)),
    impactLabel =
      paste(
        impactCategory,
        " (",
        impactUnits,
        ")",
        sep=""
      ),
    LCstage=
      factor(
        LCstage,
        levels=rev(c("production","endOfLife","endOfLifeTransport"))
      )
  )

## `summarise()` has grouped output by 'scenario', 'material', 'LCstage', 'im
pactCategory'. You can override using the `.groups` argument.

# calculating the net totals by scenario and material
tempImpactData5b <-
  tempImpactData5 %>%
  group_by(scenario, material, impactCategory, impactUnits,
           impactLabel) %>%
  summarize(impact=sum(impact))

## `summarise()` has grouped output by 'scenario', 'material', 'impactCategor
y', 'impactUnits'. You can override using the `.groups` argument.
```

Now making the chart...

```
tempImpactChart5 <-
  ggplot()+
  ggtitle("Detailed impacts by LC stage (net in black)")+
  theme_539()+
  geom_bar(
    data=tempImpactData5,
    aes(x=scenario, y=impact, fill=LCstage),
    color=NA,
    stat="identity",
    alpha=0.5
  )+
  geom_bar(
    data=tempImpactData5b,
    aes(x=scenario, y=impact),
    stat="identity",
    fill=NA,
    color="black"
  )+
  scale_y_continuous(labels=comma)+
```

```
  #coord_flip()+
  facet_grid(
    facets = c("impactLabel","material"),
    scales="free_y",
    labeller = labeller(impactLabel=label_wrap_gen(10))
  )+
  scale_fill_viridis(begin=0.32, end=1, discrete = TRUE,
                     direction = -1)+
  theme(
    axis.text.x=element_text(angle=50, hjust=1, vjust=1),
    panel.background=element_blank(),
    panel.grid = element_blank(),
    strip.text=element_text(size=8, face="bold")
  )
tempImpactChart5
```




```
# saving the chart to a disk file
ggsave(filename = "chart_output/impacts5.png")

## Saving 7.5 x 10 in image

ggsave(filename = "chart_output/impacts5.svg")
```

```
## Saving 7.5 x 10 in image
```

This chart shows you several important things:

- despite the fact that food waste has approximately the same total weight as yard debris (see earlier charts based only on weight), their life cycle impacts are very different.

- in most impact categories, it is the production phase of the materials life cycle for food waste that is dominating the impact total;
- transport impacts are usually too small to even register in this display.

The food waste reduction scenarios reduce impacts more than the composting scenarios because they reduce the amount of food waste WIC assumes is produced.

So, did composting have any benefit at all? You can check our ***impactsInDetail*** table to make sure that there are some negative impacts associated with composting...

```
# list some negative entries (impact reductions) associated
# with composting in the current impactsInDetail table
impactsInDetail %>%
  filter(LCstage=="endOfLife" &
           disposition == "composting" &
           impact < 0
         ) %>%
  # removing a few fields to make printout narrower
  select(-wasteshed, -impliedMiles, -umbDisp) %>%
  sample_n(10) %>%
  kable()
```

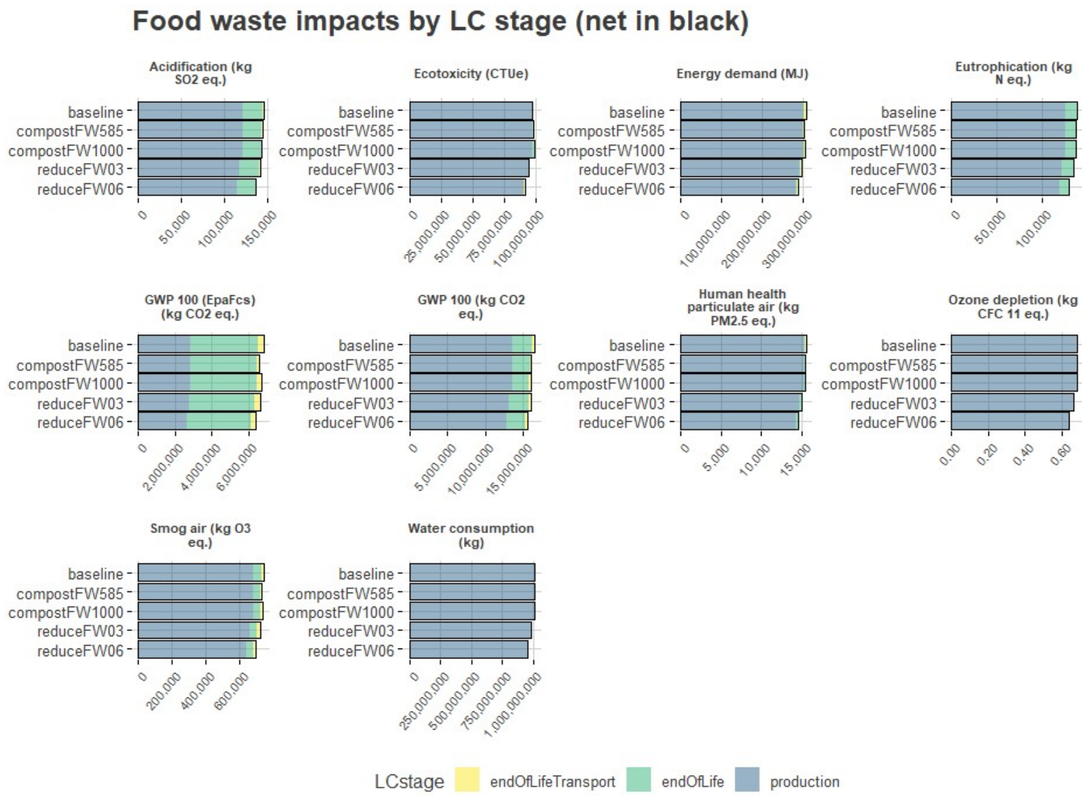
scenario	material	disposition	tons	miles	LCstage	impactCategory	impactUnits	impactFactor	impact
compostFW585	FoodWaste	composting	585	77	endOfLife	Ozone depletion	kg CFC 11 eq.	0.00000	0.00
compostFW1000	FoodWaste	composting	1000	77	endOfLife	Ozone depletion	kg CFC 11 eq.	0.00000	0.00
reduceFW06	YardDebris	composting	9000	4	endOfLife	GWP 100	kg CO2 eq.	-70.38751	-633487.57
compostFW1000	FoodWaste	composting	1000	77	endOfLife	GWP 100	kg CO2 eq.	-70.38751	-70387.51
reduceFW03	YardDebris	composting	9000	4	endOfLife	Ozone depletion	kg CFC 11 eq.	0.00000	0.00
baseline	YardDebris	composting	9000	4	endOfLife	GWP 100	kg CO2 eq.	-70.38751	-633487.57
compostFW1000	YardDebris	composting	9000	77	endOfLife	GWP 100	kg CO2 eq.	-70.38751	-633487.57
compostFW585	FoodWaste	composting	585	77	endOfLife	Energy demand	MJ	-543.11278	-317720.98
reduceFW03	YardDebris	composting	9000	4	endOfLife	Energy demand	MJ	-543.11278	-4888015.02
compostFW1000	FoodWaste	composting	1000	77	endOfLife	Energy demand	MJ	-543.11278	-543112.78

This display shows you that composting benefits certainly are being registered by the WIC system. They aren't showing up visibly on most of the impact charts because they are so small compared to the impacts of other processes (notably landfilling and production).

To see how composting is playing out with individual materials, we need to redraw the chart above so that the two materials have impacts displayed on different scales. We'll do this by making two different charts, one for food waste and the other for yard debris.

Making the chart for food waste…

```
tempImpactChart7 <-
  ggplot()+
  ggtitle("Food waste impacts by LC stage (net in black)")+
  theme_539()+
  geom_bar(
    data=tempImpactData5 %>%
      filter(material=="FoodWaste") %>%
      mutate(
        scenario = factor(scenario, levels = rev(scenarioOrder)),
      )
    ,
    aes(x=scenario, y=impact, fill=LCstage),
    color=NA,
    stat="identity",
    alpha=0.5
  )+
  geom_bar(
    data=tempImpactData5b %>% filter(material=="FoodWaste"),
    aes(x=scenario, y=impact),
    stat="identity",
    fill=NA,
    color="black"
  )+
  scale_y_continuous(labels=comma)+
  coord_flip()+
  facet_wrap(
    facets="impactLabel",
    scales="free"
    ,
    labeller = labeller(impactLabel=label_wrap_gen(20))
  )+
  scale_fill_viridis(begin=0.32, end=1, discrete = TRUE,
                     direction = -1)+
  theme(
    axis.text.x=element_text(size=8, angle=50, hjust=1, vjust=1),
    panel.background=element_blank(),
    panel.grid = element_blank(),
    strip.text=element_text(size=8, face="bold")
  )
tempImpactChart7
```




```
# saving the chart to a disk file
ggsave(filename = "chart_output/impacts7.png")

## Saving 10 x 7.5 in image

ggsave(filename = "chart_output/impacts7.svg")

## Saving 10 x 7.5 in image
```

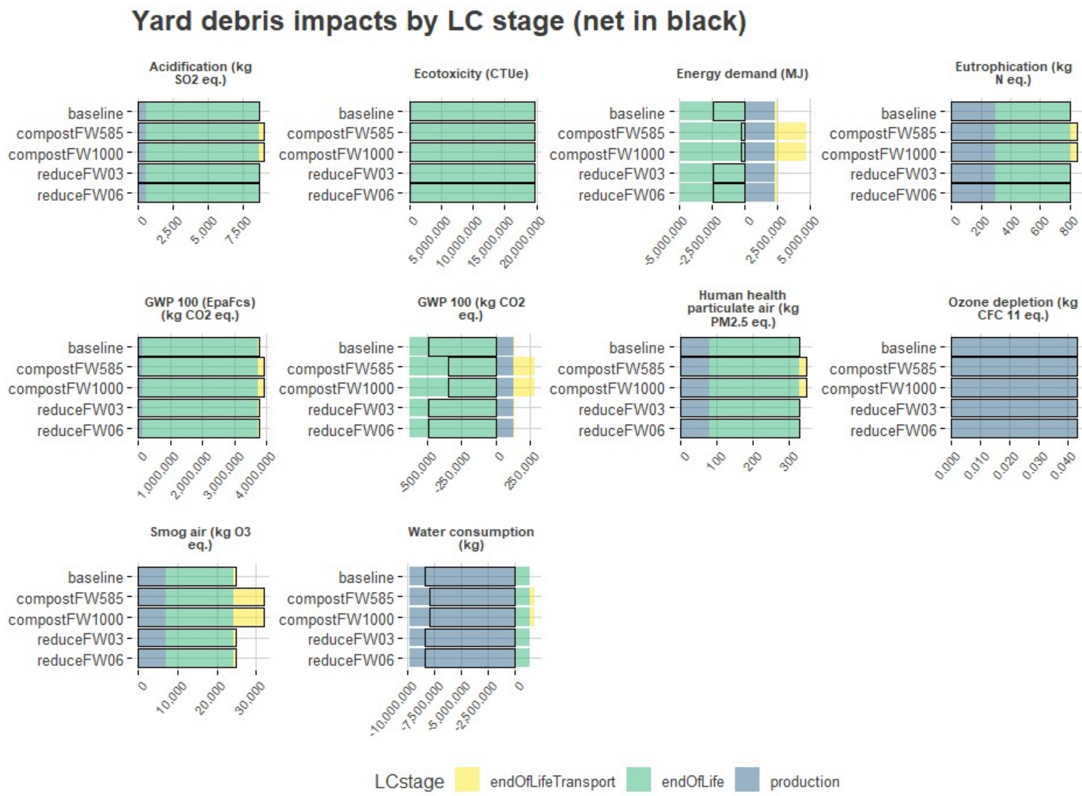
For food waste, we know that composting is contributing negative impacts in some impact categories (see earlier table), but it is not showing up in the "endOfLife" areas of the chart above because "endOfLife" also includes landfilling – and the impacts linked to landfilling are greater than the benefits linked to composting.

This chart also shows some small contributions to total impact from end-of-life-transportation.

Now, making the same chart for yard debris…

```
tempImpactChart6 <-
  ggplot()+
  ggtitle("Yard debris impacts by LC stage (net in black)")+
  theme_539()+
  geom_bar(
    data=tempImpactData5 %>%
      filter(material=="YardDebris") %>%
```

```
      mutate(
        scenario = factor(scenario, levels = rev(scenarioOrder)),
      ),
    aes(x=scenario, y=impact, fill=LCstage),
    color=NA,
    stat="identity",
    alpha=0.5
  )+
  geom_bar(
    data=tempImpactData5b %>% filter(material=="YardDebris"),
    aes(x=scenario, y=impact),
    stat="identity",
    fill=NA,
    color="black"
  )+
  scale_y_continuous(labels=comma)+
  coord_flip()+
  facet_wrap(
    facets="impactLabel",
    scales="free"
    ,
    labeller = labeller(impactLabel=label_wrap_gen(20))
  )+
  scale_fill_viridis(begin=0.32, end=1, discrete = TRUE,
                     direction = -1)+
  theme(
    axis.text.x=element_text(size=8, angle=50, hjust=1, vjust=1),
    panel.background=element_blank(),
    panel.grid = element_blank(),
    strip.text=element_text(size=8, face="bold")
  )
tempImpactChart6
```




```
# saving the chart to a disk file
ggsave(filename = "chart_output/impacts6.png")

## Saving 10 x 7.5 in image

ggsave(filename = "chart_output/impacts6.svg")

## Saving 10 x 7.5 in image
```

When the analysis is limited to yard debris only, as in the chart above, some impact categories show clear benefits linked to composting – for example, see the “endOfLife” entries for energy demand and GWP100, which are negative numbers.

The role of transport impacts can also be clearly seen. Yard debris is generally a low-impact material in production and end-of-life treatment, giving end-of-life-transport impacts a proportionately large role. The extra transport associated with the compostFW585 and compostFW1000 scenarios is enough to increase the impacts of those scenarios above baseline – for example for energy demand, eutrophication and GWP 100. When yard debris is the only material in the system, transport is a significant factor.

However, yard debris is *not* the only part of the system. In Anytown’s situation, changes in the management of food waste affect management of yard debris, so they must be considered together. When they are considered together, food waste represents the vast majority of impacts.

If Anytown is interested in reducing the impacts of food waste and yard debris, there may be some promise in composting large amounts of food waste – larger than have been considered in any of the current scenarios. Of course, WIC allows you to create more scenarios and add them to the analysis, and you may follow that course if Anytown is very motivated to increase composting.

But in general, the analysis suggests to you that a reduction in food waste generation is probably the most effective strategy for reducing the impacts of this waste system.

Screenshots from an interactive web app

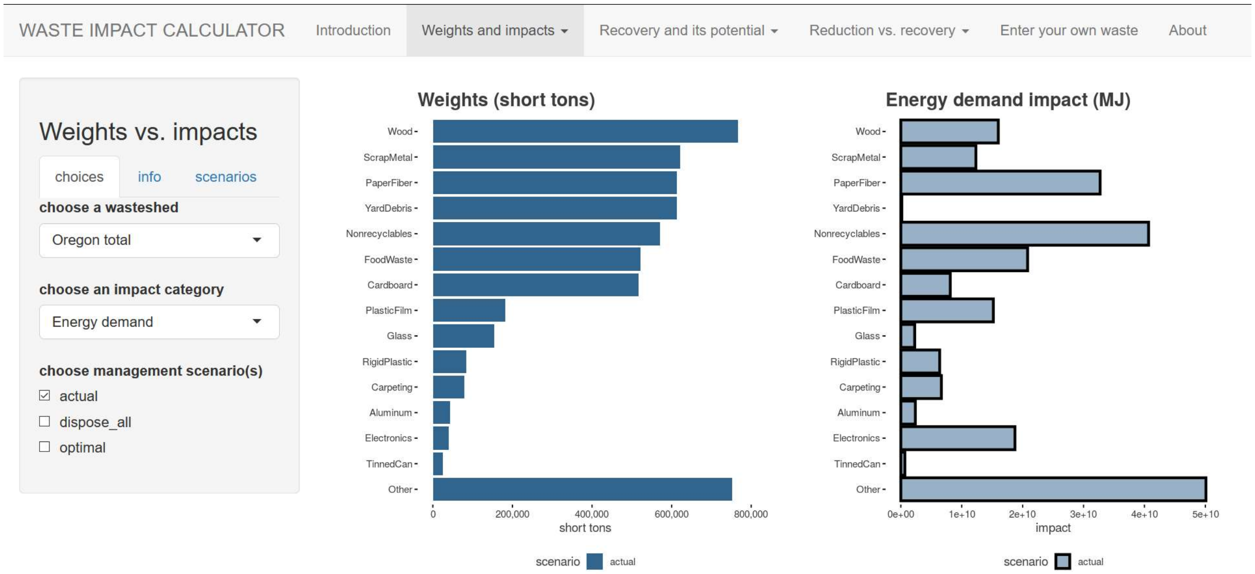
Oregon DEQ has used the WIC framework to create a web app that reports on recent solid waste statistics for Oregon counties, and the estimated life cycle impacts associated with them. It also helps users project the impact changes that might be associated with changing waste management.

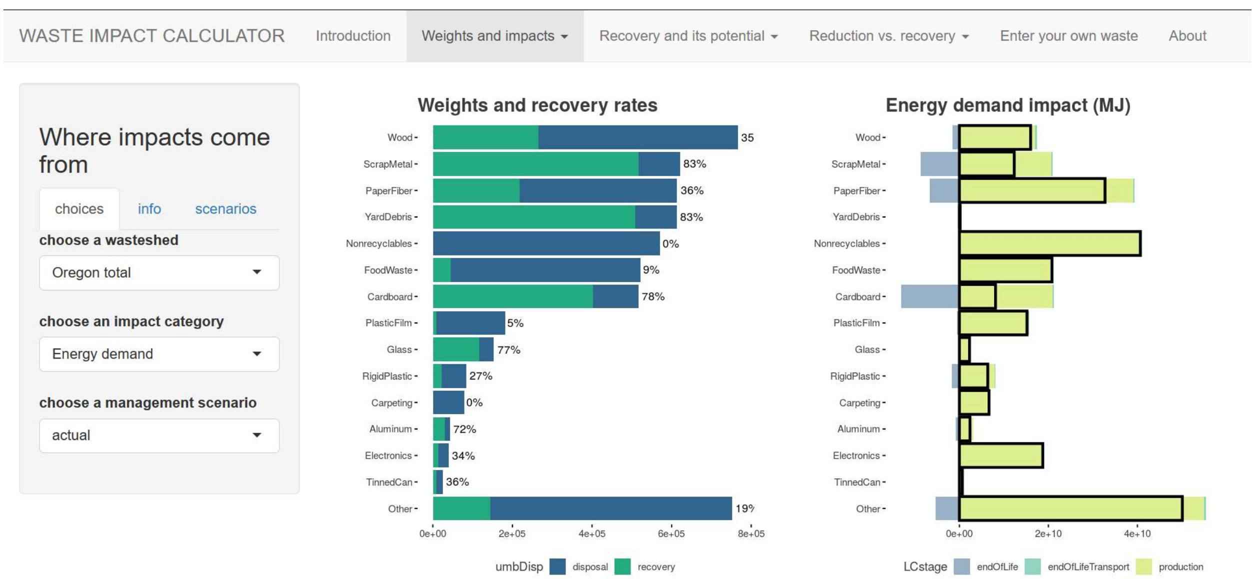
The app includes a pre-loaded ***massProfiles*** table representing Oregon "wastesheds" (counties), so the user does not need to labor to create or format one. This ***massProfiles*** table is extensive. For each "wasteshed", it describes a solid waste stream under three scenarios: "actual" recent data, "dispose_all" (a zero-recycling scenario), and "optimal" (where recovery and disposal are mixed in a way that minimizes impacts).

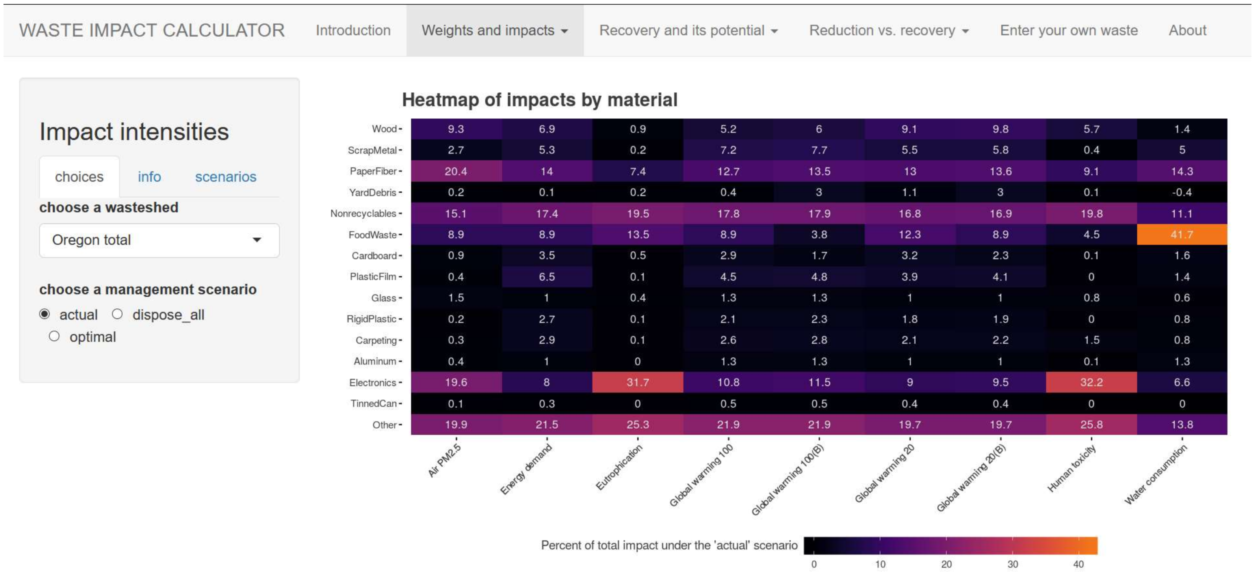
When combined with ***impactFactors***, the resulting ***impactsInDetail*** table can be displayed in diverse ways to help users understand how the weight of solid waste, and options for managing it, relate to estimated life cycle impacts. The charts help the user investigate and understand topics like:

- Which materials represent the greatest weights in the waste stream, and the greatest impacts;
- The correlation between material weight and estimated life cycle impact (which is usually poor); and
- The potential impact reductions associated with increased recovery (which often are less dramatic one might imagine).

One section of the app allows the user to go beyond the pre-loaded ***massProfiles*** table and enter their own data – though this is best suited for quick analyses involving a few materials.


WASTE IMPACT CALCULATOR
Introduction
Weights and impacts
Recovery and its potential
Reduction vs. recovery
Enter your own waste
About
Weights vs. impacts
choices
info
scenarios
choose a wasteshed
Oregon total
choose an impact category
Energy demand
choose management scenario(s)
actual
dispose_all
optimal
Weights (short tons)
Wood
ScrapMetal
PaperFiber
YardDebris
Nonrecyclables
FoodWaste
Cardboard
PlasticFilm
Glass
RigidPlastic
Carpeting
Aluminum
Electronics
TinnedCan
Other
0
200,000
400,000
600,000
800,000
short tons
scenario
actual
Energy demand impact (MJ)
0e+00
1e+10
2e+10
3e+10
4e+10
5e+10
impact
scenario
actual


WASTE IMPACT CALCULATOR
Introduction
Weights and impacts
Recovery and its potential
Reduction vs. recovery
Enter your own waste
About
Where impacts come from
choices
info
scenarios
choose a wasteshed
Oregon total
choose an impact category
Energy demand
choose a management scenario
actual
Weights and recovery rates
Wood
ScrapMetal
PaperFiber
YardDebris
Nonrecyclables
FoodWaste
Cardboard
PlasticFilm
Glass
RigidPlastic
Carpeting
Aluminum
Electronics
TinnedCan
Other
35
83%
36%
83%
0%
9%
78%
5%
77%
27%
0%
72%
34%
36%
19
0e+00
2e+05
4e+05
6e+05
8e+05
umbDisp
disposal
recovery
Energy demand impact (MJ)
0e+00
2e+10
4e+10
LCstage
endOfLife
endOfLifeTransport
production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Impact intensities
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choose a wasteshed
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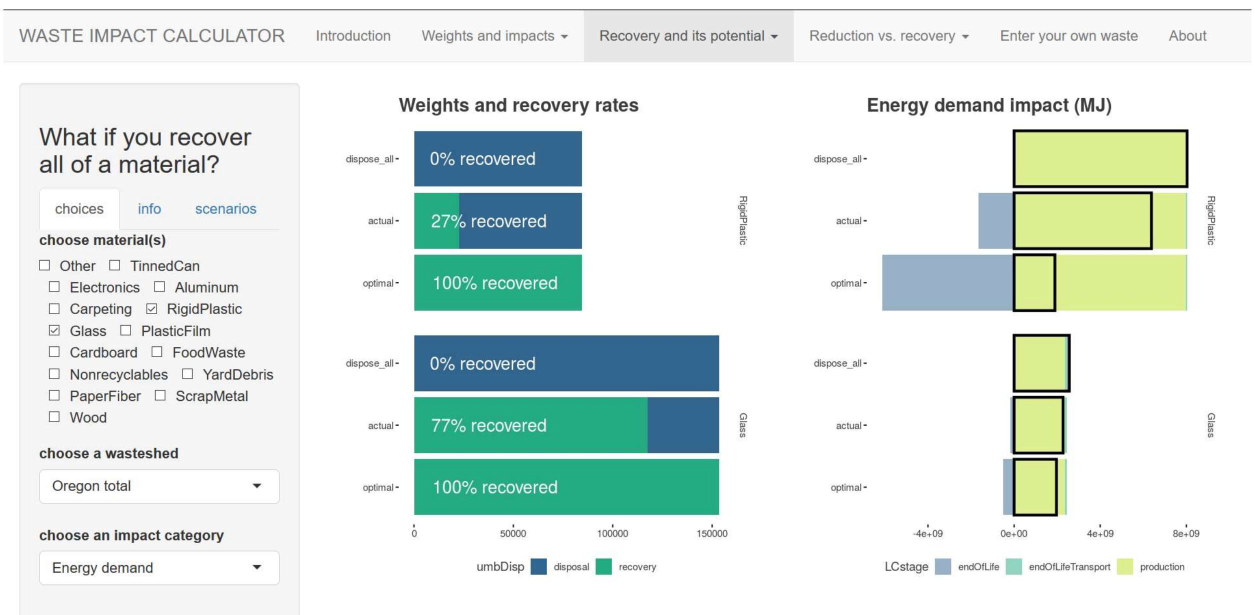
dispose_all
optimal
Heatmap of impacts by material
Wood 9.3 6.9 0.9 5.2 6 9.1 9.8 5.7 1.4
ScrapMetal 2.7 5.3 0.2 7.2 7.7 5.5 5.8 0.4 5
PaperFiber 20.4 14 7.4 12.7 13.5 13 13.6 9.1 14.3
YardDebris 0.2 0.1 0.2 0.4 3 1.1 3 0.1 -0.4
Nonrecyclables 15.1 17.4 19.5 17.8 17.9 16.8 16.9 19.8 11.1
FoodWaste 8.9 8.9 13.5 8.9 3.8 12.3 8.9 4.5 41.7
Cardboard 0.9 3.5 0.5 2.9 1.7 3.2 2.3 0.1 1.6
PlasticFilm 0.4 6.5 0.1 4.5 4.8 3.9 4.1 0 1.4
Glass 1.5 1 0.4 1.3 1.3 1 1 0.8 0.6
RigidPlastic 0.2 2.7 0.1 2.1 2.3 1.8 1.9 0 0.8
Carpeting 0.3 2.9 0.1 2.6 2.8 2.1 2.2 1.5 0.8
Aluminum 0.4 1 0 1.3 1.3 1 1 0.1 1.3
Electronics 19.6 8 31.7 10.8 11.5 9 9.5 32.2 6.6
TinnedCan 0.1 0.3 0 0.5 0.5 0.4 0.4 0 0
Other 19.9 21.5 25.3 21.9 21.9 19.7 19.7 25.8 13.8
Air PM2.5
Energy demand
Eutrophication
Global warming 100
Global warming 100(B)
Global warming 20
Global warming 20(B)
Human toxicity
Water consumption
Percent of total impact under the 'actual' scenario
0
10
20
30
40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Carpeting
RigidPlastic
Glass
PlasticFilm
Cardboard
FoodWaste
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YardDebris
PaperFiber
ScrapMetal
Wood
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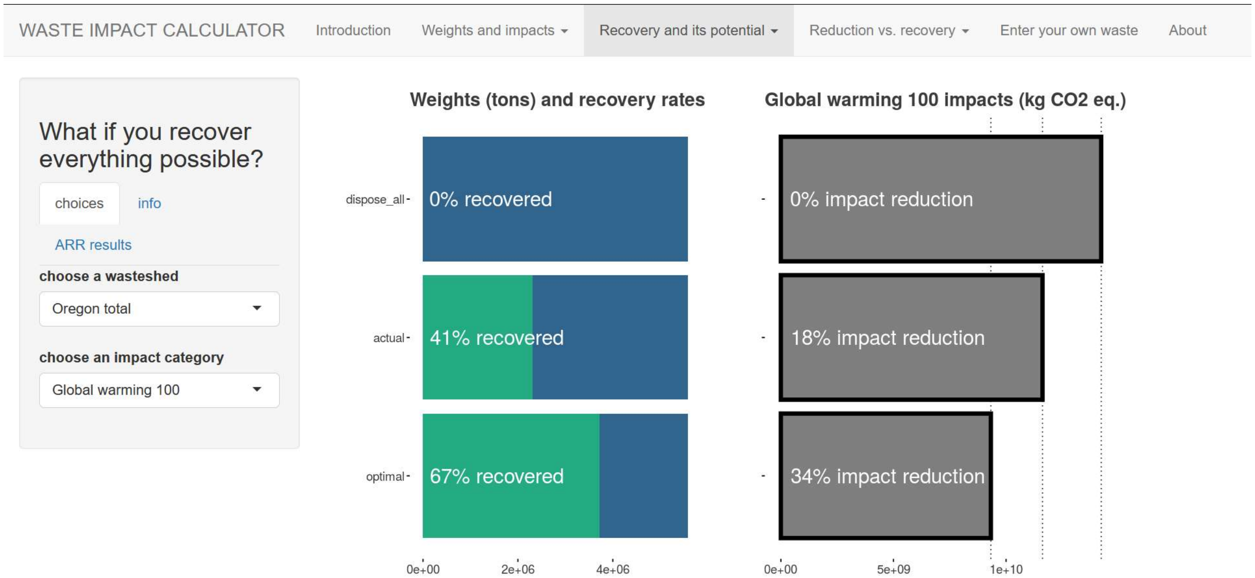
actual
optimal
0% recovered
27% recovered
100% recovered
0% recovered
77% recovered
100% recovered
RigidPlastic
Glass
0
50000
100000
150000
umbDisp
disposal
recovery
Energy demand impact (MJ)
-4e+09
0e+00
4e+09
8e+09
LCstage
endOfLife
endOfLifeTransport
production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choose an impact category
Global warming 100
Weights (tons) and recovery rates
dispose_all
actual
optimal
0% recovered
41% recovered
67% recovered
0e+00
2e+06
4e+06
Global warming 100 impacts (kg CO2 eq.)
0% impact reduction
18% impact reduction
34% impact reduction
0e+00
5e+09
1e+10


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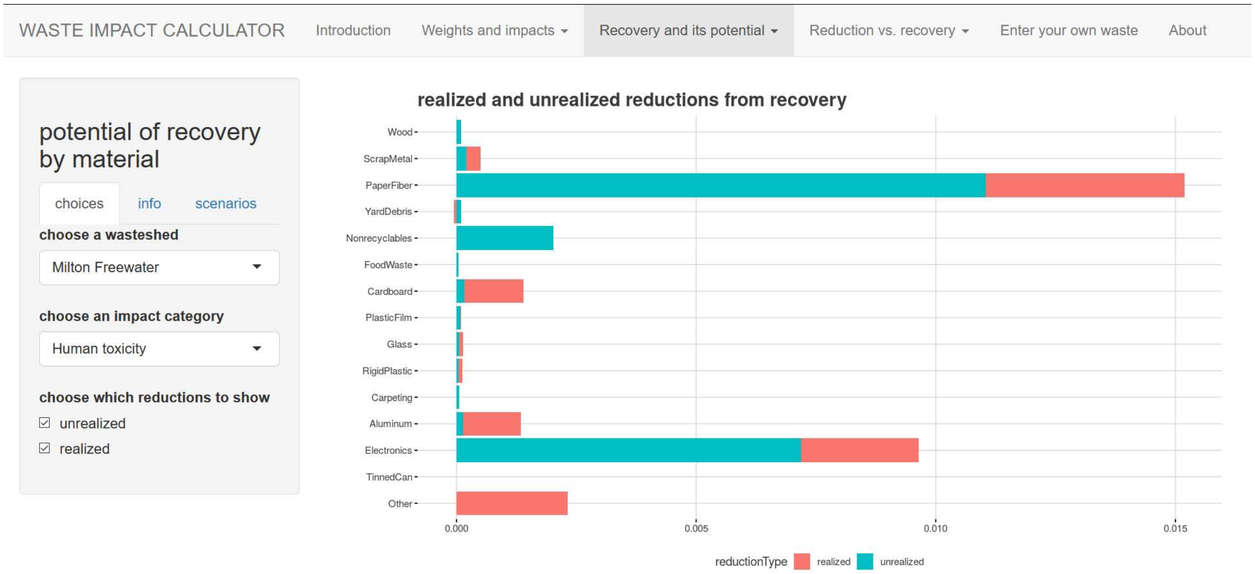
Oregon total
Normalized impacts of the 'dispose all' scenario (as % of 'actual' scenario)
Water consumption
Human toxicity
Global warming 20(B)
Global warming 20
Global warming 100(B)
Global warming 100
Eutrophication
Energy demand
Air PM2.5
0%
50%
100%
Normalized impacts of the 'optimal recovery' scenario (as % of 'actual' scenario)
Water consumption
Human toxicity
Global warming 20(B)
Global warming 20
Global warming 100(B)
Global warming 100
Eutrophication
Energy demand
Air PM2.5
0%
25%
50%
75%
100%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choose an impact category
Human toxicity
choose which reductions to show
unrealized
realized
realized and unrealized reductions from recovery
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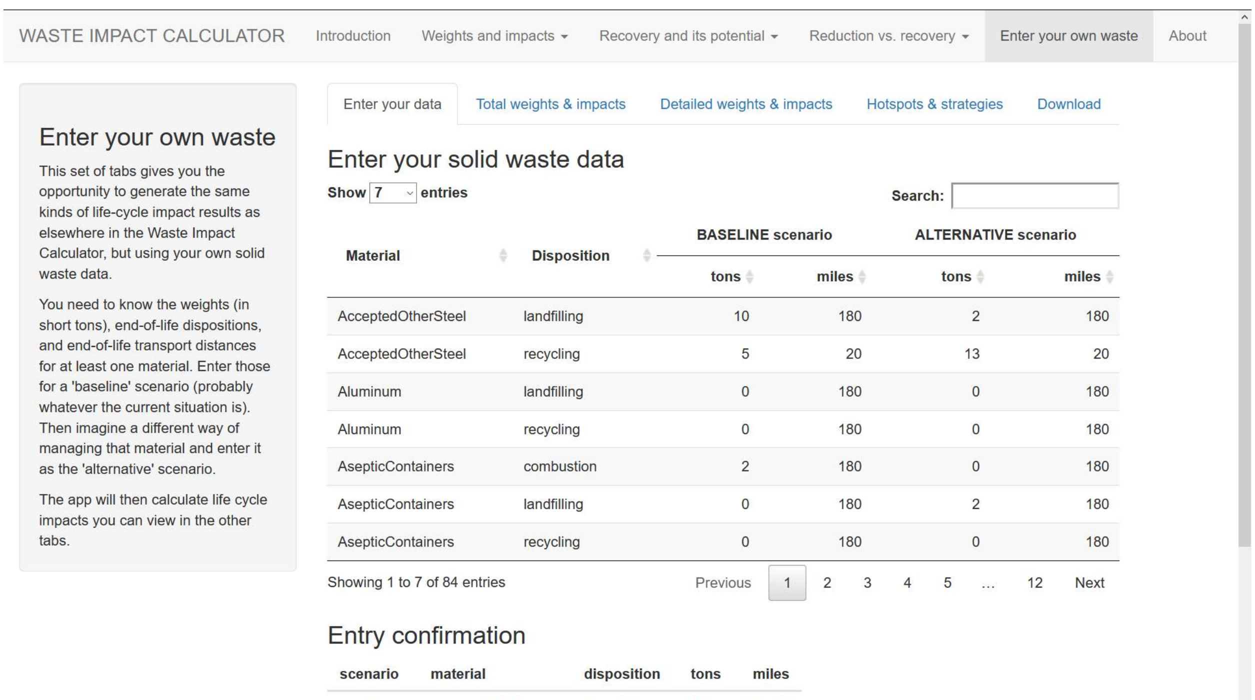
ScrapMetal
PaperFiber
YardDebris
Nonrecyclables
FoodWaste
Cardboard
PlasticFilm
Glass
RigidPlastic
Carpeting
Aluminum
Electronics
TinnedCan
Other
0.000
0.005
0.010
0.015
reductionType
realized
unrealized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Enter your own waste
This set of tabs gives you the opportunity to generate the same kinds of life-cycle impact results as elsewhere in the Waste Impact Calculator, but using your own solid waste data.
You need to know the weights (in short tons), end-of-life dispositions, and end-of-life transport distances for at least one material. Enter those for a 'baseline' scenario (probably whatever the current situation is). Then imagine a different way of managing that material and enter it as the 'alternative' scenario.
The app will then calculate life cycle impacts you can view in the other tabs.
Enter your data
Total weights & impacts
Detailed weights & impacts
Hotspots & strategies
Download
Enter your solid waste data
Show 7 entries
Search:
Material
Disposition
BASELINE scenario
ALTERNATIVE scenario
tons
miles
tons
miles
AcceptedOtherSteel landfilling 10 180 2 180
AcceptedOtherSteel recycling 5 20 13 20
Aluminum landfilling 0 180 0 180
Aluminum recycling 0 180 0 180
AsepticContainers combustion 2 180 0 180
AsepticContainers landfilling 0 180 2 180
AsepticContainers recycling 0 180 0 180
Showing 1 to 7 of 84 entries
Previous
1
2
3
4
5
…
12
Next
Entry confirmation
scenario
material
disposition
tons
miles
baseline
AcceptedOtherSteel
landfilling
10.00
180.00

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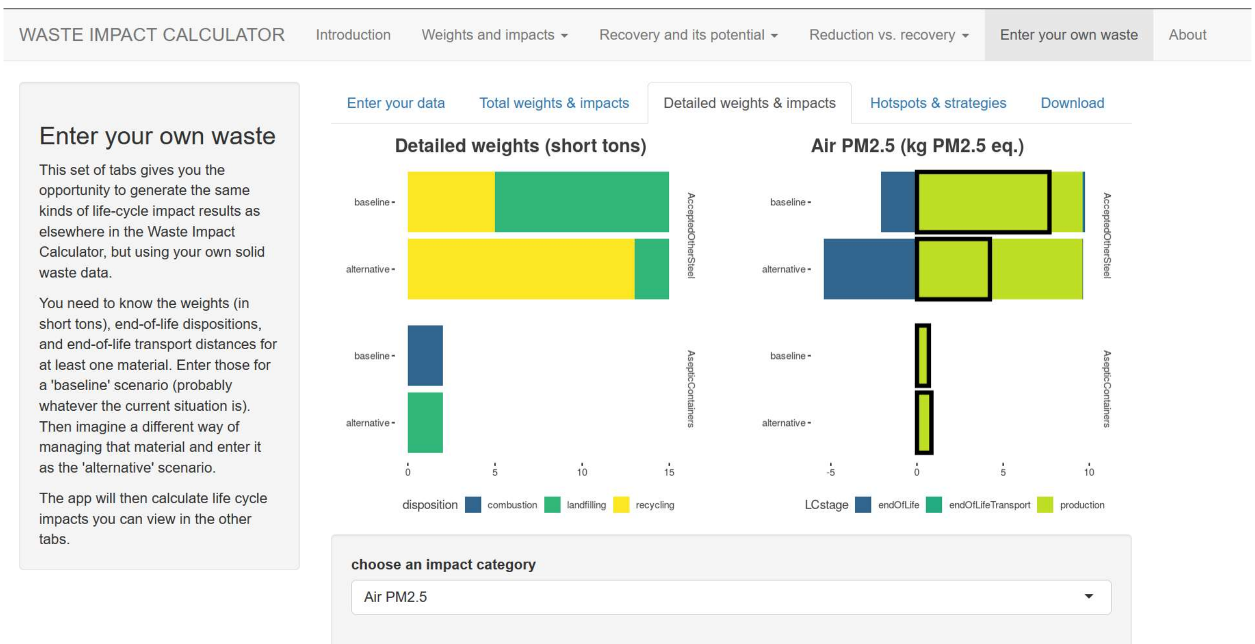
Enter your data
Total weights & impacts
Detailed weights & impacts
Hotspots & strategies
Download
Weight (short tons)
baseline
alternative
0
5
10
15
disposition
combustion
landfilling
recycling
Energy demand (MJ)
baseline
alternative
0e+00
1e+05
2e+05
3e+05
scenario
alternative
baseline
download this chart
download this chart
Choose an impact category
Energy demand



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Enter your data
Total weights & impacts
Detailed weights & impacts
Hotspots & strategies
Download
Detailed weights (short tons)
baseline
alternative
AcceptedOtherSteel
baseline
alternative
AsepticContainers
0
5
10
15
disposition
combustion
landfilling
recycling
Air PM2.5 (kg PM2.5 eq.)
baseline
alternative
AcceptedOtherSteel
baseline
alternative
AsepticContainers
-5
0
5
10
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choose an impact category
Air PM2.5

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Enter your own waste

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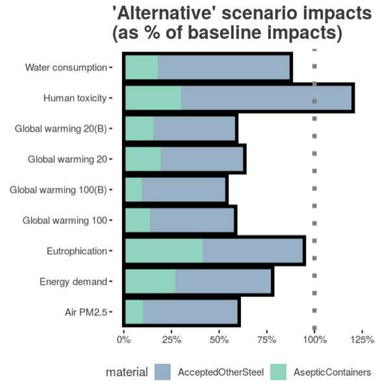
You need to know the weights (in short tons), end-of-life dispositions, and end-of-life transport distances for at least one material. Enter those for a 'baseline' scenario (probably whatever the current situation is). Then imagine a different way of managing that material and enter it as the 'alternative' scenario.

The app will then calculate life cycle impacts you can view in the other tabs.

Enter your data | Total weights & impacts | Detailed weights & impacts | Hotspots & strategies | Download



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