An Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals

June 2021

Timothy G. Townsend, Principal Investigator
Malak Anshassi, Postdoctoral Research Associate
Patrick Gilmartin, Undergraduate Research Assistant
Eleanor Brown, Undergraduate Research Assistant

University of Florida
Department of Environmental Engineering Sciences

Hinkley Center for Solid and Hazardous Waste Management
University of Florida
P.O. Box 116016
Gainesville, FL 32611
www.hinkleycenter.org

This page intentionally left blank.

ACKNOWLEDGEMENTS

The Hinkley Center for Solid and Hazardous Waste Management funded this research. We also thank the members of the stakeholder working group for their support and assistance in the development and review of this study.

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

C&D debris	Construction and demolition debris
EASETECH	Environmental Assessment System for Environmental Technologies
EPA	U.S. Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
GHG	Greenhouse gas
GWP	Global warming potential
LCA	Life-cycle assessment
LCI	Life-cycle impact
LCIA	Life-cycle impact assessment
MRF	Material recovery facility
MSW	Municipal solid waste
MSW-DST	Municipal Solid Waste Decision Support Tool
SMM	Sustainable materials management
SWOLF	Solid Waste Optimization Framework
WARM	Waste Reduction Model
WRATE	Waste Resources Assessment Tool
WTE	Waste-to-energy

UNITS OF MEASURE

CTUe	Ecosystem comparative toxic units
CTUh	Human comparative toxic units
Gallons	US Gallon = 3.785 liters
kgNeq.	Kilograms nitrogen equivalence
$kgSO_2eq.$	Kilograms sulfur dioxide equivalence
MJ	Megajoules
t	Metric tonnes = 1.1 tons
$tCO_2eq.$	Tonnes carbon dioxide equivalence
ton	US short tons = 2,000 pounds
yd^3	US cubic yard = 27 cubic feet

FINAL REPORT REQUIREMENT

(Dates: 10/01/19 to 06/30/21)

PROJECT TITLE: An Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals

PRINCIPAL INVESTIGATOR(S): Timothy Townsend

AFFILIATION: Department of Environmental Engineering Sciences, University of Florida

EMAIL: ttown@ufl.edu **PHONE NUMBER:** (352) 392-0846

COMPLETION DATE: June 2021

EXAMPLE TAG MEMBERS: Karen Moore, Suzanne Boroff, Kim Walker, Christopher Perry, Jennifer Simmons, Travis Barnes, Keith Howard, Gene Jones, Keyna Cory, Ron Beladi, Dave Gregory, Carlo Lebron, Tobin McKnight, Kevin Leo, Richard Tedder, Dawn McCormick, Bob Hyres, Kim Williams, Victor Storelli, James Suter, Kim Brunson, Steve Lezman

KEY WORDS: Sustainable materials management (SMM), life-cycle impact (LCI), life-cycle assessment (LCA), WARM, SWOLF, MSW-DST, recycling, Florida, solid waste management.

ABSTRACT:

Over the last decade the concept of Sustainable Materials Management (SMM) has been widely received in many parts of the US, including Florida. The first SMM-focused project funded by the Hinkley Center for Solid and Hazardous Waste Management entitled, *Florida Solid Waste Management: State of the State*, involved looking at Florida's solid waste stream with respect to generation, composition, and disposition (the more traditional ways of tracking solid waste), but also included an assessment whereby SMM principles were used to evaluate the implications of how we manage our wastes. For example, the research team used life cycle assessment (LCA) models to estimate environmental footprints for the Florida waste management system. In the second SMM-focused funded project, *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida,* we continued the development and refinement of SMM application in Florida by creating a life cycle tool, referred to as the HC 18/19 Tool, that can be used by Florida local governments and the Florida Department of Environmental Protection (FDEP) to estimate and compare waste management-based environmental footprints using specific waste stream and life cycle data. The main deliverable of that project was the development of life cycle impact (LCI) factors, which are used to convert a mass of a material and its management approach to an environmental footprint. Another important tool managed by FDEP is the Waste Composition Calculation Model (WasteCalc) which is used annually to estimate the composition of collected waste fraction and their recycling rate. Through funding with FDEP this tool has been updated to have the most representative data for Florida counties. Still, a need for a comprehensive tool that includes all the findings and functionality of the previous projects and tools are needed. In this project, An *Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals,* we developed a tool that has all the functionality of the WasteCalc and HC18/19 Tools, as well as allows for quantification of source reduction impacts. The tool deliverable of this provides a platform for Florida local governments to measure their environmental footprints, which can then be translated into SMM-based recycling rates and be used to set goals (beyond the current mass-based goal) and assess potential waste management alternatives that align with SMM principles.

Meanwhile, the LCI factors can be used by environmental educators and environmental industry decision makers to gain insight on the most sustainable management for materials.

PROJECT WEB SITE: https://faculty.eng.ufl.edu/timothy-townsend/research/florida-solid-waste-issues/tool-to-track-progress-toward-smm-goals/

METRICS:

1. Graduate students funded by THIS Hinkley Center project:

Name	Rank	Department	Professor	Institution
Malak Anshassi	Ph.D.	Environmental Engineering Sciences	Timothy Townsend	University of Florida

2. Undergraduate students working on THIS Hinkley Center project:

Name	Department	Professor	Institution
Patrick Gilmartin, Fionna Tennyson, Eleanor Brown	Environmental Engineering Sciences	Timothy Townsend	University of Florida

3. List research publications resulting from THIS Hinkley Center projects.
   Still in progress.

4. List research presentations resulting from THIS Hinkley Center projects.
   - *Technical Awareness Group (TAG) I Meeting* took place on January 10th, 2020.
   - *Fall 2020 SWANA Hinkley Center Symposium Meeting* took place on October 13th, 2020.
   - *Technical Awareness Group (TAG) II Meeting* took place on April 4, 2021.
   - *Educator 2021 SMM Tool Training* took place on May 5th, 2021.
   - *Recycle Florida Today Summer 2021 Conference* took place on June 8th, 2021.
   - *FDEP Webinar for Decision Makers 2021 SMM Tool Training* took place on June 24th, 2021.

5. List who has referenced or cited your publications from this project?
   Still in progress.

6. How have the research results from THIS Hinkley Center project been leveraged to secure additional research funding?
   Gained interest from other organization to complete similar studies.

7. What new collaborations were initiated based on THIS Hinkley Center project?
   Working with Recycling Coordinators, waste haulers, and LCA model developers to enhance each other’s knowledge of Florida’s SMM integration.

8. How have the results from THIS Hinkley Center funded project been used (not will be used) by FDEP or other stakeholders?

FDEP and stakeholders can make conclusions regarding Florida’s solid waste statistics and feasibility of implementing SMM.

EXECUTIVE SUMMARY

(Dates: 10/01/19 to 06/30/21)

PROJECT TITLE: An Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals

PRINCIPAL INVESTIGATOR(S): Timothy Townsend

AFFILIATION: Department of Environmental Engineering Sciences, University of Florida

EMAIL: ttown@ufl.edu **PHONE NUMBER:** (352) 392-0846

COMPLETION DATE: November 2020

EXAMPLE TAG MEMBERS: Karen Moore, Suzanne Boroff, Kim Walker, Christopher Perry, Jennifer Simmons, Travis Barnes, Keith Howard, Gene Jones, Keyna Cory, Ron Beladi, Dave Gregory, Carlo Lebron, Tobin McKnight, Kevin Leo, Richard Tedder, Dawn McCormick, Bob Hyres, Kim Williams, Victor Storelli, James Suter, Kim Brunson, Steve Lezman

KEY WORDS: Sustainable materials management (SMM), life-cycle impact (LCI), life-cycle assessment (LCA), WARM, SWOLF, MSW-DST, recycling, Florida, solid waste management.

PROJECT SUMMARY:

An item of interest on the Hinkley Center's 2019 research agenda is to incorporate SMM principles into FDEP's WasteCalc model. WasteCalc is an online tool used to estimate the composition of municipal solid waste (MSW) generated in Florida counties. Florida, like many states in the US, has an interest in incorporating Sustainable Materials Management (SMM) principles into waste management planning and policy. Two previous Hinkley Center projects, Florida Solid Waste Management: State of the State (FY16/17) and Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida (FY18/19) have worked to develop methods that allow policy makers to look at waste (materials) management performance beyond simply tracking tons. Alternative performance metrics (based on sustainability indicators) in the first project focused on greenhouse gas (GHG) emissions and energy use, while the second (ongoing) project is expanding these indicators to include categories such as water use, landfill capacity utilization and job creation. For the most part, the Florida solid waste community (local governments, regulatory agencies, businesses, waste management industry) is interested in the concept of moving beyond tons for goal setting and tracking progress. But the question always posed is, "how do we integrate this concept into real practice?"

The Hinkley Center recognized that the Florida Waste Composition Calculation Model, or WasteCalc tool, serves as an ideal platform to incorporate SMM. Currently, most Florida counties use WasteCalc to estimate their collected waste composition. Recently, the author and his research team worked with the Florida Department of Environmental Protection (FDEP) to improve WasteCalc. We updated some of the material estimating algorithms and re-calibrated it using recent Florida waste composition studies, however, more work remains to refine the model and to incorporate SMM.

In SMM it is important to evaluate the economic, social, and environmental impacts of a decision. Results from the Hinkley Center FY18/19 project can be used in conjunction with WasteCalc to produce estimates of these impacts. Another important SMM principle is reducing consumption of materials. Examples of activities that lead to less materials consumed include reusing products or instructing consumers to change their purchasing

habits. Many of these activities are referred to as source reduction activities which may be defined as changes in design, manufacture, purchase or use of materials that reduces the amount of materials entering the waste stream. A need exists to incorporate measuring and tracking source reduction activities in Florida. We developed a comprehensive tool, called 2021 SMM Tool, that included: 1) the 2019 WasteCalc functions and refined functions; 2) metrics to measure environmental and social impacts developed from the FY18/19 project; and 3) a method to measure Florida source reduction activities.

The objectives of this project were to: (i) have the 2021 SMM Tool include multiple life cycle categories beyond GHG emissions and energy, (ii) provide a mechanism (with appropriate guidance) for local governments to include source reduction activities, and (iii) expand the universe of waste components considered to account for the changing waste stream in Florida. More research is needed on the extent of source reduction activities currently in place in Florida and how best to quantify benefits and integrate them into the model. Example of existing source reduction activities that were assessed as part of this study included donation of food waste, textiles, electronics, and furniture. The last component of this project was to work with FDEP, local governments, and the working group to create training materials for the tools use.

1 INTRODUCTION

1.1 PROJECT OBJECTIVES

The objectives of this research are to refine the current WasteCalc to a more comprehensive tool that includes:

1. Refinements to the model in a manner that retains its existing functionality;
2. Incorporate SMM using metrics to measure environmental, social, and economic impacts developed from the FY18/19 project, include new waste categories, and provide a means to better integrate source reduction activities.
3. Develop necessary support materials for future users and developers.

1.2 PROJECT TASKS

Task 1. Research on Source Reduction and Materials Reuse.

Source reduction and materials reuse is one area that will be specifically expanded as part of the model. The FDEP currently requires facilities that recycle 600 or more tons annually to register as a certified recycler and submit records of the type of materials and the mass of materials recycled. While some county Recycling Coordinators may try to identify and track source reduction activities such as donation centers and thrift shops, these activities often go uncounted, and other reuse activities may not be identified altogether.

In this task, we will meet with FDEP and local governments to:

(i) Define source reduction;
(ii) Determine at what extent, if any, source reduction and reuse are currently included in reporting to the State;
(iii) Research source reduction and reuse activities currently occurring throughout the State. This information will be gathered by examining the existing body of literature and practices; around the nation/world and speaking with local governments and reuse facility operators.
(iv) We will gather data from operations such as Goodwill Industries that track materials received, reuse and recycled.

Task 2. Identify Missing Materials Categories.

Additional waste categories that should be integrated into the new model will be determined by:

(i) Examining recent waste composition studies;
(ii) Researching product and materials trends;
(iii) Reviewing the scientific literature;
(iv) Speaking with waste management professionals.

At a minimum, the potential for include electronic devices and new packaging products will be investigated.

Task 3. Develop Missing Impact Factors.

The FY 18/19 project focuses heavily on developing conversion factors to estimate the social, environmental, and economic impact associated with a material and its waste management practice. If impact factors do not exist for the source reduction and reuse activities identified in Task 1 or the new waste categories in Task 2, we will identify and develop these factors based on existing science and literature.

Task 4. Refine the Model.

The research team will use the data from Task 1-3 to expand the more recently updated WasteCalc model to include the additional waste categories, the new life cycle categories, and the new source reduction/reuse features. We envision that the model may be renamed at some point to better reflect its refined purpose and approach, but to help illustrate how WasteCalc is currently structured and how changes will be integrated, please see Figure 6. We anticipate that this tool will result in decisions that are more informed and will allow decision makers to begin to shift from solid waste management to a materials management regime.

Task 5. Training.

Training materials for the refined model will be developed. The researchers will work with FDEP, local governments and the working group to test these training materials. A series of case studies for several counties will be integrated into this exercise. The research team will work with FDEP to provide training statewide through a webinar or conference presentations. Following each training event, we expect to receive feedback or comments that will be used in potential model refinement.

1.3 REPORT ORGANIZATION

This report is organized into seven sections. Section 1 (this section) provides an overview introducing the project objectives and tasks. Section 2 includes a description of background information relating to sustainable materials management (SMM) and lifecycle assessment (LCA). In Section 3 we define source reduction and describe the research efforts to measure source reduction through different approaches. Section 4 includes background on material reuse and the methods used to quantify it, since it is an important part of source reduction activities. Section 5 introduces the types of additional material categories and impact factors that were created, and the model refinements made. Section 5 also details each tab in the workbook tool (2021 SMM Tool) as well as the documentation of the WasteCalc version used, the method to create impact factors, the source reduction calculations used, and the calculations used for the new material categories. Section 6 shows the training materials developed for Recycling Coordinators, decision makers, and educators to use the 2021 SMM Tool.

2 SUSTAINABLE MATERIALS MANAGEMENT AND LIFECYCLE ASSESSMENT BACKGROUND

The concept of SMM originated in a 2002 EPA publication entitled “Beyond RCRA: Waste and Materials Management in the Year 2020” (US EPA, 2002). In 2009, EPA further developed the idea in “Sustainable Materials Management: The Road Ahead” (US EPA, 2009), which presented a roadmap for moving toward SMM. In these and other documents, SMM is characterized as a varying set of resource-efficient actions to be taken across the entire lifecycle of a material or product — from extraction through refinement, manufacturing, assembly, distribution, use, and end-of-life management (Figure 2-1). In contrast to traditional conceptions of waste management, local governments adopting SMM may seek to establish policies that encourage the most productive uses for all resources while minimizing the impact of waste and pollutants at all stages. From the policy standpoint, SMM is meant to produce a long-term systemic solution to the problem of waste management that takes into account the interests of all public and private stakeholders.

As policymakers incorporate SMM principles into the regulatory framework, they look to promote sustainable production and use practices and to transform end-of-life management into a source of additional sustainability and productivity. To account for their decision making, they use lifecycle assessment (LCA) models, which quantify material flows throughout all lifecycle stages in terms of environmental, economic, and social impact. In addition to tracking material flow paths, LCA models identify which economic sectors generate the most waste and assess the environmental and economic effectiveness of various waste management strategies.

Figure 2-1. Schematic of the life stages included in the SMM framework (US EPA, 2009).

Solid waste decision and policy makers adopting SMM principles to improve or measure their waste management system will often rely on decision support tools that assess their system’s impact on the environment, economy, and society. Focusing on the environmental impacts, lifecycle assessment (LCA) is one of the most popular tools used by decision makers. LCA is a computer-based tool that quantifies the environmental benefits or burdens associated with a material throughout its life cycle (Khandelwal et al., 2019). The life cycle stages included in LCA begin at the extraction of raw materials, then extend to processing, manufacturing, use, and end-of-life management (Blikra Vea et al., 2018; Kirkeby et al., 2006).

The International Organization of Standards (ISO) developed guidelines referred to as ISO 14040 followed by LCA practitioners that include a description of the requirements for conducting an LCA (Guinée et al., 2011; Khandelwal et al., 2019; Pryshlakivsky and Searcy, 2013; Reap et al., 2008; Yadav and Samadder, 2018). The four key phases included in ISO 14040 are: 1) goal and scope definitions; 2) life cycle inventory (LCI) analysis; 3) life cycle impact assessment (LCIA); and 4) life cycle interpretation (as shown in Figure 2-2).

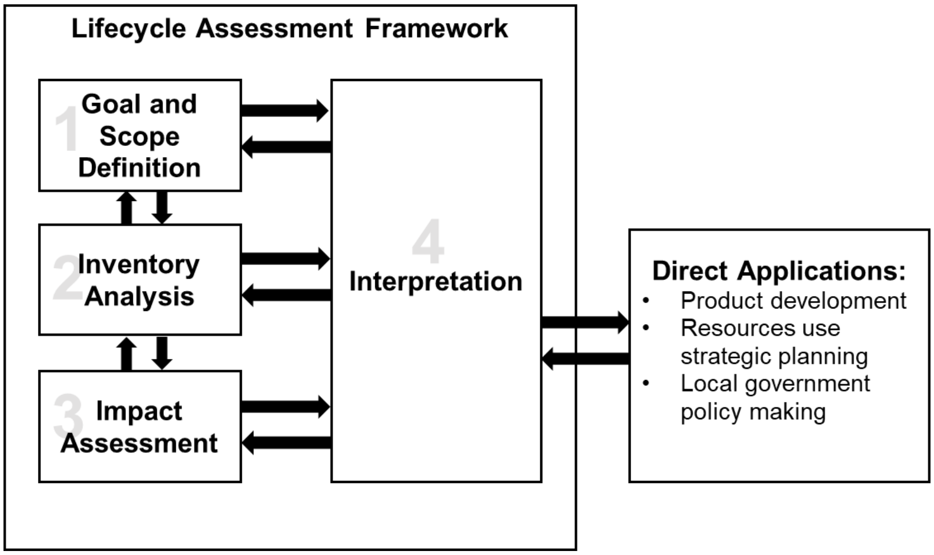


Figure 2-2. The four phases of an LCA study and example result applications.

3 SOURCE REDUCTION RESEARCH

3.1 METHODOLOGY

3.1.1 DEFINITION OF SOURCE REDUCTION

Source Reduction, also known as waste prevention, is the most preferred strategy in the waste management hierarchy and aims to eliminate waste before it is created (Anshassi et al., 2019). For this report, this includes all practices that actively minimize the amount of a material that ends up in a landfill, apart from recycling. Source reduction considers the full life cycle and could occur at any stage or throughout the life cycle of the material. Design, manufacture, use, and disposal are all periods in which source reduction methods can be implemented by reducing the impact of that material's life cycle. Producers, consumers, and the governmental all have direct impacts on the source reduction of a particular material. Producers can refurbish goods, utilize lightweight packaging, or reduce the volume of materials used in a specific good. Additionally, consumers have an impact on source reduction through selective purchasing and the government can introduce legislation to minimize unnecessary waste. In this report, we recognize two methods to calculate source reduction. The first method is what we refer to as the sales method. To calculate source reduction using the sales method, we subtract the amount of a material that was consumed at a baseline year by the amount of a material consumed in a comparison year. The End of Life (EoL) method of finding source reduction is found by comparing the amount of material that has been landfilled, recycled, composted, and incinerated in a baseline year and today. Source reduction is often forgotten in the environmental public conversation because it is invisible. It is not about the amount of material that has been used responsibly. It is about the material that was not used. For this reason, it is arguably one of the most important aspects of environmentalism. Humans have a history of using materials frivolously. Emphasizing source reduction and frugal consumption is one of the most important steps to take to live in a sustainable world.

3.1.2 MATERIAL TYPES

The materials chosen for this project are based on Municipal Solid Waste (MSW) that the Florida Department of Environmental Protection (FDEP) measures when analyzing the makeup of MSW. Additional materials such as electronics, asphalt shingles, and dimensional lumber have been added because of their additional environmental impact. The following is a list of materials that we will be analyzing for this project: Mixed MSW

- Newspaper
- Corrugated Cardboard (OCC)
- High Grade Paper (Office Type Paper)
- Magazines/third-class mail
- Books
- Mixed Paper
- HDPE
- PET
- Mixed Plastic
- Glass
- Aluminum Cans
- Steel/Tin Cans
- Mixed Metals
- Yard Waste
- Food Waste
- Tires
- Clothing and Footwear

- Furniture
- Electronics
- Wood Products
- Asphalt Shingles
- Gypsum Drywall
- Concrete
- Reclaimed Asphalt Pavement

Because of the inherent imperfection in data collection for materials, there are some estimates with a much higher probability of error. We have noted which materials have a higher probability of error when calculating the source reduction and the process for dealing with these materials change depending on the case.

3.1.3 SALES APPROACH METHODOLOGY FOR NON-C&D MATERIALS

Calculating source reduction based on the sales method allows us to observe trends based on consumers purchasing of materials. It is important to understand that comparing the mass of a material sold from year to year does not give an accurate representation of the materials produced in each individual year. We do not live in a perfectly competitive market. Material produced is always greater than material consumed. However, looking at the demand for a material in each particular year allows us to observe change in preference. Additionally, if we find the units of material sold, the sales approach allows us to calculate how much of source reduction can be attributed to a reduction of material used in production if we compare the units sold to the mass of material that was consumed.

The sales method looks at the consumption of a material at a baseline year (see Eq. 3-1). The baseline year for this report is 2005. We subtract this from the amount that was consumed in 2018 to find the source reduction of that particular material in 2018.

$$SSM = BS - TS \tag*{Eq. 3-1}$$

Equation 3-1 assumes that the source reduction for a specific material using the Sales Method is equal to the baseline year mass of a material sold (BS) minus the mass of the material sold today (TS).

This formula represents source reduction for the United States. For our report, we scaled the results to Florida based on population. This is done by dividing the United States population in 2005 (USP) by the Florida population in 2005 (FLP) and multiplying this by BS to get the Florida Baseline Year Mass of Material Sold (FBS). We must follow the same process for material sold today (TS) by dividing the United States population in 2018 by the Florida population in 2018 and multiplying this by TS. As a result, we find the mass of material sold today in Florida (FTS). Equations 3-2 through 3-4 show this.

$$FBS = BS\left(\frac{USP}{FLP}\right) \tag*{Eq. 3-2}$$

$$FTS = TS\left(\frac{USP}{FLP}\right) \tag*{Eq. 3-3}$$

$$FSSM = FBS - FTS \tag*{Eq. 3-4}$$

Calculating source reduction based on the sales method allows us to observe trends. It is important to understand that comparing the mass of a material sold from year to year does not give an accurate representation of the materials produced in each individual year. Material produced is always greater than material consumed. However, looking at the demand for a material in each particular year allows us to observe change in preference. Additionally, if we find the units of material sold, the sales approach allows us to calculate how much of source reduction can be attributed to a reduction of material used in production if we compare the units sold to the mass of material that was consumed. In many cases the data for one material type was limited to data from one source of products and many materials did not have any readily available sales data reported. Example results for aluminum cans and OCC are shown in Table 3-1.

There are several flaws to be found in this data. The sales method approach gathers consumption data, focusing little on production data. Although this allows us to observe trends and gives us an outline for rough source reduction estimates, it is important to additionally gather data on the amount of materials produced in order to get a more accurate representation of source reduction for any particular year. Also, the data collected in Table 3-1 does not clearly identify whether it accounts for the export and import of the materials, as well as whether recycled content was used in the production of the materials. If recycled content was used (which for most materials there is some fraction) then the actual amount of virgin materials consumed would translate to less virgin units sold and less virgin materials consumed. Furthermore, the state source reduction estimate is based on national source reduction data. Florida-specific material data was hard to locate, so United States sales data was used, converted into per-capita estimates, and multiplied by the state population for the year that was being analyzed. Overall, the method has many inconsistencies and flaws which led us to follow another approach to estimate source reduction as discussed in Sections 3.2.4 and 3.2.5. The results of the source reduction estimates are shown in Section 3.3.

Table 3-1. The annual volume and weight datasets used to estimate the consumption of each material category for the United States (US) 2005 and 2015 population.

Year	Year	Weight (kg/ unit)	Source	Total Units	Source	US National Consumption (tons)
Aluminum Cans						
2006		0.01	(Recycle USA Inc, 2014)	102,000,000,000	(Container Recycling Institute, 2008)	1,519,800
2018				81,281,317,309		1,211,092
Corrugated Boxes						
2001		0.06	(Zhang et al., 2014)	102,857,142,857	(Street Journal, 2001)	6,182,362
2018				531,737,174,585	(AP News, 2020)	6,270,990

3.1.4 EPA METHODOLOGY FOR C&D MATERIALS

In 2018 the EPA released *Construction and Demolition Debris Generation in the United States, 2015* (US EPA, 2018) which detailed the methods of calculating the generation of C&D debris in the U.S. in 2015 for concrete, steel, wood products, gypsum wallboard and plaster, brick and clay tile, asphalt shingles and asphalt concrete. The document contained revisions form the 2016 EPA document *Construction and Demolition Debris Generation in the United States, 2014* (US EPA, 2016). The generation of all materials except asphalt concrete were calculated using materials flow analysis, while asphalt concrete was estimated using state-reported data from solid waste management facilities and data gathered on reclaimed asphalt concrete (RAP) accepted by asphalt producers.

Construction debris was defined as the portion of purchased construction materials that are not incorporated into the actual structure, and demolition waste is the sum of materials removed from a structure during renovation and the materials generated from the demolition of a structure. The EPA included average lifespans of construction materials by their source structures because C&D generation in a given year is dependent on the lifespan of the material. Also provided was the percent of each material discarded during construction. The demolition debris generation calculation was based on average demolition debris generation for the full range of years within a material’s lifespan. What this means is that for brick discarded in 2014 which had a lifespan of 50-100 years, EPA calculated demolition debris based on brick consumption between 1914-1964 and averaged the results. For each material included, the EPA provided the data source of historical consumption data, and how that information was used to determine the yearly C&D debris generation for each material.

For concrete, which included both that made of portland cement and that made of a portland cement and fly ash mixture, EPA mainly derived historical concrete consumption based on cement consumption data from the USGS from 1900 to 2015. The type of cement used was only recorded starting in 1975 by the USGS and ending in 2014, so the EPA assumed 96% of cement prior to 1975 was portland cement, and the percentage of portland cement in 2015 was assumed the same as in 2014. Fly ash data was based on fly ash purchased from the years 2000 to 2015 as published by the American Coal Ash Association. A stepwise function was used to estimate fly ash used from when it became common in 1950 to 1999 based on the quantity in 2000. Portland cement and fly ash consumption were converted to concrete consumption mass based on density data for concrete from the American Society for Testing Materials and portland cement density from the Portland Cement Association to determine a multiplier of 6.64 tons of concrete consumed per ton of portland cement (fly ash can substitute for portland cement on a one to one basis).

Based on 2002 data which estimated how much concrete was allocated to different structures, the EPA was able to use those percentages and extrapolate from construction spending differences between 2002 and a given year to adjust the given 2002 percentages to those of the given year.

For wood, the EPA based the consumption data for lumber, wood paneling, and plywood and veneer products from USFS for the years 1900 to 2013. Another USFS document provided the volumetric data for wood product consumption for 2014 and 2015 and was then converted to mass. Based on a USFS data, the EPA estimated that 78% of lumber use was for construction and assumed all plywood and veneer products and wood paneling were used in construction. Consumption of lumber for railroad ties was based on data from the Rail Tie Association (RTA) for both Class 1 railroads from 1921 to 2015 and regional and short line railroads from 2011 to 2015. The rail ties for 1900 to 1920 for Class 1 railroads were estimated based on data form 1921-1930. Calculating the total mass of rail ties was based on the size of ties and a volume-to-weight conversion from the USFS for hardwood lumber.

For gypsum drywall and plasters, historical data on consumption from 1900 to 2015 from the USGS was used in combination with USGS data for gypsum data which provided the amount of gypsum that went to drywall and plasters for 1975-2015. The average percent of gypsum that went to drywall and plaster for those years was 75% so the EPA estimated that 75% of gypsum went to drywall and plaster for the years 1900-1974. Synthetic gypsum-based drywall and plaster were included in calculations for the years 2012 to 2015 but were assumed to be negligible before 2012 based on known annual consumption.

For steel, the historical data for steel use from 1900 to 1970 was provided by the U.S. Census bureau and from 1979 to 2014 from the USGS. The consumption from 1971-1978 was estimated by interpolating based on the consumption data in 1970 and 1979. The EPA estimated 2015 steel consumption based on the total apparent consumption reported in 2015 and by assuming that steel consumed by construction in 2015 was the same in 2014.

For bricks, clay floor and wall tile, from 1900 to 1969 the number of bricks consumed for building construction came from the U.S. Census Bureau. EPA used the conversion of 499 bricks per short ton based on Cochran and Townsend (2010). For 1970 to 2014 clay end-use data came from the USGS for common clay and shale and kaolin clay. 2015 the USGS Mineral Commodity Summary approximated the percentage of common clay and shale used to make brick and ball clay used to make tiles. Kaolin clay consumption for bricks was not reported separately in 2014 so the USGS assumed that it was the same as in 2013 for both 2014 and 2015.

For asphalt shingles, EPA used the sales of roofing granules published by the USGS to estimate use over time. End-use statistics from the USGS were available for 1980-2014 which included roofing granules made from several different materials. Years where such data was missing (every other year from 1980 to 1994) the EPA estimated the roofing granules by averaging the previous and the following year. Based on information from the Asphalt Roofing Manufacturers Association (ARMA), the EPA estimated 230 pounds per square of roofing coverage to convert the number of shingles to tons of shingles in 2006. Then, using the ratio of roofing granules in a given year to roofing granules in 2006 the EPA multiplied that number by the weight of the shingles.

For asphalt concrete, the EPA used data on reclaimed asphalt pavement (RAP) accepted by asphalt mix producers published by NAPA and FHWA with data for statepermitted solid waste management facilities. The EPA used the CDDPath method for calculating C&D concrete. CDDPath is an approach that accounts for end-of-life management of C&D asphalt concrete without needing lifespan assumptions. Methodology used in previous years for such calculations that did not use the CDDPath method but only included data from the NAPA survey underestimated the amount of asphalt concrete.

3.1.5 END-OF-LIFE APPROACH METHODOLOGY

The End-of-Life (EoL) formula accounts for the amount of the material that is discarded. As the name suggests, it is a calculation for source reduction that can only be made at the end of a material's life. To calculate source reduction using the EoL formula, we find the amount of a material that is generated. This generation is calculated by adding the amount of material that is recycled, landfilled, composted, and incinerated, as shown in Equation 3-5. We find the amount of material that is generated in 2005 and subtract this from the amount of material that was generated in 2018.

$$G = L + R + C + I \qquad \text{Eq. 3-5}$$

Equation 3-5 signifies that the amount generated is equal to the sum of the amount of a material that was landfilled (L), recycled (R), composted (C), and incinerated (I).

$$SEoL = BG - TG \qquad \text{Eq. 3-6}$$

As show by Equation 3-6, today's Source Reduction using the End of Life method is equal to the amount of a material generated in the Baseline year (BG) minus the amount the material generated today (TG).

The mass of all materials estimated each year is based on data for Florida waste generation from FDEP's Annual Solid Waste Reports, in addition to Florida's population data. The information for the lifetimes of waste materials which are not consumed and generated in the same year comes from a variety of sources as noted in Table 3-2.

Table 3-2. Material life expectancy and source of data relating to life expectancy calculation.

Material	Life expectancy (years)	Source
White Goods	14	(US EPA, 2014)
Ferrous Metals	14	
Non-ferrous metals	14	
Textiles	3	(Textile Restorations, 2021)
Tires	6	(Muller, 2017)
E-Waste	9	(US EPA, 2014)
Furniture and Textile Donations	5	(Iritani et al., 2015)

3.2 SOURCE REDUCTION MASS ESTIMATES

3.2.1 C&D ESTIMATES

C&D estimates were based on the calculation methods laid out in EPA's *Construction and Demolition Debris Generation in the United States, 2015.* 2015 was the most recent year that all sources for generation quantities were available and so was used instead of 2018. The regional rail tie data from 2015 was not readily available while following the EPA calculations and so was assumed to be the same as 2014 (included in the lumber calculations). The 2005 calculations were based on the same report, but the asphalt pavement generation data was only available for 2013 through 2015, so was calculated for 2005 by extrapolating from the three years which were available.

Table 3-3. Based on EPA methodology for calculating generated waste debris. Shown are the calculated estimates for 2015 in tons and pounds per person, and the 2015 Florida population based on FDEP Annual Solid Waste Reports data was used to determine total C&D debris waste generation in Florida in tons.

C&D Materials consumption		**2015 US (US tons)**	**US national per capita consumption (lb/person-year)**	**2015 Florida (US tons)**
Concrete	Buildings	225,933,646	1,408	13,952,070
	Roads and bridges	25,874,969	161	1,597,856
	Other	223,092,907	1,391	13,776,646
Wood Products	Lumber (buildings)	26,687,000	166	1,648,001
	Lumber (railroads)	1,043,025	7	64,410
	Wood Panel Products	8,654,000	54	534,410
	Plywood and Veneers	2,253,000	14	139,129
Drywall		12,900,000	80	796,613
Steel scrap		18,400,000	115	1,136,254
Asphalt Shingles		9,370,557	58	578,660
Bricks		4,713,000	29	291,042
Clay Tile		901,000	6	55,639
Asphalt Concrete		81,800,000	510	5,051,391
Total		***641,623,104***	***3,999***	***39,622,121***

Table 3-4. Based on EPA methodology for calculating generated waste debris. Shown are the calculated estimates for 2005 in tons and pounds per person, and the 2005 Florida population based on FDEP Annual Solid Waste Reports data was used to determine total C&D debris waste generation in Florida in tons.

C&D Materials consumption		**2005 US (US tons)**	**US national per capita consumption (lb/person-year)**	**2005 Florida (US tons)**
Concrete	Buildings	450,330,866	3,048	27,304,855
	Roads and bridges	204,075,837	1,381	12,373,705
	Other	271,331,399	1,836	16,451,603
Wood Products	Lumber (buildings)	57,714,597	391	3,499,402
	Lumber (railroads)	941,403	6	57,080
	Wood Panel Products	10,400,000	70	630,582

	Plywood and Veneers	10,500,000	71	636,645
Drywall		28,200,000	191	1,709,847
Steel scrap		21,700,000	147	1,315,733
Asphalt Shingles		10,929,144	74	662,665
Bricks		14,998,000	102	909,372
Clay Tile		991,000	7	60,087
Asphalt Concrete		52,833,989	358	3,203,477
Total		***1,134,946,235***	***7,681***	***68,815,052***

Table 3-5. Source-reduced C&D debris consumption rate calculated by subtracting 2005 data form 2018.

C&D Materials consumption		**Source Reduced US (US tons)**	**US national per capita consumption Source Reduced (lb/person-year)**	**Source Reduced Florida (US tons)**
Concrete	Buildings	-224,397,220	-1,639	-13,352,785
	Roads and bridges	-178,200,868	-1,220	-10,775,849
	Other	-48,238,493	-446	-2,674,957
Wood Products	Lumber (buildings)	-31,027,597	-224	-1,851,401
	Lumber (railroads)	101,622	0	7,330
	Wood Panel Products	-1,746,000	-16	-96,172
	Plywood and Veneers	-8,247,000	-57	-497,516
Drywall		-15,300,000	-110	-913,234
Steel scrap		-3,300,000	-32	-179,479
Asphalt Shingles		-1,558,587	-16	-84,006
Bricks		-10,285,000	-72	-618,330
Clay Tile		-90,000	-1	-4,448
Asphalt Concrete		28,966,011	152	1,847,915
Total		***-493,323,131***	***-3,682***	***-29,192,932***

3.2.2 END-OF-LIFE APPROACH ESTIMATES

The end-of-life approach for calculating source-reduced mass estimates for different materials was based on data available for Florida by FDEP Annual Solid Waste Reports. The estimates provided include mass of total waste generated in each county in Florida in 2005 and 2018 as well as the total mass of different types of waste in 2005 and 2018. The results for the end-of-life approach for source reduction are shown in Table 3-6 for a total mass basis. The individual materials collected/consumed for each material type are detailed in Tables 3-7 through 3-9. For the breakdown of waste by category, some materials are not regularly consumed and disposed of in the same year, so calculations surrounding the lifetimes of these materials had to be done, these results are shown in Figures 3-1 through 3-5. Additionally, one category of waste reported was labeled “Miscellaneous” and the composition of miscellaneous wastes was determined using data from county recycling workbooks. C&D debris was not calculated using the end-of-life approach because the sales approach was assumed to be sufficient.

End-of-life data for materials which are not consumed and discarded in the same year rely on estimations of product lifetimes to determine what year the bulk of such materials were consumed. This lifetime data is an average of available lifetime data, so is not entirely reflective of when the materials were consumed. Furthermore, the wastes then consumed in 2018 were not discarded in 2018, and so the lifetime estimation was then extended to the waste disposed 2018 + n, with n being the lifetime of the product. The mass of waste in year 2018 + n was determined using linear regression as it could not be calculated directly. Additionally, the yearly end-of-life data for certain wastes were just reported as “miscellaneous.” In order to determine composition of the miscellaneous wastes, the 2018 Florida recycling workbooks for 67 counties were used to determine the most common waste materials not categorized elsewhere. Then the percent composition of those materials within the miscellaneous category in the recycling workbook was determined, and that same percentage was applied to the overall miscellaneous waste disposed in each year. This is just an estimation and may not be an accurate representation of overall miscellaneous waste composition.

Table 3-6. End-of-life estimates for total mass of waste from each county in Florida in 2005 and 2018 and source-reduced estimates, excluding waste which are not produced and consumed in the same year or cannot be source reduced. Wastes which were not considered to be consumed and disposed in the same year included tires, textiles, ferrous and non-ferrous metals, white goods, and C&D debris. Wastes which are not considered to be able to be source reduced includes yard trash, so it was not included in the sum.

Florida County	2018 lbs./person	2018 lbs./person*	2005 lbs./person	2005 lbs./person*	Source Reduced lbs./person	Source Reduced lbs./person*
Alachua	1,631	1,400	1,101	972	531	429
Baker	1,241	1,113	832	717	410	396
Bay	2,727	2,564	926	782	1,801	1,783
Bradford	1,262	1,072	756	568	505	504
Brevard	2,351	2,189	1,622	1,420	729	768
Broward	2,316	2,036	1,444	1,307	872	729
Calhoun	457	368	1,013	964	-555	-596
Charlotte	2,307	1,986	2,265	2,142	41	-156
Citrus	1,272	1,080	1,267	1,037	5	44
Clay	1,203	994	1,058	744	145	250
Collier	1,668	1,274	1,113	674	555	600
Columbia	1,368	1,100	997	878	371	222
Desoto	1,394	1,161	1,327	1,174	68	-12
Dixie	960	820	457	365	503	455

Duval	1,661	1,402	1,307	1,306	355	95
Escambia	1,665	1,427	1,536	1,402	129	25
Flagler	768	646	1,154	276	-386	370
Franklin	2,114	1,891	2,022	1,649	92	242
Gadsden	630	531	815	809	-185	-278
Gilchrist	430	360	521	268	-91	92
Glades	1,595	1,324	1,023	981	573	343
Gulf	1,642	1,362	853	740	790	622
Hamilton	1,220	970	268	265	952	704
Hardee	1,243	1,033	766	715	476	318
Hendry	2,861	2,399	1,514	837	1,347	1,562
Hernando	1,067	891	1,051	949	16	-58
Highlands	1,310	1,087	1,848	1,704	-538	-617
Hillsborough	2,453	2,120	1,434	1,312	1,020	808
Indian River	2,140	1,847	2,252	977	-112	870
Jackson	2,024	1,694	1,077	929	947	765
Jefferson	1,370	1,143	560	460	810	683
Lafayette	627	526	513	415	114	111
Lake	1,056	864	790	535	266	330
Lee	1,849	1,336	1,418	1,071	431	265
Leon	1,735	1,443	1,021	865	713	578
Levy	1,049	873	748	618	301	256
Liberty	538	447	386	304	152	143
Madison	1,283	1,088	829	652	454	436
Manatee	1,961	1,445	1,000	843	961	602
Marion	727	590	646	590	81	-1
Martin	2,205	1,957	2,202	1,953	3	4
Miami-Dade	1,985	1,735	1,529	1,398	456	337
Monroe	3,290	2,127	2,240	1,756	1,050	370
Nassau	1,273	1,069	326	276	947	793
Okaloosa	1,477	1,238	1,495	1,263	-18	-25
Okeechobee	2,567	2,147	1,080	909	1,487	1,238
Orange	2,969	2,588	1,475	1,279	1,495	1,309
Osceola	1,635	1,382	828	633	807	749
Palm Beach	3,240	3,051	1,076	911	2,164	2,140
Pasco	1,289	1,116	875	870	414	245
Pinellas	2,930	2,336	1,645	1,481	1,285	854
Polk	1,743	1,391	1,641	1,357	102	34
Putnam	1,280	1,082	520	427	760	655
Santa Rosa	2,340	1,962	1,248	1,161	1,092	801
Sarasota	3,227	2,508	1,567	1,341	1,661	1,167
Seminole	1,338	1,148	1,109	871	230	277
St. Johns	1,431	1,203	1,401	1,146	30	57

St. Lucie	1,846	1,586	906	852	940	734
Sumter	745	657	464	408	281	248
Suwanee	1,014	729	2,723	2,201	-1,709	-1,471
Taylor	1,929	1,617	391	331	1,539	1,286
Union	905	751	882	626	23	125
Volusia	1,524	1,324	1,172	1,010	353	314
Wakulla	690	588	302	301	388	287
Walton	3,141	2,610	549	324	2,592	2,286
Washington	1,318	1,102	1,384	1,216	-66	-114

*Does not include food material category.

Table 3-7. End-of-life estimates for categories of materials disposed of in Florida in 2005 calculated by summing FDEP Annual Solid Waste Reports data from every county. The table excludes wastes categories which are not considered to be consumed and disposed in the same year or are not considered source reduced. The mass of oil was calculated by estimating the percentage of the miscellaneous category of wastes which is composed of oil using the miscellaneous data from the recycling workbooks of most Florida counties in 2018 and using the same percentage composition of total miscellaneous waste in 2005.

Waste Type	Tons Collected	lbs./person Collected
Newspaper	1,528,569	171
Glass	741,010	83
Aluminum Cans	225,006	25
Plastic Bottles	408,856	46
Steel Cans	307,434	34
Corrugated Paper	2,791,109	312
Office Paper	923,537	103
Other Plastics	1,193,702	133
Other Paper	2,285,130	255
Food	1,561,498	174
Oils	359,439	40

Table 3-8. End-of-life estimates for categories of materials disposed of in Florida in 2018 calculated by summing FDEP Annual Solid Waste Reports data from every county. The table excludes wastes categories which are not considered to be produced and consumed in the same year or are not considered source reduced. The mass of oil was calculated by estimating the percentage of the miscellaneous category of wastes which is composed of oil using the miscellaneous data from the recycling workbooks of most Florida counties in 2018.

Waste Type	Tons Collected	lbs./person Collected
Newspaper	813,510	78
Glass	101,033	10
Aluminum Cans	205,145	20
Plastic Bottles	703,873	68
Steel Cans	423,780	41

Corrugated Paper	2,657,180	256
Office Paper	626,933	60
Other Plastics	3,672,577	354
Other Paper	3,423,567	330
Food	3,106,305	300
Oils	542,252	52

Table 3-9. End-of-life estimates for source reduced materials calculated by subtracting 2018 estimates from 2015 estimates.

Material	**Source Reduced lbs./person**
Newspaper	-92
Glass	-73
Aluminum Cans	-5
Plastic Bottles	22
Steel Cans	7
Corrugated Paper	-55
Office Paper	-43
Other Plastics	221
Other Paper	75
Food	125
Oils	12

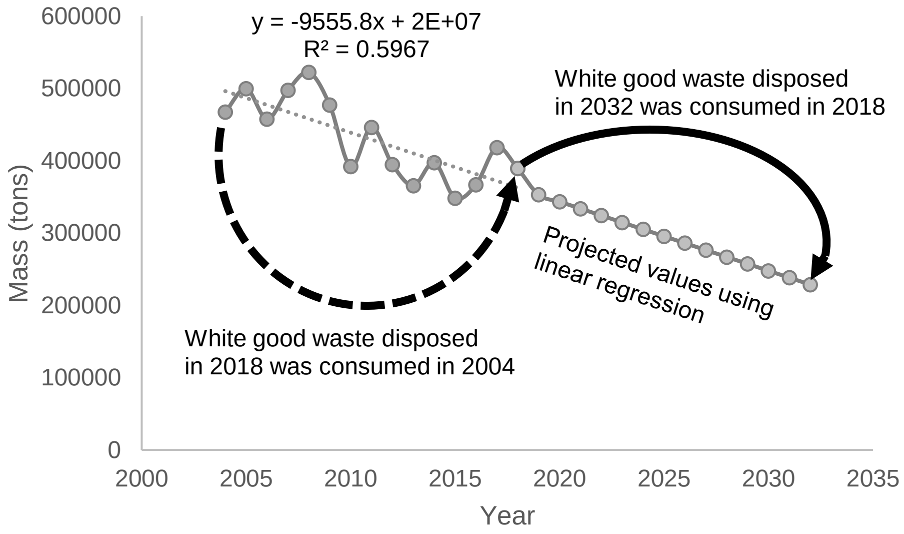


Figure 3-1. The average lifetime of white goods was determined to be 14 years based on average lifetimes of different appliances provided by the EPA ("Time Lag and Composition of Durable Goods," 2014). The figure shows the total mass of white goods waste generated in 2018, which is approximately the total mass of white goods consumed in 2004. The white goods produced in 2018 will be reflected in the mass of

white goods waste generated in 2032. The waste in years 2019-2032 was estimated based on the previous years' trend calculated in Excel.

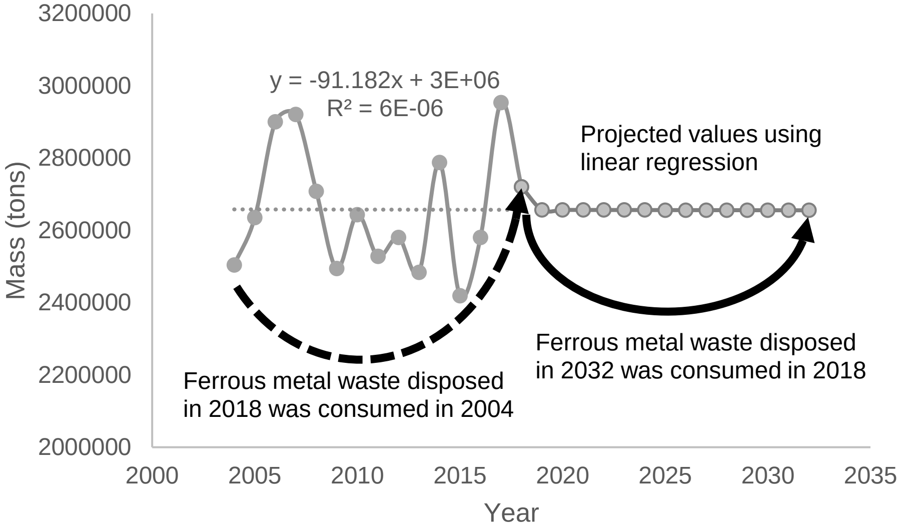


Figure 3-2. The average lifetime of ferrous metal was determined to be 14 years based on average lifetimes of different appliances provided by the EPA ("Time Lag and Composition of Durable Goods," 2014). The figure shows the total mass ferrous metal waste generated in 2018, which is approximately the total mass of ferrous metal consumed in 2004. The ferrous metal produced in 2018 will be reflected in the mass of ferrous metal waste generated in 2032. The waste in years 2019-2032 was estimated using the linear regression equation.

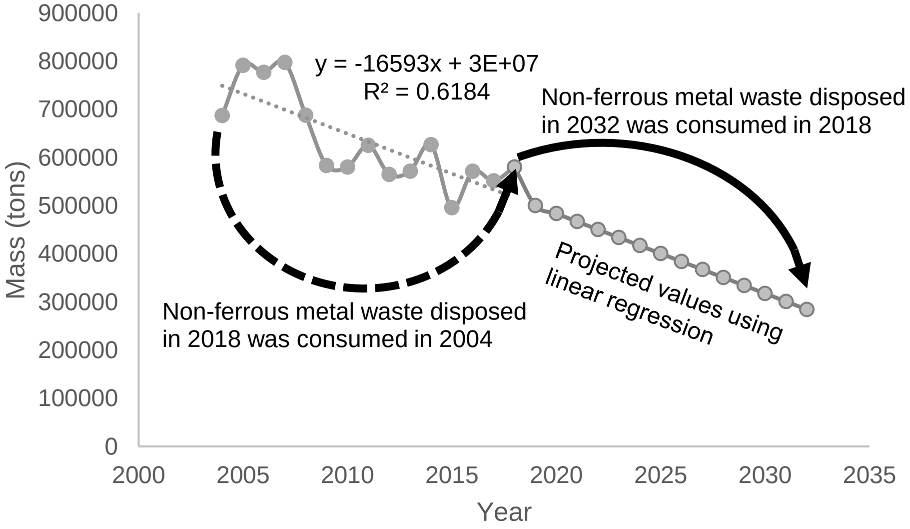


Figure 3-3. The average lifetime of non-ferrous metal was determined to be 14 years based on average lifetimes of different appliances provided by the EPA ("Time Lag and Composition of Durable Goods," 2014). The figure shows the total mass non-ferrous metal waste generated in 2018, which is approximately the total mass of non-ferrous

metal consumed in 2004. The non-ferrous metal produced in 2018 will be reflected in the mass of non-ferrous metal waste generated in 2032. The waste in years 2019-2032 was estimated using the linear regression equation.

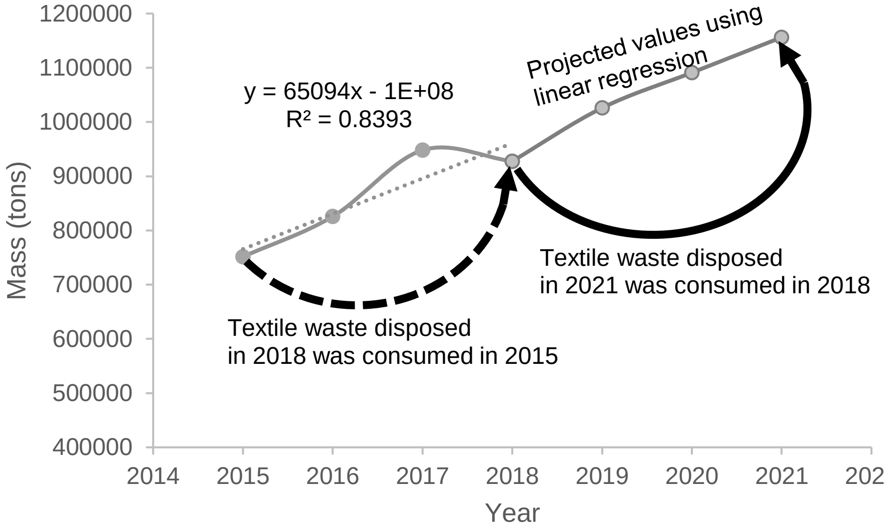


Figure 3-4. The average lifetime of textiles was determined to be 3 years based on average lifetimes of different types of garments and furniture made of textiles as documented by the International Fabricare Institute ("Average Life Expectancy of Textile Items in Years," n.d.). The total mass of textile waste generated in 2018 was consumed in 2015, and the textiles consumed in 2018 will become waste generated in 2021. The waste in years 2019-2021 was estimated using the linear regression equation.

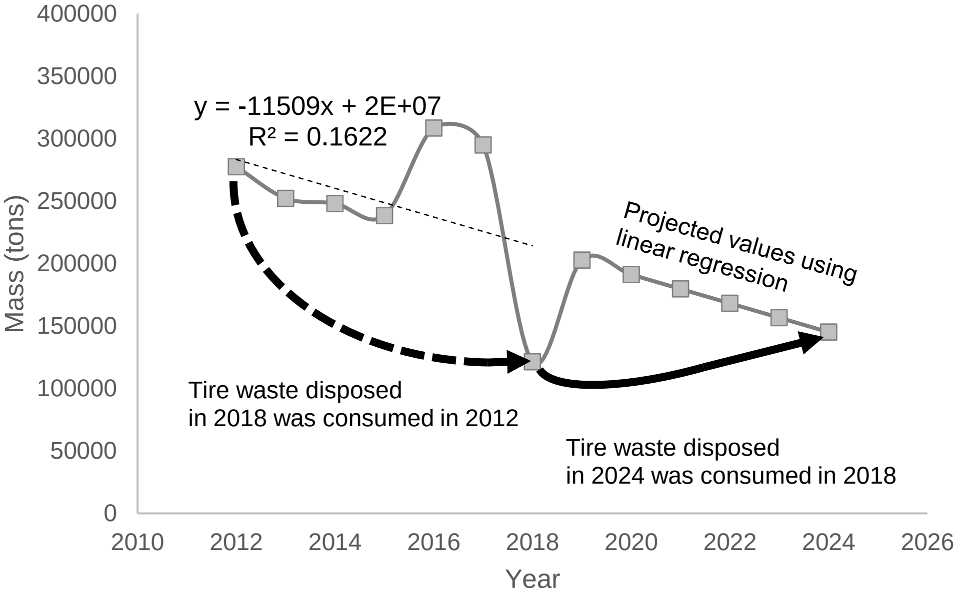


Figure 3-5. The average lifetime of rubber tires was assumed to be 6 years (Muller, 2017) and so the figure shows the total mass of tire waste generated in 2018 which is approximately the mass of tires consumed in 2012, and the tires consumed in 2018 will become tire waste generated in 2024. The waste in years 2019-2024 was estimated using the linear regression equation.

The final category of materials recorded by the Florida counties was labeled as “miscellaneous.” This categorization is not useful in determining the lifespan of the waste or its potential to be source reduced. To determine the waste types which comprise the miscellaneous category, we used the Florida FDEP Recycling Workbooks, which report every type of waste recycled which was categorized as miscellaneous. Eleven broad categories were used to define the waste defined as miscellaneous based on generalizations of the type of waste seen in the Florida FDEP Recycling Workbooks; results are shown in Figure 3-6. The categories defined approximately 95% of the waste included as miscellaneous within the Florida Recycling Workbooks, which was determined to be satisfactory as we needed a general overview of the waste disposed and the uncategorized material comprises so little of the recycled material it could be assumed to be the same issue with the miscellaneous collected waste. Since some materials are not regularly consumed and disposed of in the same year, calculations surrounding the lifetimes like those in Figures 3-1 through 3-5 were also applied here, as seen in Figures 3-7 and 3-8.

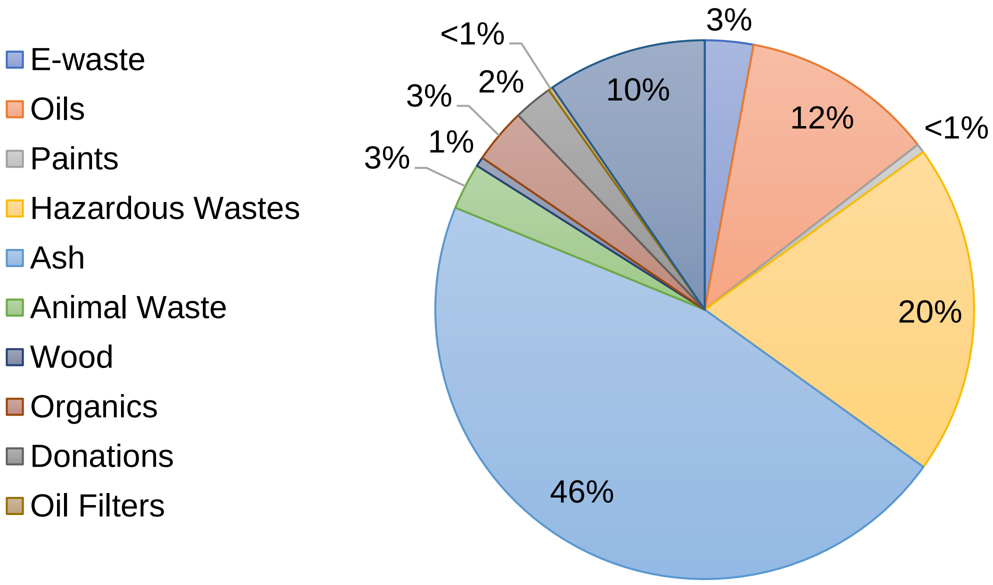


Figure 3-6. Breakdown of the 11 categories used to break down the miscellaneous waste.

To determine the quantity of each category included in the collected waste to proceed with the end-of-life estimates, the total mass of each waste in the category was divided by the total mass of all the recycled miscellaneous wastes according to the Florida

Recycling Workbooks for 2018, and this ratio was multiplied by the total miscellaneous waste collected in 2018. The ratio based on the 2018 recycling workbooks was assumed the same for the preceding years, and the proceeding years' total collected waste was determined using the linear regression equation. Not all of the categories were considered in the end-of-life analysis, only those which could be considered source reduced. Recycled organics included donated food, which is considered in a later section, and compost, which is not considered to be source-reduced so those were not included in the end-of-life analysis. The donations category includes all donated items besides food, mostly consisting of furniture and textiles.

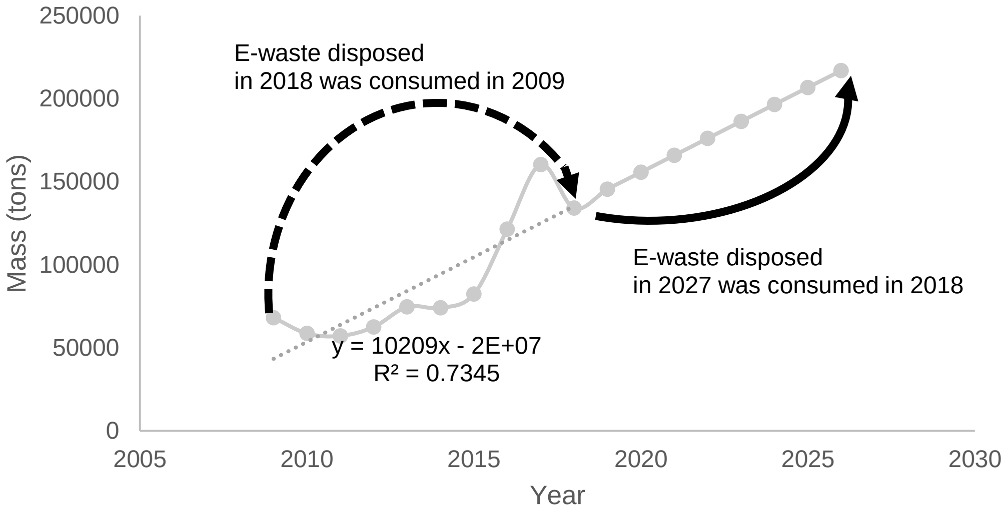


Figure 3-7. The average lifetime of electronics included in e-waste was calculated to be 9 years based on the average lifetimes of different appliances provided by the EPA ("Time Lag and Composition of Durable Goods," 2014). The mass of e-waste generated each year was estimated based on the percentage of miscellaneous waste composed of e-waste according to Florida county recycling workbooks in 2018 and multiplying that percentage by total miscellaneous waste generated in the years 2009-2018. The total mass of e-waste generated in 2018 is approximately that consumed in 2009, and the electronics consumed in 2018 will be approximately that of the e-waste generated in 2027. The mass of the waste in years 2019-2027 was estimated using the linear regression equation.

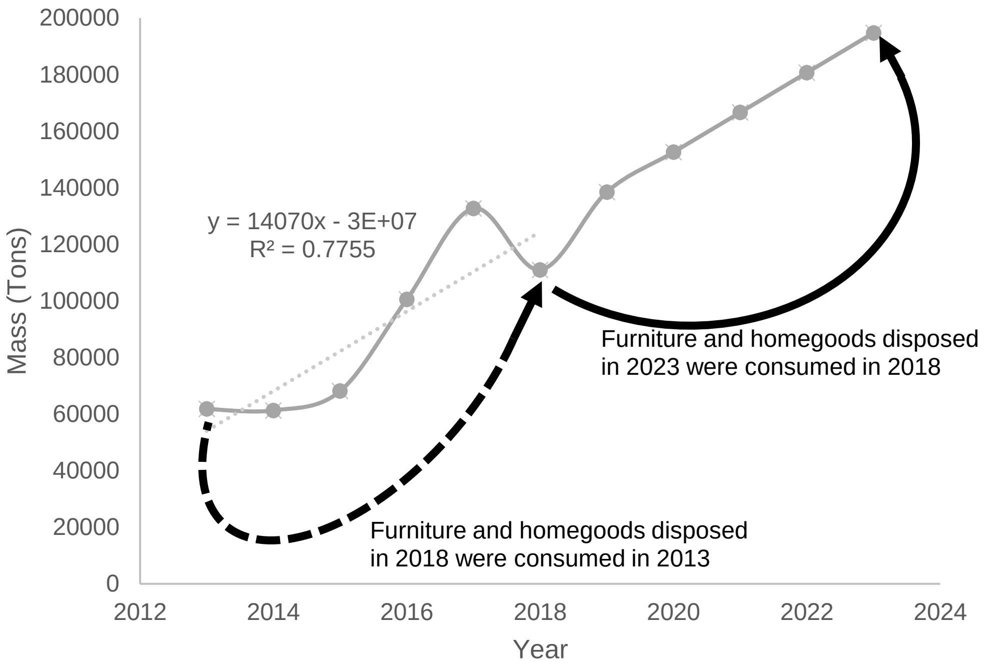


Figure 3-8. The average lifetime of furniture and textile donations was based on the average lifetime of a wardrobe, which Iritani et al., 2015 determined to be a representative item for the furniture industry. The average lifetime was therefore 5 years. The mass of furniture waste generated each year was estimated based on the percentage of miscellaneous waste composed of furniture and textile donations according to Florida county recycling workbooks in 2018 and multiplying that percentage by total miscellaneous waste generated in the years 2013-2018. The total mass of furniture waste generated in 2018 is approximately that consumed in 2013, and the furniture consumed in 2018 will be approximately that of the waste generated in 2023. The mass of the waste in years 2019-2023 was estimated using the linear regression equation.

4 MATERIAL REUSE

4.1 OVERVIEW AND BACKGROUND

When an item is donated, it has the opportunity to be purchased or otherwise acquired for a second time. This second life for the item is not tracked by the sales method as the item was already noted as being produced and is not accounted for by the end-of-life method as donation extends a product's expected lifespan. Therefore, material reuse was studied by contacted different donation centers throughout Florida to estimate the quantity of material source reduced by donation.

4.2 TYPES OF MATERIALS REUSED

Not every material is able to be reused. The materials studied for reuse include ones that still maintain their function, if unwanted or unneeded by a consumer, or unmarketable or produced in surplus by a producer. For instance, food may still be fit for consumption while going unsold in a grocery store, or clothing still wearable even if is no longer worn by the owner. Materials such as yard waste or C&D debris are harder or impossible to repurpose rather than dispose. Such materials were therefore not studied for donation source reduction. Commonly donated items such as food, furniture, textiles, and electronics were those frequently reused or reclaimed.

4.3 FOOD DONATION SYSTEM

4.3.1 METHODOLOGY FOR FLORIDA FOOD DONATION ESTIMATES

Data was collected from literature, FDEP recycling workbooks, food bank and annual reports, as well as conversations with businesses, non-profit organizations, and government entities. The information relayed in this section is from "State of Food Donation Efforts in Florida" for which the food donation study was initially conducted (Townsend et al., 2020).

After stakeholders were identified, they were each contacted. The FDEP was contacted first and provided 67 recycling workbooks which contained the quantity of food donations already reported in the state. Next the 67 county Recycling Coordinators or other employees knowledgeable about food recovery were contacted in the event that clarifying questions were needed. Next, generators were contacted at both the local and corporate level to discuss their food recovery operations. Service organizations were researched and contacted, with their annual reports being used as a source of information on operations, donors, and food distribution quantities. The percentage breakdown of donor categories discussed in 4.3.2 and the total distributed pounds of food were compiled and organized. Due to there being over 2000 community distributors in Florida, just a few county's community distributors were focused on and called to learn about their operations. FDACS was contacted to access Feeding Florida's public records as well as other pertinent data.

After collecting the data two methods were used to estimate the mass of source-reduced donated food items in 2018. Method 1 is to sum the food donation quantities produced by the generators (retail, manufacturers, restaurants, hotels, schools, and farms). This method was not used due to lack of available data from food generators and distributors. Method 2 estimates total source-reduced food donation mass by adding up the food donations made to both food banks and community distributors. The mass of source reduced food donations from generators to specific food banks was first determined for each of the 16 Florida food banks. First this calculation started with the total mass of food donations minus the food obtained by purchasing, the USDA, and food drives because this food is not considered source reduced. Then the quantity of source reduced food donations that went directly from the generator to the community distributor was calculated based on information from the Society of St. Andrews which collects post-harvest and gleaned food from agricultural generators and donates it directly to community distributors. The total source reduced food donations were then calculating by adding those two values together.

The stakeholders identified for the flow of food donations are the government, service organizations including food banks and community distributors, and recipients. The Florida Department of Agriculture and Consumer Services (FDACS) is a government entity responsible for Florida's Food Recovery Program which helps coordinate and promote other resources such as private entities, farms, and federal and non-profit food relief program to connect food to Floridians living with food insecurity.

The generators which produce food donations include retail, manufacturers, restaurants, hotels, schools, farms, food drives, and the USDA. The food they donate is generally either no longer marketable for them or was produced in surplus. Food banks are non-profit service organizations which receive food from generators or other food banks and distribute it either to community distributers or directly to the public. Food banks consist of warehouses that intake both perishable and non-perishable food items and inspect and weigh them.

Community distributors are organizations and programs such as food pantries and soup kitchens which directly distribute food to recipients. Recipients are those who receive the food donations, often food-insecure community members. FDEP provided recycling workbooks which include some collected data on food donations. Generators were contacted about their food recovery programs and the ones which responded provided information on the process for donating food, which food may be donated, which locations may or may not participate, etc. Individual food bank responses are recorded in Table 4-1. Table 4-2 reports community distributor responses, which were not used in estimate calculations due to inconsistent metrics. Tables 4-1 and 4-2 are originally from "State of Food Donation Efforts in Florida" for which this research was initially conducted (Townsend et al., 2020).

Table 4-1. Food bank responses.

Food Bank	Responses
Feeding Second Harvest of Central Florida	Not able to help at the time
Heartland Food Bank	Provided 2019 and 2020 data breakdown based on weights of food item categories monthly.
Feeding Tampa Bay	Conversed on general operations
All Faiths Ending Hunger Food Bank	The initial introduction of the project was made but no further communication
Midwest Food Bank	Provided 2019 data
Harry Chapin Food Bank	Conversed on general operations
Feeding South Florida	Not able to help at the time
Palm Beach County Food Bank	Provided 2018-2019 data

Bread of the Mighty Food Bank, Farmshare, Feeding the Gulf Coast, Feeding Northeast Florida, First Step Food Bank, Florida Gateway Food Bank, Second Harvest of the Big Bend, Treasure Coast Food Bank	No response

Table 4-2. Service organization responses.

County	# of Service Organizations Contacted	Responses
Orange County	29	Three food pantries responded. One church pantry gets 90% from church goers. One church pantry receives 20% from community, 1000 pounds from Second Harvest monthly. Another community distributor runs over 68 food pantries and food programs. They equal one meal to a pound. They run three food pantries, which procure food mostly through the community, such as food drives. One of those locations distributes around 2,700 meals per month. The organization procures food for about 68 school food programs, mostly from Second Harvest of Central Florida. Food for the two soup kitchens is procured from other service organization, grocery alliances, and contacts from the community. Each soup kitchen feeds around 350-400 people a day. The representative said they have a capacity issue, not a demand issue.
Broward	27	Many pantries stated that they did not keep inventories. Most counties that replied stated that all their food came from Feeding South Florida.
Martin	1	The community distributor feeds 5500 families a month and procures donations from Publix, Fresh Market, and food drives.
Hillsborough	5	A community distributor receives inventory two times a week. The organization feeds 500 families/week and 160 homeless/month. Food is procured through Feeding Tampa Bay, Save-a-Lot, and has a personal relationship with a store manager who helps them get donations.
Lee	5	A community distributor feeds 300,000 people a year. They procure food from Midwest once a month and Harry Chapin once a week.
Manatee	2	An organization feeds 200-250 families a week.
Alachua	4	Smaller pantries retrieve only enough donations for their patrons from Bread of the Mighty. Larger outreach programs maintain relationships with grocery stores, Bread of the Mighty, and uphold conditions to receive Farmshare deliveries.
Martin/Palm Beach	One organization runs 8 community distributors	Five food pantries and one soup kitchen in Palm Beach County and one in Martin County; documents food donations in dollar amount of $1.68/pound. The dollar equivalence of food the locations handle varies; for example, ~$350, ~$12,000, $45,000, up to ~$174,000. Food pantries mainly procure from food drives and the soup kitchen procures from restaurants, vendors, negligible from food drives. Neither food pantry nor soup kitchen receives donations from USDA or is purchased. The organization also organizes gleaning, in which most of the produce goes to the local food bank.

4.3.2 FOOD DONATION SYSTEM FLOW

Food donations come from generators who are no longer able to market the food or they have the food in surplus. The generator donates the food to a food bank or community distributor. When a food bank has the food, they may choose to disperse the item to recipients via a mobile food pantry, to a community distributor, or to another food bank which then may also choose one of the first two options. Community distributors deliver food to recipients.

Much of FDACS work surrounds food donations from the agricultural industry, and these donations are largely delivered to community distributors and food banks as indicated by receipts from FDACS.

Retail may donate perishable food items that do not sell due to excess supply or do not meet consumer expectations as well as bakery items they can no longer sell and non-perishable items that are bent or mislabeled. Similarly, manufacturers may donate foods which cannot be sold due to incorrect labeling, are bent, or do not meet product expectations (the donation of these foods happens less frequently due to the emergence of secondary grocers who will sell such foods at a discounted rate such as dollar stores). Restaurants may donate food which was prepared but not sold and cannot be made available for purchase and hotels may donate food which was prepared in excess for a conference or event. Schools may or may not have policies in place for donating uneaten foods, some have systems where the food can be made available to anyone who wants to take it. Farms often have food items that may be donated when the produce is harvested or food which is gleaned and harvested. Gleaning is when produce which was not harvested due to excess or because it did not meet aesthetic standards is collected. Food drives collected food to be donated from individuals in a community, and the food may come from their homes or purchased from retailers with the intent of donating. These items from food drives were assumed not to be source reduced because they were never considered to be waste. The USDA has federally appropriated money for hunger relief programs, which is allocated to different programs or to purchase specific food from markets.

Service organizations are made up of food banks and community distributors who receive food from the generators. The Feeding Florida organization because it receives and handles the largest quantity of food donations of any Florida food bank system. Feeding Florida contracts with 12 food banks in Florida, each of which serve different counties and have partnered with community distributors called partner agencies. The second largest food bank system in the state outside of Feeding Florida is Farmshare, which has four Florida locations. Other food banks in the state include Heartland Food Bank, Midwest Food bank, and Palm Beach County food bank. Food banks may purchase food directly to supplement their stores, which is not considered source reduced. From there, the food is sent to community distributors or mobile pantries.

Community distributors receive food from food banks or directly from generators and often work with food banks to ensure a consistent supply of food which then goes to the recipients. Common community distributers include soup kitchens, food pantries, and homeless shelters. Food banks may be supplemental, supplying food to community members on a regular basis, or emergency, where they only supply food a maximum number of times per year.

The recipients of food donations are food insecure community members, and often community distributors require identification to show residency within a community.

4.3.3 FOOD DONATION ESTIMATES

Based on the estimation method 2, the total annual quantity of food donations distributed by food banks in Florida is 200,006 tons. Accounting for food that was purchased by the food bank or the USDA, as well as food from food drives means subtracting those quantities from the total tons to get the source-reduced quantity. The total source-reduced quantity of food was estimated to be 148,248 tons.

4.4 ELECTRONICS, FURNITURE, AND TEXTILES DONATION SYSTEM

4.4.1 METHODOLOGY FOR FLORIDA ELECTRONICS, FURNITURE, AND TEXTILES ESTIMATES

Items defined as electronics donations include personal devices such as cell phones, laptops, and tablets as well as small appliances like vacuum cleaners and coffee makers. The method used for collecting data began by identifying service organizations within Florida, especially North Central Florida, which accept donations in the forms studied in this section. Contact was made, either by email or phone, to ask if they would participate in the study by answering some questions about the collections process. The questions were focused on gathering quantifiable data about the amount of donations and the donation flow system. These questions included:

- What/who are the sources of the donations?
- What is the quantity of donations over time (estimate or otherwise)?
- What is the collection procedure for donations?
- What happens to items when they arrive; what is the sorting process?
- What happens to materials that are not able to be sold/given away?
- How is value determined?
- What is the approximate or exact percentage of material that stays vs is thrown out?
- What percentage of materials goes to landfill?
- Do they ship donated items outside of the local area?
- Who are the recipients of the donations?
- Are new materials ever purchased to supplement stock?

For some organizations when specific locations were called the store clerk was able to answer the questions immediately, others directed us to contact regional headquarters to provide the information we sought. Meetings were planned with directors of Jacksonville’s Habitat for Humanity ReStore and Goodwill Manasota to discuss general operations of the store locations they oversaw.

4.4.2 ELECTRONICS

4.4.2.1 Data Collection

Data collected for electronics was mainly sourced from year-end reports from manufacturers which collected electronics donations ("FY19 Corporate Social Responsibility Report," 2019; "Xerox 2019 Global Corporate Social Responsibility Report Showcases Commitment to Sustainability, Social Investment, Governance," 2019; VIZIO, 2020), as well as from Goodwill Manasota. Most of the other service organizations contacted did not often handle electronics donations. While there is significant data about the quantity of donated items returned to manufacturers, many of these items are recycled and not refurbished for reuse. Goodwill Manasota provided quantitative data for January – July of 2020.

4.4.2.2 Donation System Flow

The flow of electronic donations starts with individuals, manufacturers, schools, or retailers of the equipment; summarized in Figure 4-1. When it reaches the end of its life for those sources, or if the sources have excess supply, e-waste will often go to a service organization. For individual sources, the e-waste may first be left in a donation bin, often located in public spaces or in retail stores. For e-waste, the donations will sometimes return to the manufacturer, where they can be refurbished and sold again, however this is often not for charitable reuse. Service organizations have several options for what they can do with waste. While ideally the donations are refurbished and sold or given to recipients, often they will also be sent to landfills or broken down to recycle, or they may be sent overseas.

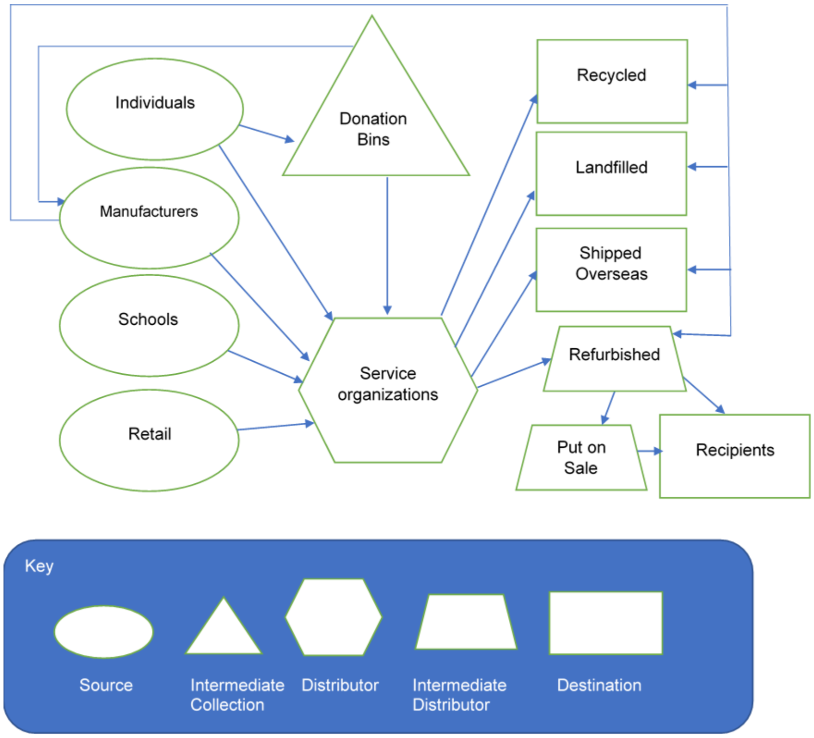


Figure 4-1. Flow of electronics, which is distinct in that manufacturers often collect electronic donations to refurbish or recycle in addition to the service organizations.

4.4.2.3 Donation Estimates

Goodwill Manasota provided the donation estimates for electronics for the time period January - July 2020. The total mass of electronics donated during this time was 239,227 lbs. or 120 tons. Table 4-3 provides the breakdown of these types of donations. If electronics donations continued at the same rate for the following five months, the total mass of electronics donations in 2020 would be 410,103 lbs. or 205 tons. However, this is just an estimate and the rate of donations fluctuates month to month. The donation rate during 2020 will also likely be impacted by the behavioral changes resulting from the COVID-19 pandemic. Of the total salvaged waste recorded by Goodwill, 6,656,980 lbs., electronic donations make up 3.6%.

Table 4-3. Breakdown of the types of electronic waste collected by Goodwill Manasota.

	Computers (lbs.)	Electrical (lbs.)	Phones (lbs.)	Total (lbs.)
Jan	19,223	22,125		41,348
Feb	30,183	29,797		59,980
Mar	7,603	9,935		17,538
Apr	19,655	19,843		39,498
May	9,123	9,649		18,772
Jun	8,124	9,803		17,927
Jul	21,880	21,945	339	44,164
7-month Total				***239,227***

In addition to the total salvaged waste, Goodwill Manasota landfilled 6,656,980 lbs. of the donations received. If 3.6% of this waste was made up of electronics, that is 239,651 lbs. of e-waste sent to the landfill. However, this is just an estimate and a breakdown of how frequently the different categories of donations were salvaged or landfilled was not provided.

4.4.3 FURNITURE

4.4.3.1 Data Collection

Data on furniture donation quantities was mainly derived from Goodwill Manasota data, but the collection of data on furniture donation flow was provided by Goodwill Manasota, Habitat for Humanity ReStore, The Repurpose Project, and ESOL Closet. The latter two service organizations are small, based only in Gainesville, Florida, but were more responsive than some national chains. Goodwill Manasota provided mass intake for the different categories of donations for 2020 from January to July as well as the quantity of their intake which was landfilled. Supplementary data was gathered from organization websites which provided annual reports about donation quantities, but this was generally not broken down into the types of donations received.

4.4.3.2 Furniture donation system flow

Furniture donations begin at sources which are generally individuals, manufacturers, hotels, and retail; summarized in Figure 4-2. While individuals may also choose to put their furniture donations in donation collection bins, this often limited to smaller furniture items. Larger items are typically brought directly to service organizations.

Hotels may donate old furniture when they remodel, manufacturers and retailers may donate overstock. Sometimes these items are refurbished before being sold, but often they are sold as is. Again, service organizations may give items directly to recipients or sell them, but they may as frequently dispose of the items or ship them overseas.

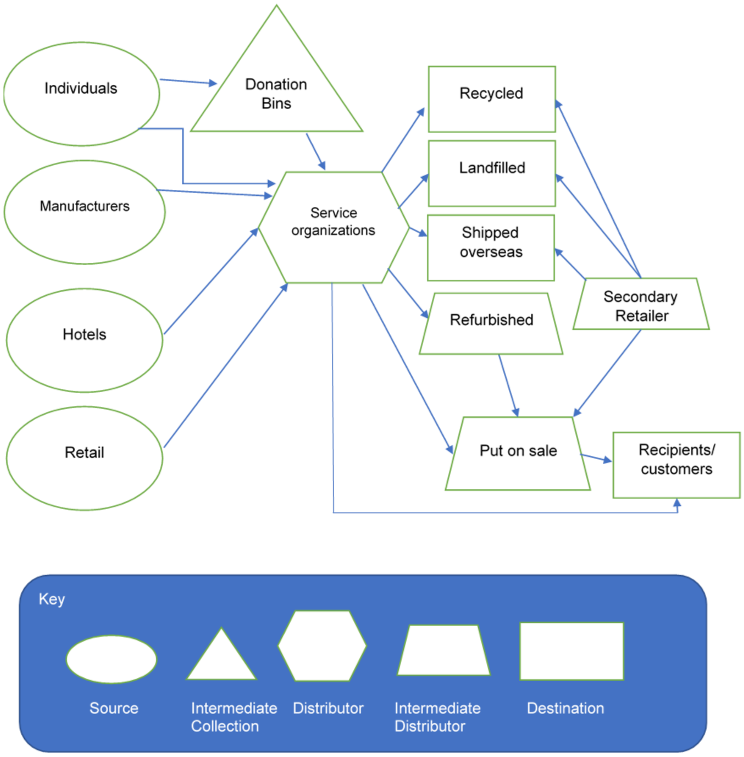


Figure 4-2. Furniture donation flow.

4.4.3.3 Furniture donation estimates

For the months January through July, Goodwill Manasota received and salvaged 1,013,852 lbs. of furniture or about 507 tons. See Table 4-4 for the breakdown of types of donations. Estimating a similar donation pattern for the next five months, they would receive a total of 1,738,032 lbs. or 869 tons of furniture donations in 2020, though this number would be impacted by behavioral changes due to the COVID-19 pandemic. This accounts for 16% of the total mass salvaged, which is 6,173,836 lbs. for the provided months in 2020.

For the months January-July of 2020, Goodwill Manasota's locations landfilled 6,656,980 lbs of donations. If 16% of the landfilled items were furniture, that would be 1,093,192 lbs of furniture landfilled. However, this is just an estimate and a breakdown of how frequently the different categories of donations were salvaged or landfilled was not provided.

Table 4-4. Furniture donation breakdown based on data provided by Goodwill Manasota.

	Bric Brac/Wares (lbs.)	**Metal (lbs.)**	**Kitchen Wares (lbs.)**	**Total (lbs.)**
Jan	41,256	127,718	12,340	181,314
Feb	41,297	95,526	10,335	147,158
Mar	25,794	101,646	10,069	137,509
Apr	1,743	159,760	8,636	170,139
May	4,802	105,783	8,862	119,447
Jun	9,332	104,583	9,679	123,594
Jul	14,606	106,342	13,743	134,691
7-month Total				***1,013,852***

4.4.4 TEXTILES

4.4.4.1 Data Collection

Data on textile donation quantities was mainly derived from Goodwill Manasota which provided donation mass quantities from January 2020 to July 2020. Data on textile donation flow was derived from interviews with Goodwill Manasota, ESOL Closet, and Gainesville Thrift. The latter two service organizations are small, based only in Gainesville, Florida, but were more responsive to being interviewed than some national or state-wide chains. Supplementary data was gathered from organization websites which provided annual reports about donation quantities, but this was generally not broken down into the types of donations received.

4.4.4.2 Donation System Flow

Textile donation systems start with individual, manufacturer, or retail sources; summarized in Figure 4-3. The individual sources may choose to drop their donations in a donation receptacle which are often located in public spaces. Manufacturers and retailers may donate overstock. The path to sale, disposal, or overseas shipment resembles the flow of furniture and electronics, but some clothing retailers have secondary retailers which take further overstock from the service organization stores. For example, Goodwill has some locations referred to as pound-stores, where they sell clothing priced by the pound instead of by the item.

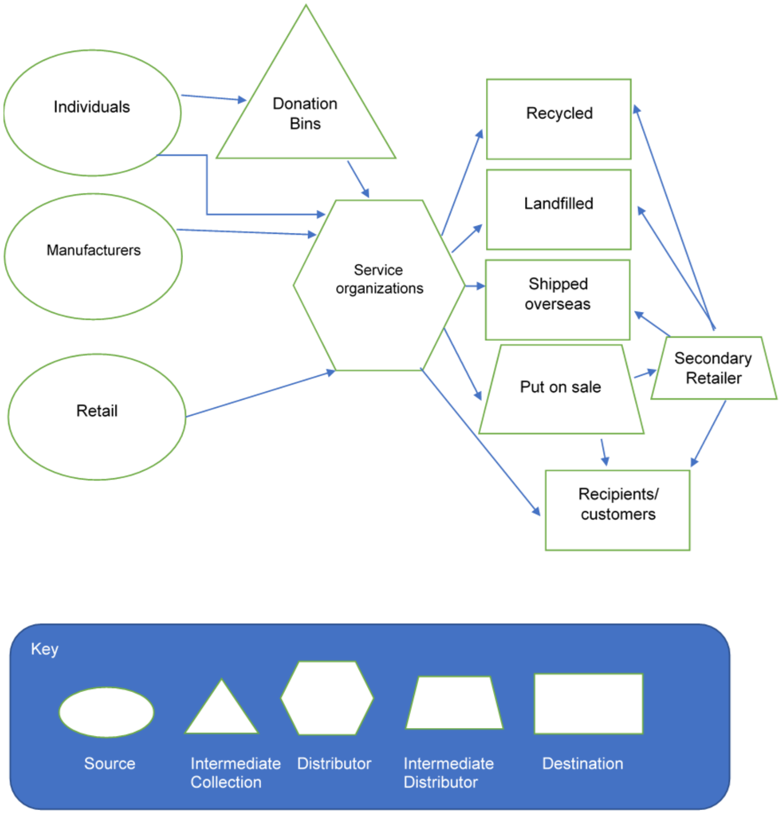


Figure 4-3. Textile donation flow.

4.4.4.3 Textiles Donation Estimates

Goodwill Manasota provided a breakdown of salvaged donations for the months January-July of 2020. For textiles, Goodwill Manasota salvaged 3,518,885 lbs. or about 1759 tons of textiles. Table 4-5 provides a breakdown of the types of textiles donated. If the rate of textile donations remains consistent over the following five-month period for 2020, the total quantity of textile donations would be 6,032,374 lbs. or 3016 tons, though this is just an estimate as donations rates fluctuate and are also likely to be impacted by the COVID-19 pandemic. The total quantity of salvaged donations for January – July, 2020 is 6,173,836 lbs., and textiles make up 57% of that mass.

Table 4-5. Textile donation breakdown based on data provided by Goodwill Manasota.

	Apparel (lbs.)	**Linens (lbs.)**	**Total (lbs.)**
Jan	431,852	115,628	547,480
Feb	367,108	91,557	458,665
Mar	470,895	80,836	551,731
Apr	366,281	56,776	423,057
May	386,510	74,567	461,077
Jun	403,259	96,312	499,571
Jul	452,794	124,510	577,304
7-month Total			***3,518,885***

Goodwill Manasota sent 6,656,980 lbs. of donated items to landfills over the course of the seven months studied. If 57% of that mass was textiles, that would be 3,794,261 lbs. or 1897 tons of textiles landfilled. However, this is just an estimate and a breakdown of how frequently the different categories of donations were salvaged or landfilled was not provided.

4.5 DATA COLLECTION CHALLENGES

This research was conducted during the COVID-19 pandemic, which had an impact on donation flow quantities and processes. Generally, the research focused on normal operations prior to the global event but some data collected was influenced by behavioral changes for the health crisis. This also meant that all research had to be conducted virtually as visiting different service organizations was not a viable option.

Many locations could not accurately quantify mass or volume of donations received. Estimates in “truckloads” were often used when lacking other quantifiable units. Therefore, much of the quantifiable data included is from corporate year-end reports for large organizations or was provided by Goodwill Manasota. Many service organizations contacted could not or would not provide the information needed for this research, so the data analyzed did not come from an exhaustive list of service organizations who take in and distribute donations.

Due to the research being conducted during the pandemic, food recovery organizations were often unresponsive due to the increased need within their communities. Also due to the pandemic, staff and volunteer numbers and hours of operation were both reduced, and some organizations had to limit their responses to limit contact with other people. Several issues of reporting food donations were identified while researching food donation flow. Lack of public information, lack of documentation, and inconsistent weighing metrics caused challenges in data collection.

Lack of public information from food banks and generators was sometimes due to privacy barriers which prevented those entities from willingly releasing quantitative data on their food donations and much of the information therefore gathered was qualitative. Community distributors frequently lacked documentation on their incoming and outgoing food quantities. Inconsistent metrics when food was quantitatively tracked also posed difficulty in estimation.

5 2021 SMM TOOL DEVELOPMENT AND DOCUMENTATION

5.1 IDENTIFYING ADDITIONAL MATERIAL CATEGORIES/ IMPACT FACTORS AND MODEL REFINEMENTS

5.1.1 ADDITIONAL MATERIAL CATEGORIES

FDEP tracks the mass of 18 material categories as part of their annual solid waste reporting, which include municipal solid waste and construction and demolition waste. The 18 material categories tracked provide insight to solid waste decision makers on their materials disposed and recycled. For some of the 18 categories they are generalized and allow for various types of similar materials to be included (e.g., the category C&D debris, the category plastic bottles). The general categories were created for simplified reporting purposes; however, we believe there is an opportunity to create subcategories that account for the nuances in the general category. Identifying subcategories is critical when measuring the environmental impact, since each material has its own environmental footprint (some greater than others). The original 18 FDEP material categories and how they were subcategories are discussed in Section 5.6.

5.1.2 ADDITIONAL IMPACT FACTORS

The impact factors created as part of *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020) were used. The impact factors created for that project were specifically for the end-of-life management approaches (e.g., recycling, landfilling, combustion, anaerobic digestion, composting). In this project, we created additional impact factors that accounted for the upstream management of materials, which is referred to here as the environmental footprint when producing a material/product. Since source reduction is a major activity that leads to increased environmental benefits and is a critical task of this project, we also created impact factors for when materials are donated for reuse. The material categories books and furniture were not included in the previous project, therefore we created new impact factors for when they are produced, donated, and treated at end-of-life. The impact factors allow for users to estimate the environmental footprint of producing, donating, recycling, and disposal treatment of their county's solid waste stream. The details of the development of the impact factors are discussed in Section 5.4.

5.1.3 WASTECALC MODEL REFINEMENTS

The FDEP Waste Composition Calculation Model (WasteCalc) is an online application used to estimate the composition of MSW generated in Florida counties. It is a useful tool for Recycling Coordinators for preparing annual reports when actual waste composition data for a particular county is not available. The model presents results for the collected and recycled masses of the 18 material categories. We refined this model so that it also provides annual mass results for each individual material collected, recycled, landfilled, and combusted. We also refined the model to allow for users to input the mass of donated books, clothing and footwear, furniture, food, and electronics. The refined model allows users to input historic collected tons for the 18 materials to receive estimates for source reduction (when materials are disposed at a lower rate than a previous year) and source generated (when materials are disposed at higher rates than a previous year). The version of WasteCalc used in the 2021 SMM tool is described in Section 5.3 and the methods used to estimate the modified outputs are in Section 5.5.

5.2 OVERVIEW OF 2021 SMM TOOL

5.2.1 TAB 1 "INTRODUCTION"

The main purpose of this tab is to provide users a simplified background on the motivation and project history associated with this tool. This tab provides resources related to the tool and SMM. A screenshot of the Tab 1 is shown in Figure A1.

5.2.2 TAB 2 "2019 WASTECALC INPUT"

The version included here is described in Section 5.3 and it is the 2019 version which is compatible with the online version managed on the FDEP website. In this tab, users input their county's name, population, and MSW tonnage data (collected, landfilled, combusted and recycled), along with the new modifications previously mentioned in Section 5.1.3. An example screenshot of the workbook tool for this Tab 2 is shown in Figure A2 which shows the original 2019 WasteCalc user inputs and Figure A3 which shows the new refined 2019 WasteCalc user inputs.

5.2.3 TAB 3 "2019 WASTECALC RESULTS"

The results from the inputted data in Tab 2 for the waste composition and their associated masses collected, recycled, combusted, landfilled, and source reduced/generated are provided for users. A screenshot of example outputted data is shown in Figure A4.

5.2.4 TAB 4 "SMM INPUT"

The majority of the data included in Tabs 4-6 derive from the Hinkley Center 2018/2019 Project entitled, *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020). The goals of that project were to develop a publicly available LCA tool and LCA factors that will allow users to consider a wider variety of impacts associated with various materials management scenarios. In Tab 4, it contains clear instructions for users to select one of six model preferences (i.e., MSW-DST (FL), SWOLF (FL), SWOLF (US), WARM (FL), WARM (US), and Literature). The (FL) indicates to the user that the impact factors were developed using the Florida average energy grid and (US) is for the US national average energy grid. The Literature preference must be used if the user desires to estimate jobs produced and landfill use footprints, as well as for furniture waste management footprints and any donation footprints. Example screenshots of Tab 4 is shown in Figure A5 and A6.

5.2.5 TAB 5 "SMM RESULTS"

The data from Tab 2, along with Tab 6 (which are based on the selections in Tab 4) are used to estimate the environmental footprint for corresponding material category and its management method. The results are shown for "produced" and each management method, including source reduced/generated and donated. Note, the environmental footprint for "produced" were estimated by multiplying the mass of collected material categories by the available produced impact factors. The results on a total basis are shown for "produced" and each management and for lifecycle total (all management methods) and waste management total (all management methods except for source reduced/generated, donated, and produced). Example screenshot for one environmental footprint is shown in Figure A7.

5.2.6 TAB 6 “LCI FACTORS”

Users have access to all the impact factors associated with their selected LCA model from Tab 4. Figure A8 shows an example screenshot for the SWOLF (FL) option. The impact factors were developed using both waste LCA models and industry reports or data. Section 5.4 describes how the impact factors were created, which mainly refers to the data reported in the previous Hinkley Center project *Looking Beyond Florida’s 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020).

5.3 WASTECALC VERSION IN TOOL

The first version of WasteCalc was released in 2002 and remained unchanged until the University of Florida made several significant updates in 2018. These updates are documented in the September 2018 University of Florida report entitled, “Assessment Update of the Florida Waste Composition Model (WasteCalc)”. The current WasteCalc program is based in an Excel workbook. This workbook contains background information for the user and 67 tabs for each of the counties in Florida. These tabs are similar in format and divided into seven sections which are essential in calculating county factors.

The 2018 report recommended that the county factors used by WasteCalc be updated as new waste composition studies become available. The 2019 updates included new county factors based on three waste composition studies conducted by the UF team and eight waste composition studies conducted by various counties in the past year. This study documents the three waste composition studies that were funded by the FDEP, Solid Waste Authority of Palm Beach County (SWA), Orange County, and the Aucilla Area Solid Waste Administration for the purpose of updating the WasteCalc county factors.

Within the WasteCalc program, waste composition study results are correlated with population density as a way to provide material composition data to a particular county that has not completed a waste composition study. Pictures of a waste composition study are shown in Figures 5-1 through 5-3. To achieve accurate material composition output percentages for counties that have not completed a waste composition study, the data from counties within the same population density group that have recent studies is averaged. The average percentage for each material is then used as the expected material percentage for the specific county and incorporated later in the workbook. The population density grouping was reorganized from the 2018 WasteCalc Update Report. The counties were organized into groups with similar waste treatment (either with or without WTE) and similar population densities in a manner that at least two waste composition studies have been conducted in each group. Group 1 is comprised of all counties above 1000 PSM (persons per square mile), group 2 is from 500 to 999 PSM, group 3 is 300 to 499 PSM, group 4 is 100 to 299, and group 5 is 0.1 to 99 PSM.

WasteCalc provides an estimate of the material composition for a particular county by multiplying county population by published USEPA material generation factors and county-specific waste generation factors (county factors). A more detailed explanation of this calculation is provided in the FDEP 2018 WasteCalc report. The county factor for a particular location can be determined if a waste composition analysis has been performed on the disposed fraction of waste using Equation 5-1.

$$CF = \frac{(Recycled) + (Combusted)(Category\,\%) + (Landfilled)(Category\,\%)}{\frac{US\ Data}{2000}(County\ Population)/(1 - MC)}$$

Eq. 5-1

Where:

CF= County Factor

Recycled= The reported tonnage of recycled material to FDEP

Combusted= The reported tonnage of combusted material to FDEP

Landfilled= The reported tonnage of landfilled material to FDEP

Category %= Percentage of the material found from waste composition data

US Data= Average dry weight of the material in pounds per person per day

County Population= Population of the county in the desired year

MC= Moisture content of the material

Figure 5-1. Set-up of Aucilla Landfill waste composition study.

Figure 5-2. Sorting table with a sample.

Figure 5-3. Examples of different category bins.

5.4 LIFE CYCLE IMPACT FACTORS IN TOOL

The majority of the language and explanations provided here are derived from the *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* Hinkley Center report; please refer to that report for details not provided here (University of Florida, 2020).

5.4.1 FUNCTIONAL UNIT

Waste generation rate, waste composition, and population must be defined in all the models except for WARM to estimate the mass of the waste fraction generated annually. The functional unit was one US ton of each material managed in Florida. All the models except for WARM rely on a reasonable mass of waste to model the emissions associated with individually constructing and operating a waste treatment facility. Modeling only one short ton of waste and dividing the total emissions by that one ton will be associated with a much larger emission than modeling 100,000 tons of waste and dividing the associated emissions by 100,000 tons for certain treatment options (e.g., landfilling). Therefore, the functional unit will remain one short ton. However, to estimate the emissions associated with one ton, the modeled mass (or reference flow) will be 100,000 tons. This value was chosen to represent a hypothetical community of 50,000 people generating waste at 4.5 lbs/person-day (equivalent to the reported mass of waste generated by a US resident (US EPA, 2019)). The only exception was for when we collected data from literature, in which, we converted any of the reported data to a per ton basis.

5.4.2 MATERIAL CATEGORIES

The material categories modeled using each of the three LCA models is shown in Table 5-1. The impact factors were determined for each of the materials listed in Table 5-1 in grey. Each model either had the exact material category shown in grey or a proxy material(s) was used depending upon the model. When running the model only one material was assessed at a time. For example, when developing the impact factor for recycling newspaper 100,000 short tons of 100% newspaper was modeled. The only exception was for modeling collection, which was modeled using the average Florida single family residential home waste composition as shown in Table A2 of (University of Florida, 2020).

Table 5-1. The material categories used in the SMM portion of the 2021 SMM Tool and their corresponding material proxies for WARM, MSW-DST, and SWOLF.

Material Category	WARM Proxy	MSW-DST Proxy	SWOLF Proxy
Mixed MSW	Mixed MSW	Average of misc. combustible and misc. incombustible	Average of misc. organic and misc. inorganic
Newspaper	Newspaper	Newspaper	Newsprint
Corrugated Cardboard (OCC)	Corrugated Containers	Corrugated Cardboard	Corr. Cardboard
High Grade Paper (Office Type Paper)	Office paper	Office paper	Office paper

Magazines/third-class mail	Magazines/3rd-class Mail	Average of magazines and 3rd class mail	Average of magazines and 3rd class mail
Books	Textbooks	Textbooks	NA
Mixed Paper	Mixed Paper (general)	Average all paper categories	Mixed paper
HDPE	HDPE	Average of HDPE translucent and HDPE pigmented	Average of HDPE translucent and HDPE pigmented
PET	PET	PET	PET containers
Mixed Plastic	Mixed plastic	Average all plastic categories	Mixed plastic
Mixed Glass	Glass	Clear glass	Mixed glass
Aluminum Cans	Aluminum cans	Aluminum cans	Aluminum cans
Steel/Tin Cans	Steel Cans	Ferrous cans	Ferrous cans
Mixed Metals	Mixed Metals	Average of ferrous metal other and aluminum other	Average of ferrous metal other and aluminum other
Yard Waste	Yard Trimmings	Average of yard trimmings leaves, yard trimmings grass, and yard trimmings branches	Average of yard trimmings leaves, yard trimmings grass, and yard trimmings branches
Food Waste	Food Waste	Food waste	Average of food waste vegetable and food waste non-vegetable
Tires	Tires	NA	Rubber/leather
Clothing and Footwear	Carpet	NA	Textiles
Furniture*	NA	NA	NA
Electronics	Mixed Electronics	NA	E-waste
Dimensional Lumber	Dimensional Lumber	NA	Wood
Asphalt Shingles	Asphalt Shingles	NA	NA
Gypsum Drywall	Drywall	NA	NA
Concrete	Concrete	NA	NA
Reclaimed Asphalt Pavement	Asphalt Concrete	NA	NA

*No traditional waste LCA model has a material proxy; we used data from literature which described the material component breakdown of steel, aluminum, wood, and plastic used in furniture (US EPA, 2014) and we multiplied it by the impact factors for recycling, landfilling, and combustion from WARM and SWOLF (done separately).

5.4.3 MANAGEMENT CATEGORIES

The management categories modeled using each of the three LCA models is shown in Table 5-2. The impact factors were determined for each of the materials managed in grey. Each model either had the option to model the management highlighted in grey or it did not.

Table 5-2. The management categories used in the 2021 SMM Tool and their corresponding management proxies.

Management Type	WARM Proxy	MSWDST Proxy	SWOLF Proxy	Literature
Produced	Default option	NA	Calculated by using the LCI data used in SWOLF	Collected data from literature for clothing/footwear, furniture, and electronics materials
Donated	NA*	NA	NA*	
Collection	Default option	Single family residential	Single family residential	
Recycling	Default option	Single stream materials recovery facility	Single stream materials recovery facility	Collected data from literature for furniture
Composting	Default option	Windrow	Windrow	
Anaerobic Digestion	Dry anaerobic digestion	NA	Wet anaerobic digestion	
Landfill	Traditional	Traditional	Traditional	Collected data from literature for furniture
Combustion	Default option	Waste-to-Energy	Waste-to-Energy	

*Although the model does not include donation as a management type we assumed that the factors for donated would be the same as the produced impact factors (for a given donatable material) multiplied by -1, to account for an avoidance.

5.4.4 IMPACT CATEGORIES

Each model inherently contains either one or multiple LCIA methods. WARM does not rely on a traditional LCIA method; instead it quantifies only the climate change (or global warming potential and energy use impact categories by summing the equivalent metric tons of carbon dioxide or the energy consumed associated with a materials management. MSW-DST relies on a US EPA developed LCIA method (TRACI) to estimate impact categories. SWOLF utilizes a collection of LCIA methods that estimate many impact categories and allow user flexibility in selecting the LCIA method. Table 5-3 presents the model and the selected LCIA method and impact categories that will be used in the study to develop impact factors.

Table 5-3. The impact categories used in the 2021 SMM Tool and their corresponding LCIA method used for WARM, MSW-DST, and SWOLF simulation runs. Note data for Jobs Produced and Landfill Space Savings were collected from various literature which are detailed in (University of Florida, 2020) Sections 5.7.8 and 5.7.9.

Impact Categories	Measure Description	Impact Factor Unit	LCIA Method		
			WARM	**MSWDST**	**SWOLF**
Climate Change	Greenhouse gases (GHG) absorb energy and slow energy from escaping into space which causes the Earth to get warmer. GHG are expressed as units of $tCO_2eq.$of material to allow for comparison of global warming impacts of different gases relative to CO_2. This is a measure of how much energy the emission of 1 ton of gas will absorb over a given period of time, relative to the emissions of 1 ton of CO_2.	$tCO_2eq.$/short ton	Embedded method created by the US EPA for WARM	US EPA TRACI 2.0	IPCC 2007
Energy Use	Amount of direct and indirect energy use throughout the life cycle from non-renewable energy sources.	MJ/short ton			Ecoinvent
Water Use	Amount of the water used in such way that the water is evaporated, incorporated into products, transferred to other watersheds, or disposed into the sea.	Gallons water/short ton	NA	NA	ReCiPe v.1.11 Midpoint Hierarchical
Human Toxicity	Release of toxic materials to humans due to inhalation or ingestion by humans. The units are expressed as comparative toxic units (CTUh) which is interpreted as disease cases per kg of substance emitted. This is a measure of adverse impacts and includes causing cancer and other non-cancer diseases (or total human toxicity potential).	CTUh/short ton		US EPA TRACI 2.0	US EPA TRACI 2.0
Ecotoxicity	Release of toxic materials to aquatic ecosystem. The units are expressed as comparative toxic units (CTUe), which is interpreted as the potentially affected fraction of species over time and volume per kg of substance emitted (or total ecotoxicity potential).	CTUe/short ton			
Eutrophication Potential	Enrichment of aquatic ecosystems with nutrients (nitrates and phosphates) that causes undesirable algal growth. The units are expressed as kgNeq. to allow for comparison of nutrients in the water relative to N.	kgNeq./short ton			
Acidification Potential	Increasing concentration of hydrogen ions within the environment due to addition of acids. The units are expressed as $kgSO_2eq.$ to allow for comparison of acids in the air relative to SO_2.	$kgSO_2eq.$/short ton			
Jobs Produced	The number of jobs associated with each type of waste management. This includes both direct and indirect jobs.	Jobs/10,000 short ton		NA	NA
Landfill Space Use	The measure of space a material, when compacted, occupies in a landfill.	yd^3/short ton			

5.4.5 SYSTEM BOUNDARIES

Each model contains LCI data and assumptions specific to the country where it was developed. Defining the system boundaries will be important to decide which life stages, parameters, and assumptions are included in the assessed system. The six systems evaluated here are: collection; recycling; landfilling; combustion; composting; and anaerobic digestion. These systems are evaluated for each of the material categories. Under the zero burden assumption the waste entering any of these six processes is considered to carry none of the emissions associated with the extraction, processing, manufacture, and use (with some exceptions) these life stage are referred to as upstream (Ekvall et al., 2007; Gentil et al., 2010; Martin et al., 2015). This assumption is commonly adopted because the emissions associated with the upstream stages are not typically considered with respect to solid waste decision-making. However, certain processes, such as recycling, do account for the upstream emissions by assuming that the recycled material offsets the emissions associated with using a virgin material. Similarly, when electricity is generated from landfill gas or combustion, that electricity offsets the use of fossil fuels consumed to produce electricity. The offset of virgin materials and fossil-fuel generated electricity are important considerations in a system and many other parameters exist that significantly impact the outcomes of the LCA.

An important system boundary consideration not shown in the next sections is the properties of the materials. However, it is worth noting that the properties like calorific value, moisture content, carbon content, methane potential, chemical content are crucial in proper calculation of certain impact categories. Sections 5.4.5.1- 5.4.5.7 describe the seven system boundaries used for the produced/donated impact factors and for the six waste management options for all the impact categories expect for jobs produced and landfill space use. Creation of the impact factors using the LCA models requires the user to select the offset electricity region; for this study the US national average and Florida average electricity regions were used to separately develop two impact factors for each waste management option.

5.4.5.1 Produced and Donated

To create a product, raw materials are first extracted from the earth, then through processing the material, it is transformed to a more usable form. Manufactures will then create various products from the transformed material and transport it for human consumption or purchase. Depending on the material, the process of converting it from a virgin material to a purchasable product may require intensive use of resources (e.g., energy, equipment, labor, and other products). The environmental footprint associated with the upstream processes of raw material acquisition, transformation, manufacture, and transport for sale can be referred to as the embodied environmental footprint of a product. In our project, we created/compiled impact factors specific to those upstream processes and we call them the produced impact factors. We created the donated impact factors by multiplying the produced impact factors by -1, in doing so, we assumed that donating a material will 100% offset producing a new product.

In WARM they directly provide produced impact factors for many of the material categories we considered as part of the 2021 SMM Tool, therefore, they were directly compiled from WARM and included in the tool. Note, the only assumption we used was that the produced impact factors were assumed to offset 100% virgin materials. In SWOLF and MSW-DST there are no existing produced impact factors, however, SWOLF provides the documentation associated with the recycling impact factors. In recycling, the impact factors are created using the embodied emissions data (see Section 5.4.5.3 for more information). We collected the embodied emissions sources and created produced impact factors for the available material categories (this corresponds to only the recyclable material categories). With WARM and SWOLF we were able to create the produced impact factors for most material categories, yet many of the durable material categories (e.g., clothing, electronics, furniture) were not will documented in either of the models. Therefore, we conducted a literature review to compile data on the embodied emissions associated with producing durable materials; this data is shown in Table A1.

5.4.5.2 Collection

The default collection parameters (e.g., capacity of truck, fuel mileage of truck, number of truck employees, etc.) vary across the three models as well as the type of method used to estimate the transportation emissions. The mechanistic method is used to calculate the emissions associated with the total distance and fuel consumed by the vehicles in MSW-DST and SWOLF, which is based on numerous user-defined input parameters. WARM follows a deterministic method that uses only the user-defined total distance and fuel consumed (Gentil et al., 2010). The default values will be used for everything except for transportation distance, which will be set as 20 miles as shown in Figure 5-4.

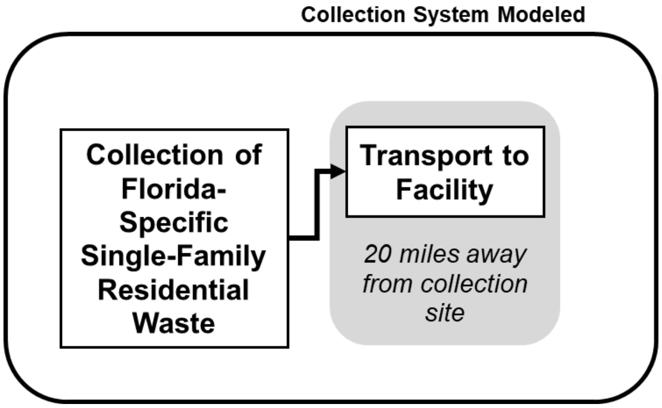


Figure 5-4. The system boundary selected and used for collection for WARM, MSW-DST, and SWOLF simulation runs.

5.4.5.3 Recycling

The recycling system boundary does not include the emissions associated with constructing the materials recovery facility (MRF). Instead, the recycling LCI accounts for only the fossil fuels consumed in the operation of the equipment to sort, process, and bale the recyclables. The baled materials are then transported for remanufacture, which is a parameter that may be different in the model since some the materials may be exported thousands of miles to another country (e.g., China) or only hundreds of miles within the US. The only emissions avoidances credited in recycling systems in MSW-DST and

SWOLF are when the recycled materials are substituted in place of virgin material in the remanufacturing stage. WARM includes an additional offset for recycling paper products where a carbon storage is credited assuming that the recycled paper products reduces wood harvest.

The remanufacturing avoidance credit varies across models depending upon the default substitution ratio (amount of virgin material the recycled material can replace to make a product) and the type of recycling (i.e., open-loop recycling, closed-loop recycling). In most models the substitution ratio of recycled material to virgin material is not 1:1 but closer to 0.9:1, illustrating that a recycled material does not have the same quality as virgin material. The substitution ratio is dependent on the technology and specific to a material. The type of recycling is either closed-loop, which assumes a discarded product is recycled back into its original product (e.g., a discarded glass bottle is remanufactured into a new glass bottle), or open-loop, which assume a discarded product is recycled into a new product (e.g., a discarded glass bottle is remanufactured into tile). The type of recycling follows the same dependent constraints as the substitution ratio. SWOLF and MSW-DST provide a default substitution value that can be modified and assume closed-loop recycling for the six materials. WARM does not allow user flexibility with the substitution ratio. WARM assumes both closed-loop and open-loop recycling for materials (e.g., 76% of recycled cardboard is closed-loop and 24% is open-loop) (ICF International, 2016a). In the study the default substitution ratio and recycling type will be used and the recycling system boundary is shown in Figure 5-5.

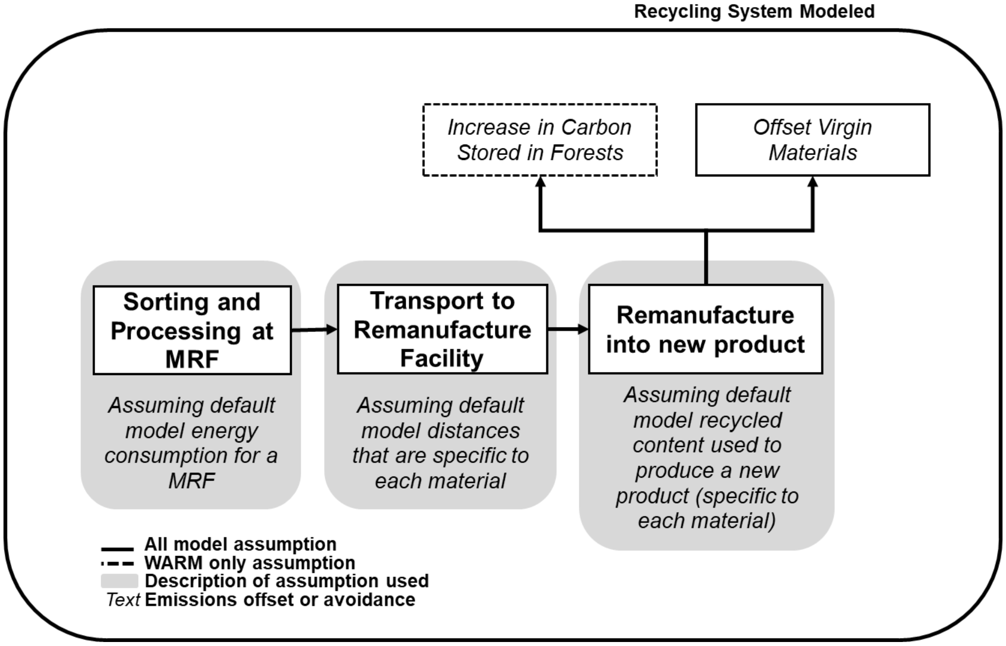


Figure 5-5. The system boundary selected and used for the recycling system for WARM, MSW-DST, and SWOLF simulation runs.

5.4.5.4 Landfilling

The main parameters included in the landfill system are landfill carbon storage, landfill construction, operation, closure, landfill gas collection, and landfill leachate collection. The carbon storage is only related to organic materials and their biogenic carbon content. The carbon storage is credited as an avoidance of GHG emissions and only the climate change impact category is affected. Nonbiogenic carbon has no attributed benefit or impact on climate change (Gentil et al., 2010; ICF International, 2016b). In this study, landfilling products like newspaper and food waste will generate an avoidance due to their carbon storage capacities. Worth noting is MSW-DST does not include carbon storage offset by default and users must decide to include it in the LCA results. The carbon storage avoidance will be included as part of the landfill climate change impact factor.

Time horizon assumptions are essential in quantifying the measured emissions from landfill gas and leachate. A time horizon corresponds to the duration emissions are modeled; longer time horizons can possibly account for more emissions. SWOLF and MSW-DST by default assume a 100-year time horizon for both leachate and landfill gas and they allow user flexibility with respect to leachate. WARM only considers the emissions from landfill gas and assumes a 100 year time horizon (Gentil et al., 2010). In the study the 100-year time horizon will be adopted for all the models.

In the landfill system the methane emissions typically are more significant than the carbon dioxide emissions, thus many waste LCA models will focus on calculating the methane after oxidation and collection. Methane oxidation refers to the amount of methane that can be oxidized to become carbon dioxide as it travels up through the landfill system. The collection efficiency is specific to the rate of waste decomposition at a landfill. Decomposition is waste-specific and a function of the amount of precipitation entering a landfill. For example, office paper will have a faster decomposition rate than textiles when placed in the same landfill because of the methane potential of the waste. Organic waste in landfills with high amounts of precipitation will decompose faster than in dryer landfills. The decay rate value of 0.06 day^{-1} will be used because it represents the average Florida landfill decay rate. The waste LCA models have different default values for the oxidation and collection efficiency for each year from year 1-100. The default oxidation rates and collection efficiencies will be changed to the values shown in the landfill system boundary in Figure 5-6. The collected gas will be modeled as recovered for energy and will offset the Florida national average fossil fuel usage.

The leachate emissions are modeled assuming a leachate collection efficiency, the quantity of leachate generated based on hydrological conditions, the composition of trace chemicals in the leachate, and trace chemicals removal efficiencies for SWOLF and MSW-DST. WARM does not rely on these parameters to estimate the leachate emissions for each material because it does not measure any environmental impacts from leachate generation and management. Default leachate LCI data and methods for SWOLF and MSW-DST will be used to model the waste fractions to create the impact factors.

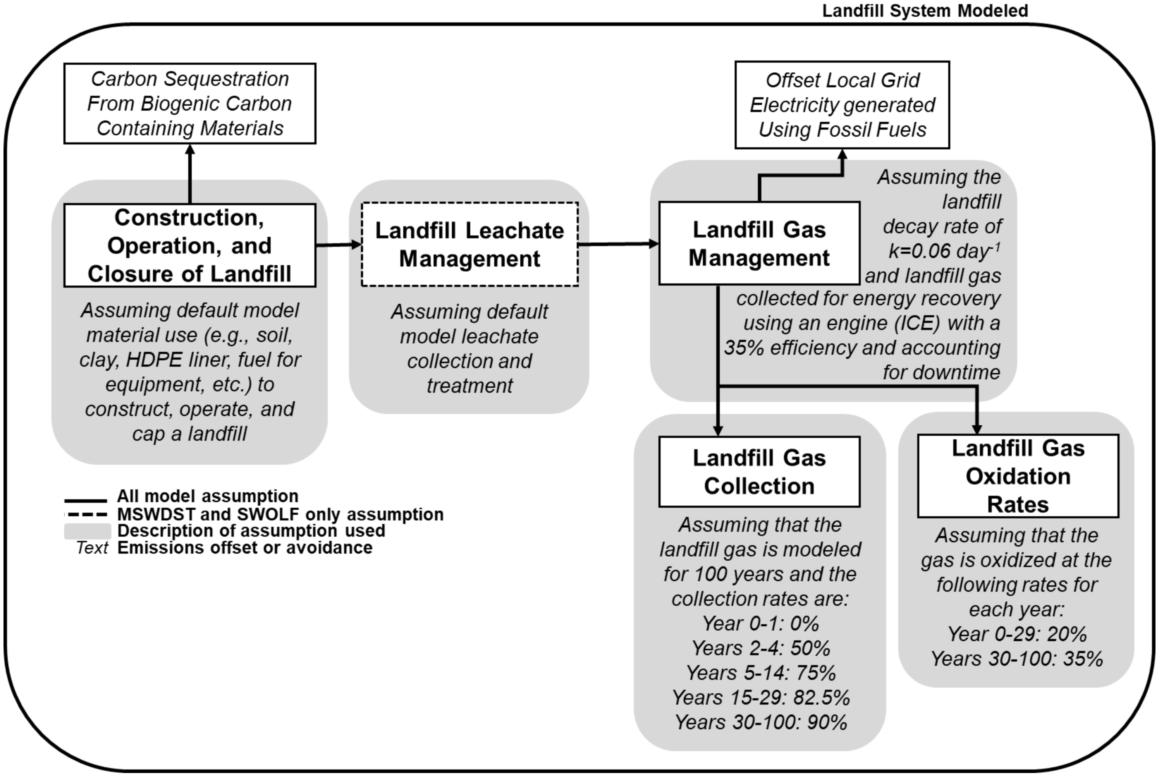


Figure 5-6. The system boundary selected and used for the landfilling system for WARM, MSW-DST, and SWOLF simulation runs.

5.4.5.5 Combustion

The main parameters included in the combustion system are emissions associated with waste-to-energy (WTE) operations, releasing embodied substances (e.g., chemicals) during material combustion, electricity generation, and ash management. Some LCA models account for the emissions associated with WTE facilities adding chemicals such as lime, activated carbon, or ammonia. WARM does not account for the emissions associated with manufacturing or using these chemicals. However, MSWDST and SWOLF do include those associated emissions.

As waste is combusted it releases emissions such as N_2O, CH_4, and CO_2. Combusting biogenic materials are assumed to be carbon neutral and the emissions are not modeled in combustion emissions. However, non-biogenic carbon sources, such as plastics and tires, when combusted are modeled as emissions. The default LCI values for all three models will be used to estimate the associated environmental impacts when combusting materials.

The amount of energy generated from a WTE facility is dependent on its incoming waste stream and each material component contains varying levels of energy. Plastics typically have the highest energy content; the energy content of plastics is higher than the energy content of any other material component in the three models. The sources of LCI data for each material differ relative to the three models. In several cases there are large differences in how the energy content of that material is estimated. For example, aluminum cans in MSWDST are associated with no energy recovery and in WARM they are associated with a negative energy content. The negative value in WARM indicates that combusting that material will consume energy from the WTE facility instead of generate energy (ICF International, 2016c). MSWDST recognizes this concept however it assumes that instead of consuming energy the aluminum cans will be neutral (RTI International, 1997). Other notable examples of the differences in methods to estimate energy content is where MSWDST assumes ferrous cans and glass contain some energy content (very little relative to other materials) and WARM assumes a negative energy content. Also related to energy content is the combustion system efficiency calculated from the WTE heat rate. MSWDST assumes a slightly higher combustion system efficiency than WARM and was estimated based on a data source indicating that WTE facilities obtain heat rates ranging from 15,000-30,000 BTU/kWh. The EPA derived the WARM WTE combustion system efficiency by collecting data from a peer-reviewed study published in 1997. The electricity generated based on each model's WTE heat rate is assumed to offset emissions associated with a fossil fuel-based grid. The default energy content for each material and WTE heat rate in each model will be used in the study; the Florida energy grid will be assumed to be the offset region.

The emissions associated with transporting waste to the WTE facility and the ash to the landfill are calculated in the same manner as described for waste collection discussed in Section 5.5.1(University of Florida, 2020). Unlike the landfill modeling system, the models do not account for the emissions concerning the construction or operation of the WTE facility. What is accounted for are the emissions associated with disposing of the ash in an ash landfill. Along with avoided utility emissions, the second parameter that results in an offset of emissions associated with WTE is when metals are recovered from ash and used in the remanufacturing process. Both MSWDST and WARM assume only ferrous metals are recovered from the ash as default. SWOLF differs and estimates the emissions offset corresponding to ferrous and nonferrous metals recovery. Model default transportation distances to the ash landfill, ash landfilling emissions, and ash metals recovery are used in the study. The summarized combustion system boundary is shown in Figure 5-7.

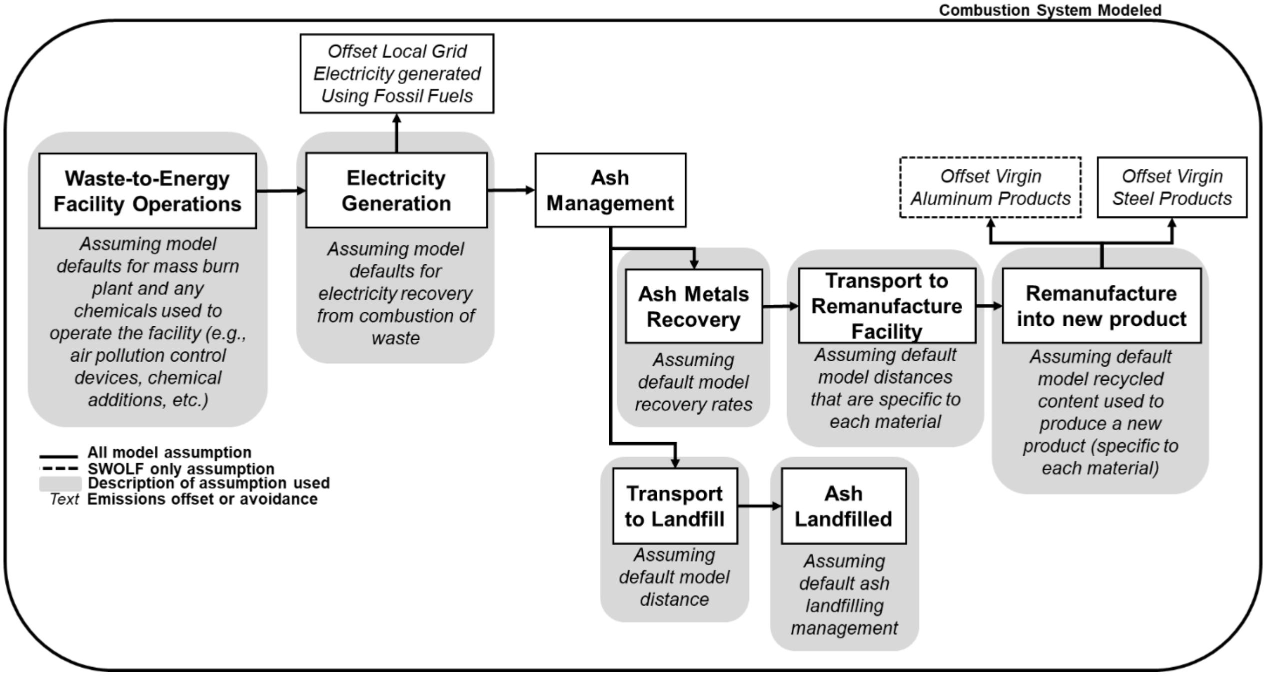


Figure 5-7. The system boundary selected and used for the combustion system for WARM, MSW-DST, and SWOLF simulation runs.

5.4.5.6 Composting

The main parameters included in the composting system are emissions associated with windrow composting operations, releasing embodied substances (e.g., chemicals) during composting in leachate, and compost land application offsetting the use of fertilizer and increasing carbon storage. The composting system boundary modeled in the study is shown in Figure 5-8.

Windrow composting operations include two main processes: pre-composting and composting. Waste is shredded using a tub grinder into a uniform size fraction and then screened using a series of trommel screens to remove certain waste constituents in the pre-composting stage. Once the waste is properly prepared it is arranged in a windrow shape on a compost pad and composted. During the composting process air is introduced into the windrow via turning using a windrow turner. Typically composting produces unwanted odors, thus vacuums are used to control odor. The compost will be cured for several weeks and then be processed into a compost product. During pre-composting and composting, various types of heavy equipment requiring a fossil fuel based energy source are used. The equipment type and curing time differs among the three models and the default assumptions were used in the study.

Biological degradation is the driving force of composting and it results in emissions (e.g., volatile organic carbons (VOCs), CH_4, NH_3, and N_2O) originating from the embodied substances in a material. In most composting operations biofilters are used to reduce these emissions or oxidize them to become less harmful substances. Default assumptions for the type of emissions included in each model and the efficiency in the composting process to reduce the emissions are used in the development of the composting impact factors.

The compost product is typically assumed to generate two offsets: 1) when it is land applied it stores carbon and; 2) land applying the compost product offsets the use of fertilizer. Although land application generates those offsets it also generates an emission due to the evaporation or leaching of substances (e.g., NH_3, chemical oxygen demand (COD), etc.). Each model assumes a unique carbon storage estimate, fertilizer offset benefit, and land application emission and the defaults were used.

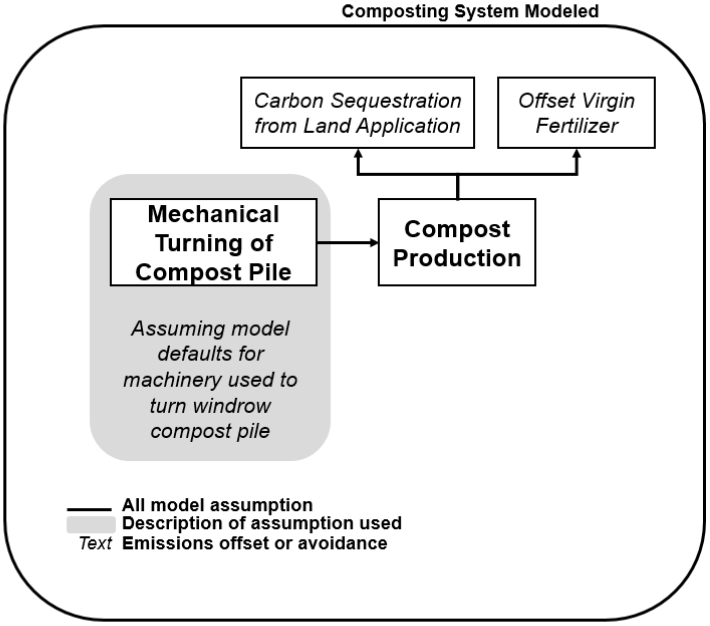


Figure 5-8. The system boundary selected and used for the composting system for WARM, MSW-DST, and SWOLF simulation runs.

5.4.5.7 Anaerobic Digestion

The main parameters included in the anaerobic digestion system are emissions associated with operations, releasing embodied substances (e.g., chemicals) during treatment, biogas generation and electricity offset, compost land application offsetting the use of fertilizer and increasing carbon storage. The anaerobic digestion system boundary modeled for only WARM and SWOLF is shown in Figure 5-9.

Anaerobic digestion operations include three main processes: prescreening, digestion, and post-treatment. Similar to pre-composting, waste is shredded and screened prior to the treatment stage. During treatment, waste and water are mixed in a reactor for a specified retention period (e.g., weeks). The mixture produces biogas that is compressed, cleaned, and flared to generate electricity. Depending upon the model, a specific decay rate and biogas collection efficiency are associated with the treatment process. The end of treatment produces digestate which must be managed. In post-treatment, digestate is managed through dewatering and screening processes to produces two products, a liquid and solid. The solids are cured via windrow composting and produce a fertilizer. Meanwhile, the liquid product (leachate) is transported to a wastewater treatment facility for treatment. Various types of heavy equipment requiring a fossil fuel based energy source are used in anaerobic digestion. The equipment type and curing time differs among the two models and the default assumptions were used in the study. As for offsets from the compost product each model assumes a unique carbon storage estimate, fertilizer offset benefit, and land application emission and the defaults were used.

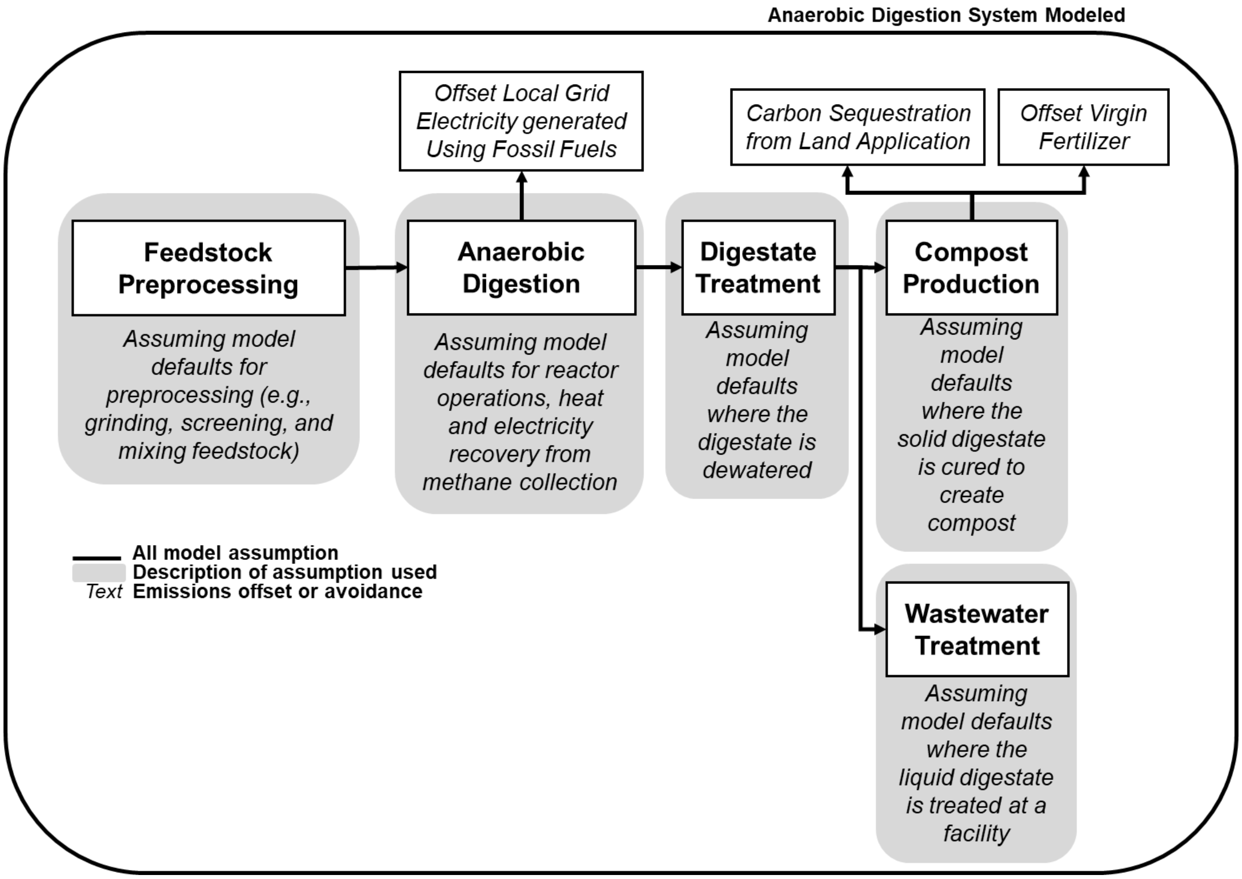


Figure 5-9. The system boundary selected and used for the anaerobic digestion system for WARM and SWOLF simulation runs.

5.4.6 IMPACT FACTORS DIFFERENCES

As recognized earlier, each model has inherent assumptions, LCI data, and LCIA methods that differ among the models. We attempted to minimize the differences in these assumptions by modeling each of the six waste management options in a similar manner (as seen in the system boundaries in Section 5.5). However, even in doing so several of the impact factors for the same material and management were different among the three models. In this section an explanation for the differences are presented. Table 5-4 through 5-9 summarize the differences between the GWP recycling, landfilling, combustion, composting, and anaerobic digestion impact factors, respectively. Table 5-9 summarizes the differences among the energy use, human toxicity, ecotoxicity, eutrophication potential, and acidification potential impact factors.

Table 5-4. Summary explanation for the differences between the GWP recycling impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

	Impact Factor from Each Model			
Material	**MSWDST**	**SWOLF**	**WARM**	**Explanation for difference**
Paper	Refer to spreadsheet tool			WARM impact factors are more negative (indicating more avoidance) than the other two models. WARM assumes that recycling paper products increases the carbon stored in forests because using recycled paper instead of virgin paper eliminates the need to harvest trees.
Aluminum Cans	-9.86	-15.85	-9.13	WARM and MSWDST have similar magnitude values for the impact factors, however SWOLF greatly differs. All three models rely on varying data sources for the LCI analysis, thus there will be a difference in the results. In most cases the LCI results do not vary largely among the three models, but in some cases, such as for aluminum cans, the difference may be more pronounced.
Mixed Metals	-5.35	-8.91	-4.39	SWOLF has a larger value than WARM and MSWDST because it accounts for aluminum cans in the mixed metals and, as seen in this Table, the aluminum can value is larger in SWOLF than the other two models.

Table 5-5. Summary explanation for the differences between the GWP landfill impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

	Impact Factor from Each Model			
Material	**MSWDST**	**SWOLF**	**WARM**	**Explanation for difference**
Mixed MSW	-0.18	0.01	0.15	WARM is the only model that provides an estimate for mixed MSW, while the other two models do account for mixed MSW they do so by segregating it into two fractions: miscellaneous inorganic and organic. The exact material composition for all three models are not readily described in each model. The composition is hypothesized to have a large impact on the impact factor.
Corrugated Cardboard (OCC)	-0.77	0.0041	-0.05	The landfill system modeled in all three models was modified to match a single system as closely as possible (Figure 8). However, there are still cases, specifically with the landfill gas-to-energy (LFGTE) system, that differ within each model because of the model's inflexibility resulting in user inability to change inputs. In regards to the LFGTE system, two default input parameters (annual landfill gas collection efficiency; duration of gas collection for energy generation) are conflicting within each model. Of the three models, WARM offers the least flexibility in changing input parameters. MSWDST and SWOLF input parameters were modified to meet not only the system described in Figure 8 but using similar WARM input assumptions. As seen here for cardboard, the LFGTE system assumptions have the greatest impact on organic materials (or materials containing biogenic carbon) because they are the driving source for generating landfill gas, and if properly collected such materials can be used to produce enough electricity to offset the use of fossil fuels (resulting in negative values (savings)) and thus produce electricity offsets.
Plastic	0.0039	0.09	0.02	Plastic, glass, and metals when landfilled are considered inert materials since they do not easily decompose and release many emissions. However, some of these materials will react with landfill leachate and if they contain trace compounds (e.g., metals, organic compounds, etc.), those compounds may leach from the materials into the leachate. This leaching is significant when considering the impact categories for human toxicity and ecotoxicity. The differences between all three models can be traced back to the type of LCI data used in each model.
Glass	0.0039	0.09	0.02	
Metals	0.0039	0.09	0.02	
Tires	NA	-0.87	0.02	SWOLF does not directly model tires or clothing and footwear emissions. We assumed that rubber and textiles would be used as a proxy. In SWOLF, unlike WARM, rubber and textiles are assumed to contain biogenic carbon. When landfilling these materials their biogenic carbon content is considered sequestered in the landfill resulting in a GHG emissions offset. For some materials the offset results in a net negative number (savings), as seen for tires but not for clothing and footwear.
Clothing and Footwear	NA	0.34	0.02	

Table 5-6. Summary explanation for the differences between the GWP combustion impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

Material	Impact Factor from Each Model			Explanation for difference
	MSWDST	**SWOLF**	**WARM**	
Mixed MSW	-0.27	-0.16	0.02	Refer to explanation described in Table 27.
Paper	Refer to spreadsheet tool			Overall, the factors for the paper and plastic categories created using the three models are similar to one another. Slight differences can be observed that are primarily due to the difference in data sources used for the LCI analysis.
Plastic				
Aluminum Cans	0.03	-7.83	0.03	In all three models' ferrous metals are assumed recovered from the WTE ash. Only SWOLF assumes nonferrous metals ash recovery, hence the larger savings.
Mixed Metals	-0.88	-8.57	-1.02	
Tires	NA	-0.14	0.50	WARM assumes that tires contain recoverable steel, thus tires are credited with an offset. Also, combusting tires generates electricity, which is used in place of fossil fuel electricity generation. However the emissions associated with combusting the fossil carbon found in the rubber in tires results in net emissions, indicating that in WARM the tire fossil carbon has the biggest impact on the GHG emissions impact factor. Previously mentioned in Table 27, rubber was used as a proxy for tires modeling in SWOLF so no metals recovery offsets are credited. The results are a negative value, which indicates that the electricity generated from combusting tires produces a large enough offset to outweigh the emissions released when combusting the fossil carbon.
Clothing and Footwear	NA	-0.40	1.11	WARM does not directly provide clothing and footwear as a modeling material category, so the most similar material used as a proxy was carpet. Combusting carpet generates electricity, which is used in place of fossil fuel electricity generation. However, the emissions associated with combusting the fossil carbon found in the carpet results in a net emissions. Previously mentioned in Table 27, textiles was used as a proxy. Since the results are a negative value, the results indicate that the electricity generated from combusting textiles produces a large enough offset to outweigh the emissions released when combusting the fossil carbon.

Table 5-7. Summary explanation for the differences between the GWP composting impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

	Impact Factor from Each Model			
Material	**MSWDST**	**SWOLF**	**WARM**	**Explanation for difference**
Yard Waste	0.02	0.02	-0.15	WARM impact factors are more negative (indicating more avoidance) than the other two models. WARM assumes that composting increases the carbon stored in forests and that virgin fertilizer is offset. Although all models account for the virgin fertilizer offset, only WARM accounts for a separate offset from increasing carbon storage. Refer to Figure 10.
Food Waste	0.02	0.04	-0.18	

Table 5-8. Summary explanation for the differences between the GWP anaerobic digestion impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

	Impact Factor from Each Model			
Material	**MSWDST**	**SWOLF**	**WARM**	**Explanation for difference**
Yard Waste	NA	0.05	-0.09	WARM impact factors are more negative (indicating more avoidance) than SWOLF. WARM assumes that anaerobic digestion increases the carbon stored in forests, offsets virgin fertilizer, and the generation of electricity from the biogas offsets fossil fuel electricity generation. Although SWOLF account for the latter two offsets, only WARM accounts for a separate offset from increasing carbon storage. Refer to Figure 11.

Table 5-9. Summary explanation for the differences between the energy use, human toxicity, ecotoxicity, eutrophication potential, and acidification potential impact factor (developed by each model using Florida-specific energy grid and landfill assumption).

Impact factor	Explanation for difference between MSWDST and SWOLF
Energy Use	The three models use differing LCI data and LCIA methods to measure energy use, resulting in large differences for: recycling and landfilling of cardboard, office paper, magazines/third-class mail, and HDPE; composting organics; and landfilling organics and "other" materials.
Human toxicity	Of the three models, MSWDST and SWOLF permit users to measure these four impact categories using the same LCIA method, TRACI 2.0. However, SWOLF appears to account for a larger scope of substances emitted during processes in the LCI analysis phase than MSWDST. Although TRACI 2.0 is used by both, because the LCI analysis results differ greatly between the two models it results in a difference in the developed impact factors for the four impact categories. This is largely apparent for human toxicity and ecotoxicity, thus indicating that the LCI results for SWOLF and MSWDST are extensively different between the two models. Meanwhile, the LCI results used for eutrophication and acidification potential are less pronounced as evidenced in the developed impact factors.
Ecotoxicity	
Eutrophication potential	
Acidification potential	

5.5 MODIFIED WASTECALC OUTPUTS CALCULATIONS

The mass of materials landfilled and combusted was determined for each individual material and on a per county basis. The steps to estimate were:

1. WasteCalc version 2019 already provides the individual material recycled and landfilled masses. We used that data to identify the mass potentially landfilled or combusted by subtracting the recycled mass from total collected mass.
2. Then, using the total landfilled (for all 18 materials) and total net combusted (for all 18 materials) masses we calculated: a) total landfilled divided by the sum of total landfilled and net combusted; b) total net combusted divided by the sum of total landfilled and net combusted. We applied these ratios to the mass potentially landfilled or combusted from Step 1 to get the individual mass combusted and landfilled. Note, if a county reported waste was combusted in a non-WTE facility, instead, we assumed all the mass combusted was associated with yard trash only.

The mass of materials source reduced/generated were calculated by subtracting the WasteCalc results for the future year (e.g., 2019) from the user's inputted individual material collected mass from a past baseline year (e.g., 2013). If the result was negative, then that material was assumed source reduced and if the result was positive that material was assumed source generated. Example hypothetical data are shown in Table 5-10.

Table 5-10. Hypothetical calculations used for source reduced/generated for the FDEP 18 material categories.

Material	Collected 2019	Collected 2013	Source reduced mass Tons
Newspaper	13,098	32,718	-19,620
Glass	34,945	51,041	-16,096
Aluminum Cans	7,839	6,544	1,295
Plastic Bottles	21,159	26,175	-5,016
Steel Cans	6,115	5,235	880
Corrugated Boxes	84,656	91,612	-6,956
Office Paper	14,284	26,175	-11,891
Yard Trash	489,520	308,539	180,981
Other Plastics	97,039	91,612	5,427
Ferrous Metals	80,943	48,054	32,889
White Goods	11,167	10,470	697
Non Ferrous Metals	9,660	11,396	-1,736
Other Paper	117,890	100,404	17,486
Textiles	31,577	26,175	5,402
C&D Debris	516,676	383,461	133,215
Food Waste	119,039	37,953	81,086
Miscellaneous	164,363	3,096	161,267
Tires	9,764	3,926	5,838
Process Fuel	-	-	0

5.6 CALCULATIONS FOR NEW MATERIAL CATEGORIES

As previously introduced in Section 5.1.1 several additional material categories were identified and included as part of the SMM portion of the 2021 SMM Tool. The new categories are subcategories (or renamed categories) based on the original 18 FDEP materials. The exact breakdown of subcategories or whether its name was changed, and their corresponding original category are detailed in Table 5-11. More details on how the original material category was divided into the subcategory, including the exact proportions applied to the original material category used to estimate the mass of the new subcategory is described in Table 5-12. Several assumptions were used and these reference data in Table 5-13 and Figure 5-10.

Table 5-11. The breakdown of new subcategories and their corresponding original FDEP category. The original 18 material categories were subcategorized to a new total of 25 materials.

Original FDEP Category	New Subcategories
Newspaper	No change.
Glass	No change.
Aluminum Cans	No change.
Plastic Bottles	HDPE and PET
Steel Cans	No change.
Corrugated Boxes	No change.
Office Paper	No change.
Yard Trash	No change.
Other Plastics	Name change to mixed plastic.
Ferrous Metals	Combined with nonferrous metals and called mixed metals.
White Goods	Combined with a percentage of miscellaneous associated with electronics and called electronics.
Non Ferrous Metals	See ferrous metals note.
Other Paper	Magazines/third-class mail, books, and mixed paper.
Textiles	Name change to clothing and footwear.
C&D Debris	Wood products, asphalt shingles, gypsum drywall, concrete, reclaimed asphalt pavement.
Food Waste	No change.
Miscellaneous	Furniture, electronics, and mixed MSW.
Tires	No change.

Table 5-12. Details on how the original material category was divided into the new subcategories. The percentages are used in the 2021 SMM Tool and are applied to the mass results from the WasteCalc model to estimate the new mass breakdown for the new list of 25 material categories.

Original FDEP Categories	Does the material have a new category? (Y-Yes, N-No)	New Categories	Notes	% HDPE of plastic bottles	% PET of plastic bottles	% Magazine/ third class mail of other paper	% Books of other paper
Newspaper	N						
Glass	N						
Aluminum Cans	N						
Plastic Bottles	Y	HDPE and PET	Category broken apart using assumptions	38%[1]	62%[1]		
Steel Cans	N						
Corrugated Boxes	N						
Office Paper	N						
Yard Trash	N						
Other Plastics	Y	Mixed plastics	Only name change				
Ferrous Metals	Y	Mixed metals	Sum of the ferrous and nonferrous categories				
White Goods	Y	Electronics	Included in electronics along with the portion from miscellaneous				
Non Ferrous Metals	Y	Mixed metals	Sum of the ferrous and nonferrous categories				
Other Paper	Y	Mixed paper, magazines/third-class mail, and books	Category broken apart using assumptions			23%[2]	2%[2]
Textiles	Y	Clothing and footwear	Only name change				

[1] See data in Table 5-13 for source of estimates.

[2] Data retrieved from (Stewardship Ontario, 2016).

Table 5-12. continued.

Original FDEP Categories	Does the material have a new category? (Y-Yes, N-No)	New Categories	Notes	% Wood products of C&D debris	% Asphalt shingles of C&D debris	% Gypsum drywall of C&D debris	% Concrete of C&D debris	% Asphalt pavement of C&D debris	% Electronics of Miscellaneous	% Furniture of Miscellaneous
C&D Debris	Y	Wood products, asphalt shingles, gypsum drywall, concrete, asphalt pavement	Category broken apart using assumptions	25%[3]	22%[3]	12%[3]	34%[3]	9%[3]		
Food Waste	N									
Miscellaneous	Y	Mixed MSW, electronics, and furniture	Category broken apart using assumptions						3%[4]	2%[4]
Tires	N									
Process Fuel	N									

[3] Data retrieved from (University of Florida, 2017).

[4] Data retrieved from Figure 3-6.

Table 5-13. Recyclables waste composition study used to determine the percentage of HDPE and PET in plastic bottles material category.

		Recyclables Composition										
County/City	**Year**	**Newspaper**	**Mixed Paper Nondurable Goods**	**Glass Packaging**	**Steel Packaging**	**Aluminum Packaging**	**Corrugated Boxes**	**Other Paper & Paperboard Packaging**	**PET Bottles**	**HDPE Bottles**	**Mixed Plastics Packaging**	**All other garbage**
Sarasota[1]	2015	17%	30%	22%	2%	2%	9%	0.2%	5%	3%	2%	8%
Lee[2]	2018	7%	18%	13%	2%	2%	26%	0.3%	6%	3%	5%	17%
Brevard[3]	2016	10%	23%	19%	2%	2%	9%		4%	2%	1%	28%
Pasco[4]	2014	1%	2%	42%	8%	4%	1%	0.3%	16%	10%	12%	4%
Lakeland[5]	2015	16%	24%	10%	4%	1%	17%	0.3%	5%	2%	9%	11%
Santa Rosa[6]	2017	4%	19%	4%	3%	1%	22%	0.0%	4%	3%	2%	38%
Okaloosa[7]	2014	14%	24%	19%	3%	2%	15%	0.4%	5%	4%	7%	7%
Average		**10%**	**20%**	**19%**	**3%**	**2%**	**14%**	**0%**	**6%**	**4%**	**6%**	**16%**

[1] Data retrieved from (Kessler Consulting, Inc., 2016).

[2] Data retrieved from (Kessler Consulting, Inc., 2018).

[3] Data retrieved from (Florida Tech Consulting, 2016).

[4] Data retrieved from (Kessler Consulting, Inc., 2014a).

[5] Data retrieved from (Kessler Consulting, Inc., 2015).

[6] Data retrieved from (Geosyntec, 2017).

[7] Data retrieved from (Kessler Consulting, Inc., 2014b).

6 TRAINING MATERIALS

6.1 BETA TESTING PROCESS AND FINDINGS

After discussions with the stakeholder group, we determined that conducting beta testing of the 2021 SMM Tool for Recycling Coordinator usage would be valuable in determining what functionalities of the tool should be improved or what areas needed additional instructions. Several small, medium, and large counties were contacted to participate in the beta testing and five counties provided feedback. The counties were provided the 2021 SMM Tool along with a set of feedback questions. The counties were not instructed beforehand on how to operate the tool, instead, they were directed to rely on the instructions in tool only and provide feedback. The standardized feedback questions provided to the county participants were:

1. Do you currently use WasteCalc for your annual report? If not, what do you use to calculate your collected masses/composition for the annual report?
2. Which year data did you use for the Tab 2 2019 WasteCalc Input?
3. Which model (or models) did you select in the Tab 4 SMM Input? Why?
4. Is the collected composition and collected tons output in Tab 3 2019 WasteCalc Results accurately reflecting your county? If not, can you explain what changes you needed to make to reflect your composition better?
5. Are any of the directions confusing in Tab 2 2019 WasteCalc Input or in Tab 4 SMM input? If so which ones?
6. Are you confused on which LCA model to select in the Tab 4 SMM? If so please explain why.
7. Are you confused on which LCI indicator (e.g., GHG emissions, energy use) is most important? If so please explain why.
8. Do you expect your county to use this tool for solid waste management planning?
9. Do you have any suggestions on anything missing from the tool that you'd like to see/use?
10. What are your other general feedbacks on the tool?
11. What type of training material would you like on how to use the tool? A workshop? A recorded walkthrough? A webinar? Something else?

The feedback provided from the counties included for each question included:

1. Many of the counties do use WasteCalc annually for solid waste reporting. The county that did not use WasteCalc was because they preferred to use their existing waste composition study data, however, after the beta testing they indicated they will likely begin using WasteCalc since it has more updated data.

2. Most used 2019 data.

3. All selected the SWOLF (FL) model citing that it had: the most impact factors of interest and previous staff experience with the model. One county explained that although they selected SWOLF it was at random and unclear to them which model is most important.

4. All counties that participated agreed that the data accurately reflects their waste composition, except for one county which indicated they were not sure since they have not conducted a waste composition study the last 10 years.

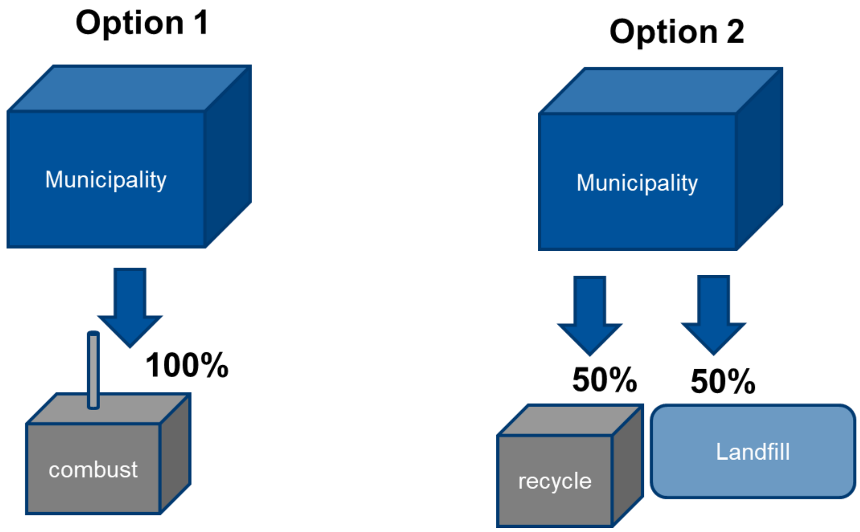
5. All agreed the directions were clear and easy to follow. Several counties provided suggestions for the instructions to be presented in another way (e.g., numbered steps, bullets) and this was used to modify the tool.
6. Most agreed that the explanations were straight forward. Some included suggestions such as “users of the tool could benefit from a disclaimer of the pros, cons, limitations of the different models.” And “having more information provided about how to properly interpret the outputs from the models may be helpful.” The suggestions were included in the tool and in this report.
7. Most agree they were not confused by the indicator’s importance since definitions were provided for each LCI indicator. Some counties did select energy use as important while other explained that it is important to lower all of them, but which one should be prioritized may differ from one county to the next.
8. Some of the direct feedback included: “we would recommend this as a tool to use moving forward, not only for planning purposes but for educational purposes as well for residents and schools to learn from”; “We anticipate using this tool in future solid waste management planning”; “Due to the ease of use and consolidation of reputable and accurate models, the tool can help inform and prioritize proposed solid waste management strategies.”
9. Most feedback was included however some feedback was time intensive and required more planning with the stakeholder group, albeit the feedback may be used in a second version of this tool and included: “possibility to add a multi-year data/chart to show any trends occurring with specific LCIs.”; “Input more waste strategy methods and the outputs associated with managing you waste in various ways.”
10. Some of the direct feedback included: “we have mentioned a few things in other questions, but overall a great tool for future planning and reporting.” ; “Overall this is a great tool that is easy to use and we anticipate using it when evaluating future program changes as well as in developing our Sustainability Action Plan.” ; “Having more information provided about how to properly interpret the outputs from the models may be helpful, especially for staff with less experience with sustainably metrics.”
11. Some feedback was to provide a webinar, live-training, multi-day training, step-by-step recorded tutorial, attend a conference, and a live workshop. We have successfully conducted three recorded live webinars (one in April 2021 for a general overview, one in May 2021 for educator usage, and one in June 2021 for decision makers usage) and posted these on our project website along with the corresponding PowerPoint. We also presented an overview of the tool at the June 2021 conference for Recycle Florida Today.

6.2 TOOL USE FOR RECYCLING COORDINATORS, DECSION MAKERS, AND EDUCATORS

Florida county Recycling Coordinators can use the 2021 SMM Tool to obtain any data related to the collected waste stream which is necessary as part of the FDEP solid waste annual reporting. While, for local government decision makers (which may include Recycling Coordinators) the tool is most useful for them to understand the mass flow of their materials and how they can use the tool for SMM/sustainability planning purposes. Since the tool includes a breakdown of each material collected, recycled, landfilled, combusted, donated, and source reduced/generated it provides a comprehensive map of the waste flow and types in each of the Florida 67 counties. The tool is valuable for SMM/sustainability planning purposes because of its direct link of the waste stream data to LCA data (the LCI factors) which allows for a simplified life cycle environmental footprint analysis of a county's upstream (produced materials) and end-of-life (waste materials) streams. For other stakeholders, including waste planning decision makers, environmental educators, and manufacturing decision makers the 2021 SMM model can be used similar to the US EPA WARM LCA model, where the LCI factors can be used directly in their specific decision-making scenarios. An example scenario that shows how an educator and waste planning decision maker may use this tool is shown below.

Example Problem

A municipality is evaluating two option for managing cardboard in their waste stream. If they collect 20 tons per day of cardboard. Which option results in the lowest GHG emissions ($tCO_2eq.$) per day?



Example Problem Step-by-Step Walkthrough:

Solve for Option 1 (used LCI factors from SWOLF (FL):

$$20\,\frac{tons}{day}\ *100\%\ *-1.08\ \frac{tCO2eq.}{ton\,cardboard\,combusted}=-22\ \frac{tCO2eq.}{day}$$

Solve for Option 2 (used LCI factors from SWOLF (FL):

$$20\,\frac{tons}{day}\ *50\%*0.19\ \frac{tCO2eq.}{ton\,cardboard\,recycled}=2\,\frac{tCO2eq.}{day}$$

$$20\,\frac{tons}{day}\ *50\%*-0.77\ \frac{tCO2eq.}{ton\,cardboard\,landfilled}=\ -8\,\frac{tCO2eq.}{day}$$

$$2+(-8)=-6\,\frac{tCO2eq.}{day}$$

Outcome:

In this hypothetical scenario, Option 1 has more environmental avoidance/lowest GHG emissions footprint (more negative) than Option 2. This is because, recall in SWOLF recycling cardboard (based on our selected Florida assumptions) is associated with an emission primarily due to the fact that SWOLF does not include a forest carbon credit (see Section 5.4.6 for more information). While, when cardboard is landfilled, it is assumed to generate landfill gas that is collected for energy recovery which offset local fossil fuel usage, likewise, when cardboard is combusted, it has a high energy content which generates electricity and offsets fossil fuel usage. These results may change depending on the selected LCI factors and model selected in the 2021 SMM Tool.

7 REFERENCES

Anshassi, M., Laux, S.J., Townsend, T.G., 2019. Approaches to integrate sustainable materials management into waste management planning and policy. Resources, Conservation and Recycling 148, 55–66. https://doi.org/10.1016/j.resconrec.2019.04.011

AP News, 2020. North America Corrugated Boxes Market Estimated to Reach a Volume of 49.4 Billion Sq. Metres by 20204 with a CAGR of 1.45% - ResearchAndMarkets.com [WWW Document]. AP NEWS. URL https://apnews.com/press-release/Business%20Wire/bd2fe82a930b42298a54792e795ae227 (accessed 6.10.21).

Average Life Expectancy of Textile Items in Years, n.d.

Baxter, J., 2019. Systematic environmental assessment of end-of-life pathways for domestic refrigerators. Journal of Cleaner Production 208, 612–620. https://doi.org/10.1016/j.jclepro.2018.10.173

Blikra Vea, E., Martinez-Sanchez, V., Thomsen, M., 2018. A Review of Waste Management Decision Support Tools and Their Ability to Assess Circular Biowaste Management Systems. Sustainability 10, 3720. https://doi.org/10.3390/su10103720

Bobba, S., Ardente, F., Mathieux, F., 2015. Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA: Durability assessment of vacuum cleaners.

Cascini, A., Gamberi, M., Mora, C., Rosano, M., Bortolini, M., 2016. Comparative Carbon Footprint Assessment of commercial walk-in refrigeration systems under different use configurations. Journal of Cleaner Production 112, 3998–4011. https://doi.org/10.1016/j.jclepro.2015.08.075

Ciceri, N.D., Gutowski, T.G., Garetti, M., 2010. A tool to estimate materials and manufacturing energy for a product, in: Proceedings of the 2010 IEEE International Symposium on Sustainable Systems and Technology. Presented at the Proceedings of the 2010 IEEE International Symposium on Sustainable Systems and Technology, pp. 1–6. https://doi.org/10.1109/ISSST.2010.5507677

Container Recycling Institute, 2008. Sales by container type [WWW Document]. URL https://www.container-recycling.org/index.php/sales-by-container-type (accessed 6.9.21).

Dietz, B.A., 2005. Life Cycle Assessment of Office Furniture Products (No. CSS05- 08). Center for Sustainable Systems University of Michigan.

Ekvall, T., Assefa, G., Björklund, A., Eriksson, O., Finnveden, G., 2007. What life-cycle assessment does and does not do in assessments of waste management. Waste Management, Life Cycle Assessment in Waste Management 27, 989–996. https://doi.org/10.1016/j.wasman.2007.02.015

Florida Tech Consulting, 2016. Composition of the Single Stream Recyclables Waste Stream for Brevard County Solid Waste Management Department.

FY19 Corporate Social Responsibility Report [WWW Document], 2019. . Dell Technologies. URL https://corporate.delltechnologies.com/en-us/social-impact/reporting/fy19-csr-report.htm (accessed 10.10.20).

Gentil, E.C., Damgaard, A., Hauschild, M., Finnveden, G., Eriksson, O., Thorneloe, S., Kaplan, P.O., Barlaz, M., Muller, O., Matsui, Y., Ii, R., Christensen, T.H., 2010. Models for waste life cycle assessment: Review of technical assumptions. Waste Management 30, 2636–2648. https://doi.org/10.1016/j.wasman.2010.06.004

Geosyntec, 2017. Recycled Material Composition Study in Santa Rosa County, Florida.

Gonzalez, A., Chase, A., Horowitz, N., 2012. What We Know and Don’t Know about Embodied Energy and Greenhouse Gases for Electronics, Appliances, and Light Bulbs 12.

Guinée, J.B., Heijungs, R., Huppes, G., Zamagni, A., Masoni, P., Buonamici, R., Ekvall, T., Rydberg, T., 2011. Life Cycle Assessment: Past, Present, and Future. Environ. Sci. Technol. 45, 90–96. https://doi.org/10.1021/es101316v

ICF International, 2016a. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Containers, Packaging, and Non-Durable Good Materials Chapters.

ICF International, 2016b. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Management Practices Chapters.

ICF International, 2016c. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Background Chapters.

Iritani, D.R., Silva, D.A.L., Saavedra, Y.M.B., Grael, P.F.F., Ometto, A.R., 2015. Sustainable strategies analysis through Life Cycle Assessment: a case study in a furniture industry. Journal of Cleaner Production, Integrating Cleaner Production into Sustainability Strategies 96, 308–318. https://doi.org/10.1016/j.jclepro.2014.05.029

Japan Electrical Manufacturer’s Association, 2014. Report on Life Cycle Inventory (LCI) Analyses of Refrigerators.

Kessler Consulting, Inc., 2018. Lee County 2018 Recyclables Composition Study.

Kessler Consulting, Inc., 2016. Sarasota County 2016 Recyclables Composition Study.

Kessler Consulting, Inc., 2015. City of Lakeland 2015 Recyclables Composition Study.

Kessler Consulting, Inc., 2014a. Pasco County 2014 Recyclables Composition Study.

Kessler Consulting, Inc., 2014b. 2014 Waste and Recyclables Composition Study Okaloosa County, Florida.

Khandelwal, H., Dhar, H., Thalla, A.K., Kumar, S., 2019. Application of life cycle assessment in municipal solid waste management: A worldwide critical review. Journal of Cleaner Production 209, 630–654. https://doi.org/10.1016/j.jclepro.2018.10.233

Kirkeby, J.T., Birgisdottir, H., Hansen, T.L., Christensen, T.H., Bhander, G.S., Hauschild, M., 2006. Environmental assessment of solid waste systems and technologies: EASEWASTE. Waste Manag Res 24, 3–15. https://doi.org/10.1177/0734242X06062580

Linkosalmi, L., Husgafvel, R., Fomkin, A., Junnikkala, H., Witikkala, T., Kairi, M., Dahl, O., 2016. Main factors influencing greenhouse gas emissions of wood-based furniture industry in Finland. Journal of Cleaner Production 113, 596–605. https://doi.org/10.1016/j.jclepro.2015.11.091

Martin, E.W., Chester, M.V., Vergara, S.E., 2015. Attributional and Consequential Life-cycle Assessment in Biofuels: a Review of Recent Literature in the Context of

System Boundaries. Curr Sustainable Renewable Energy Rep 2, 82–89. https://doi.org/10.1007/s40518-015-0034-9

Medeiros, D.L., Tavares, A.O. do C., Rapôso, Á.L.Q.R. e. S., Kiperstok, A., 2017. Life cycle assessment in the furniture industry: the case study of an office cabinet. Int J Life Cycle Assess 22, 1823–1836. https://doi.org/10.1007/s11367-017-1370-3

Muller, D., 2017. How Long Should a New Set of Tires Last? [WWW Document]. Car and Driver. URL https://www.caranddriver.com/news/a15339994/how-long-should-a-new-set-of-tires-last (accessed 8.25.20).

Project Learning Tree, 2020. Activity 10: Adventures in Life Cycle Assessment: Comparing Outdoor Furniture.

Pryshlakivsky, J., Searcy, C., 2013. Fifteen years of ISO 14040: a review. Journal of Cleaner Production 57, 115–123. https://doi.org/10.1016/j.jclepro.2013.05.038

Reap, J., Roman, F., Duncan, S., Bras, B., 2008. A survey of unresolved problems in life cycle assessment Part 1. Int J Life Cycle Assess 13, 290. https://doi.org/10.1007/s11367-008-0008-x

Recycle USA Inc, 2014. Application of life cycle assessment in municipal solid waste management: A worldwide critical review - ScienceDirect [WWW Document]. URL https://www.sciencedirect.com/science/article/pii/S0959652618332591?via%3Dihub (accessed 6.9.21).

RTI International, 1997. Waste-to-Energy Process Model. RTI International.

Sandin, G., Roos, S., Spak, B., Zamani, B., Peters, G., 2019. Environmental assessment of Swedish clothing consumption - six garments, sustainable futures. MISTRA.

Spitzley, D.V., Dietz, B.A., Keoleian, G.A., Table, A., Spitzley, D.V., Dietz, B.A., Keoleian, G.A., Spitzley, D.V., Dietz, B.A., Keoleian, G.A., 2006. Life Cycle Assessment of Office Furniture Products: Final report on the study of three Steelcase office furniture (No. CSS06-11).

Stewardship Ontario, 2016. 2013 MRF Material Composition Study.

StreetJournal, D.M.R. of T.W., 2001. Sales of Corrugated Boxes Offer One Measure of Economy’s Health. Wall Street Journal.

Teehan, P., Kandlikar, M., 2013. Comparing Embodied Greenhouse Gas Emissions of Modern Computing and Electronics Products. Environ. Sci. Technol. 47, 3997–4003. https://doi.org/10.1021/es303012r

Textile Restorations, 2021. Average Life Expectancy of Textile Items in Years [WWW Document]. URL https://www.textilerestorations.com/lifeexpectancy.pdf (accessed 6.10.21).

Time Lag and Composition of Durable Goods, 2014. . U.S. Environmental Protection Agency 9.

Townsend, T., Laux, S., Behdad, S., Wasserman, M., Anshassi, M., Baylor, C., Vallecillo, D.Z., Hendricks, A., 2020. State of Food Donation Efforts in Florida.

University of Florida, 2020. Looking Beyond Florida’s 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida. Hinkley Center for Solid and Hazardous Waste Management.

University of Florida, 2017. Benefits of Construction and Demolition Debris Recycling in the United States. CDRA.

US EPA, 2019. Advancing sustainable materials management: 2017 fact sheet. Office of Resource Conservation and Recovery.

US EPA, 2018. Construction and Demolition Debris Generation in the United States, 2015.

US EPA, 2016. Construction and Demolition Debris Generation in the United States, 2014.

US EPA, 2014. Time Lag and Composition of Durable Goods.

US EPA, 2009. Sustainable Materials Management: The Road Ahead (No. EPA530--R-- 09--009). US EPA Office of Resource Conservation and Recovery.

US EPA, 2002. Beyond RCRA: Waste and Materials Management In the Year 2020. US EPA Office of Resource Conservation and Recovery.

VIZIO, 2020. VIZIO's Sustainability Efforts Praised by Environmental Protection Agency [WWW Document]. URL https://www.prnewswire.com/news-releases/vizios-sustainability-efforts-praised-by-environmental-protection-agency-300984642.html (accessed 10.10.20).

Wenker, J.L., Richter, K., Rüter, S., 2018. A Methodical Approach for Systematic Life Cycle Assessment of Wood-Based Furniture. Journal of Industrial Ecology 22, 671–685. https://doi.org/10.1111/jiec.12581

Wiedemann, S.G., Biggs, L., Nebel, B., Bauch, K., Laitala, K., Klepp, I.G., Swan, P.G., Watson, K., 2020. Environmental impacts associated with the production, use, and end-of-life of a woollen garment. Int J Life Cycle Assess 25, 1486–1499. https://doi.org/10.1007/s11367-020-01766-0

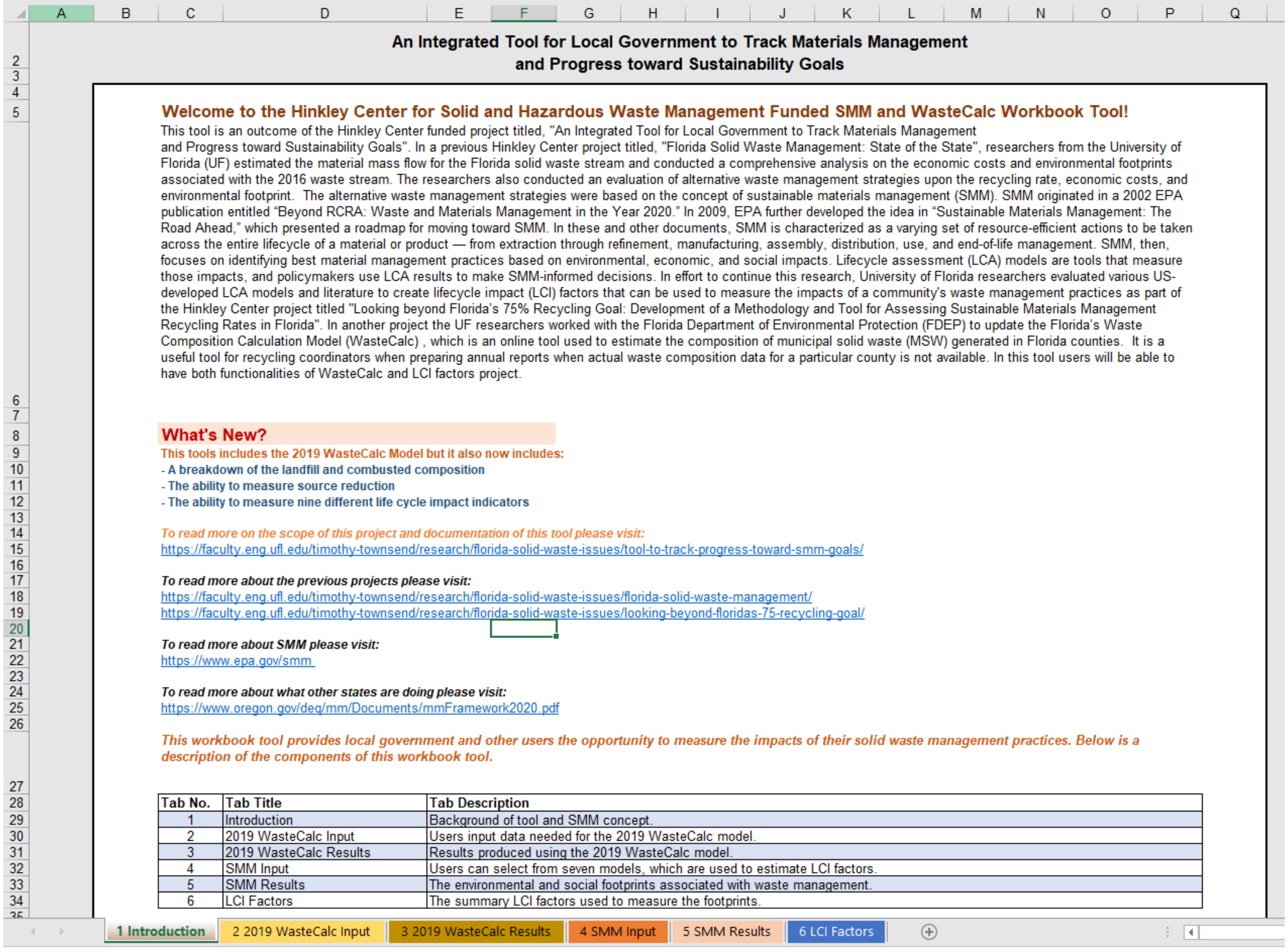
WRAP, 2010. Environmental assessment of consumer electronic products (No. MDD030).

Xerox 2019 Global Corporate Social Responsibility Report Showcases Commitment to Sustainability, Social Investment, Governance [WWW Document], 2019. . Xerox. URL https://www.news.xerox.com/news/Xerox-2019-Global-Corporate-Social-Responsibility-Report (accessed 10.10.20).

Yadav, P., Samadder, S.R., 2018. A critical review of the life cycle assessment studies on solid waste management in Asian countries. Journal of Cleaner Production 185, 492–515. https://doi.org/10.1016/j.jclepro.2018.02.298

Zhang, Z., Qiu, T., Song, R., Sun, Y., 2014. Nonlinear Finite Element Analysis of the Fluted Corrugated Sheet in the Corrugated Cardboard. Advances in Materials Science and Engineering 2014, e654012. https://doi.org/10.1155/2014/654012

8 APPENDIX



An Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals

Welcome to the Hinkley Center for Solid and Hazardous Waste Management Funded SMM and WasteCalc Workbook Tool!

This tool is an outcome of the Hinkley Center funded project titled, "An Integrated Tool for Local Government to Track Materials Management and Progress toward Sustainability Goals". In a previous Hinkley Center project titled, "Florida Solid Waste Management: State of the State", researchers from the University of Florida (UF) estimated the material mass flow for the Florida solid waste stream and conducted a comprehensive analysis on the economic costs and environmental footprints associated with the 2016 waste stream. The researchers also conducted an evaluation of alternative waste management strategies upon the recycling rate, economic costs, and environmental footprint. The alternative waste management strategies were based on the concept of sustainable materials management (SMM). SMM originated in a 2002 EPA publication entitled "Beyond RCRA: Waste and Materials Management in the Year 2020." In 2009, EPA further developed the idea in "Sustainable Materials Management: The Road Ahead," which presented a roadmap for moving toward SMM. In these and other documents, SMM is characterized as a varying set of resource-efficient actions to be taken across the entire lifecycle of a material or product — from extraction through refinement, manufacturing, assembly, distribution, use, and end-of-life management. SMM, then, focuses on identifying best material management practices based on environmental, economic, and social impacts. Lifecycle assessment (LCA) models are tools that measure those impacts, and policymakers use LCA results to make SMM-informed decisions. In effort to continue this research, University of Florida researchers evaluated various US-developed LCA models and literature to create lifecycle impact (LCI) factors that can be used to measure the impacts of a community's waste management practices as part of the Hinkley Center project titled "Looking beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida". In another project the UF researchers worked with the Florida Department of Environmental Protection (FDEP) to update the Florida's Waste Composition Calculation Model (WasteCalc) , which is an online tool used to estimate the composition of municipal solid waste (MSW) generated in Florida counties. It is a useful tool for recycling coordinators when preparing annual reports when actual waste composition data for a particular county is not available. In this tool users will be able to have both functionalities of WasteCalc and LCI factors project.

What's New?

This tools includes the 2019 WasteCalc Model but it also now includes:

- A breakdown of the landfill and combusted composition
- The ability to measure source reduction
- The ability to measure nine different life cycle impact indicators

To read more on the scope of this project and documentation of this tool please visit:
https://faculty.eng.ufl.edu/timothy-townsend/research/florida-solid-waste-issues/tool-to-track-progress-toward-smm-goals/

To read more about the previous projects please visit:
https://faculty.eng.ufl.edu/timothy-townsend/research/florida-solid-waste-issues/florida-solid-waste-management/
https://faculty.eng.ufl.edu/timothy-townsend/research/florida-solid-waste-issues/looking-beyond-floridas-75-recycling-goal/

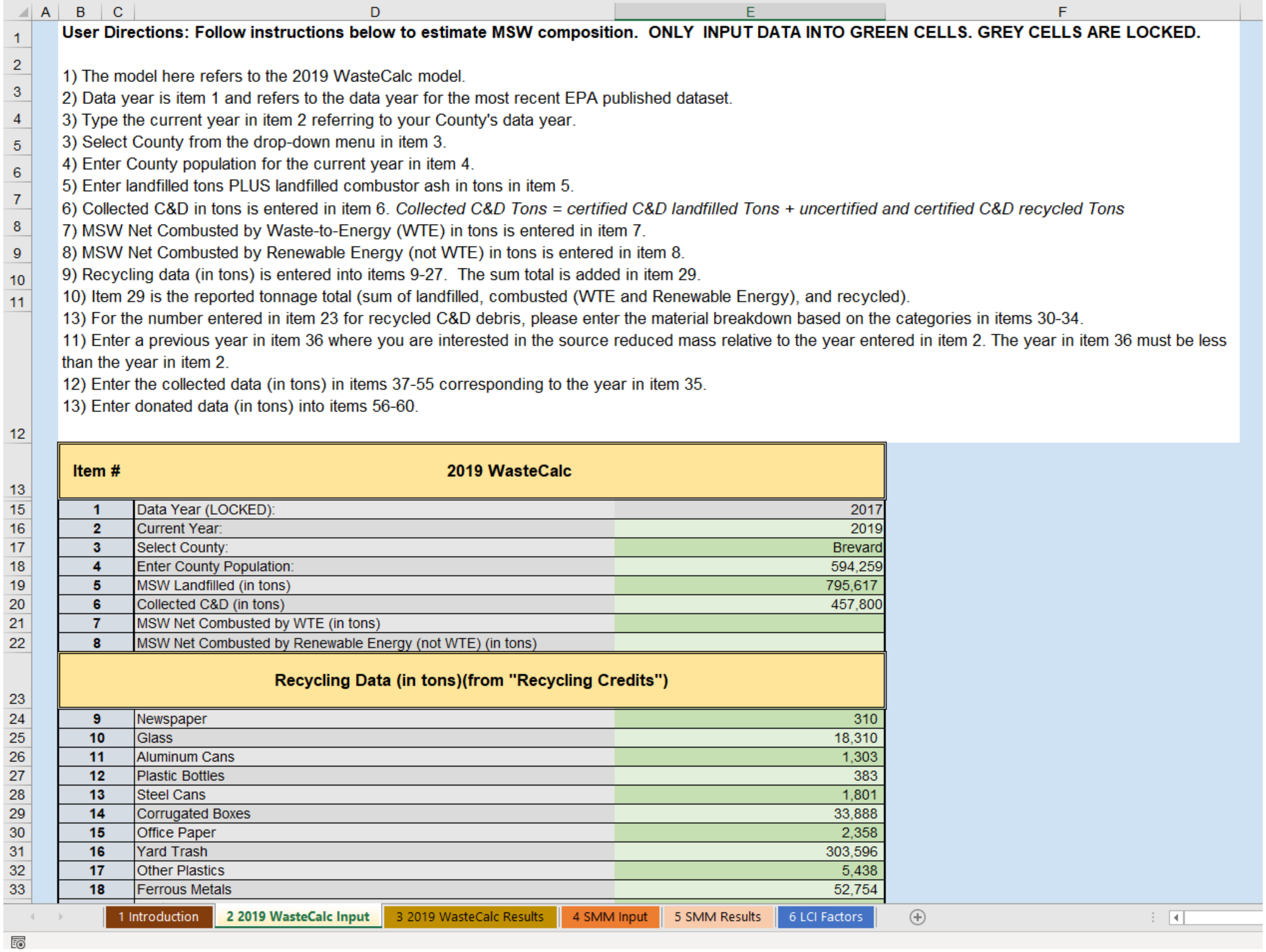
To read more about SMM please visit:
https://www.epa.gov/smm

To read more about what other states are doing please visit:
https://www.oregon.gov/deq/mm/Documents/mmFramework2020.pdf

This workbook tool provides local government and other users the opportunity to measure the impacts of their solid waste management practices. Below is a description of the components of this workbook tool.

Tab No.	Tab Title	Tab Description
1	Introduction	Background of tool and SMM concept.
2	2019 WasteCalc Input	Users input data needed for the 2019 WasteCalc model.
3	2019 WasteCalc Results	Results produced using the 2019 WasteCalc model.
4	SMM Input	Users can select from seven models, which are used to estimate LCI factors.
5	SMM Results	The environmental and social footprints associated with waste management.
6	LCI Factors	The summary LCI factors used to measure the footprints.

Figure A1. Screenshot of the Tab 1 Introduction in the 2021 SMM Tool.

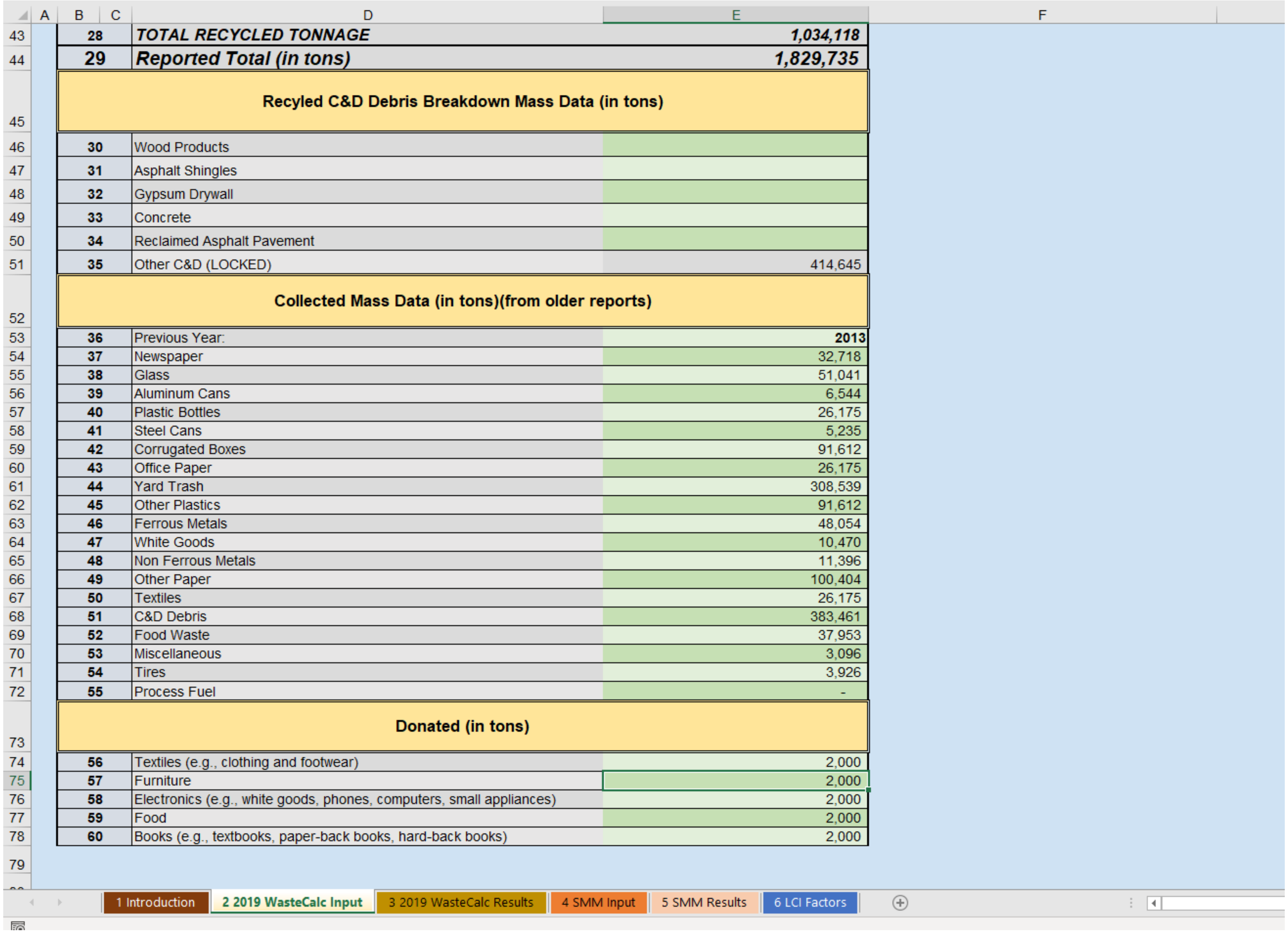


User Directions: Follow instructions below to estimate MSW composition. ONLY INPUT DATA INTO GREEN CELLS. GREY CELLS ARE LOCKED.

1) The model here refers to the 2019 WasteCalc model.
2) Data year is item 1 and refers to the data year for the most recent EPA published dataset.
3) Type the current year in item 2 referring to your County's data year.
3) Select County from the drop-down menu in item 3.
4) Enter County population for the current year in item 4.
5) Enter landfilled tons PLUS landfilled combustor ash in tons in item 5.
6) Collected C&D in tons is entered in item 6. *Collected C&D Tons = certified C&D landfilled Tons + uncertified and certified C&D recycled Tons*
7) MSW Net Combusted by Waste-to-Energy (WTE) in tons is entered in item 7.
8) MSW Net Combusted by Renewable Energy (not WTE) in tons is entered in item 8.
9) Recycling data (in tons) is entered into items 9-27. The sum total is added in item 29.
10) Item 29 is the reported tonnage total (sum of landfilled, combusted (WTE and Renewable Energy), and recycled).
13) For the number entered in item 23 for recycled C&D debris, please enter the material breakdown based on the categories in items 30-34.
11) Enter a previous year in item 36 where you are interested in the source reduced mass relative to the year entered in item 2. The year in item 36 must be less than the year in item 2.
12) Enter the collected data (in tons) in items 37-55 corresponding to the year in item 35.
13) Enter donated data (in tons) into items 56-60.

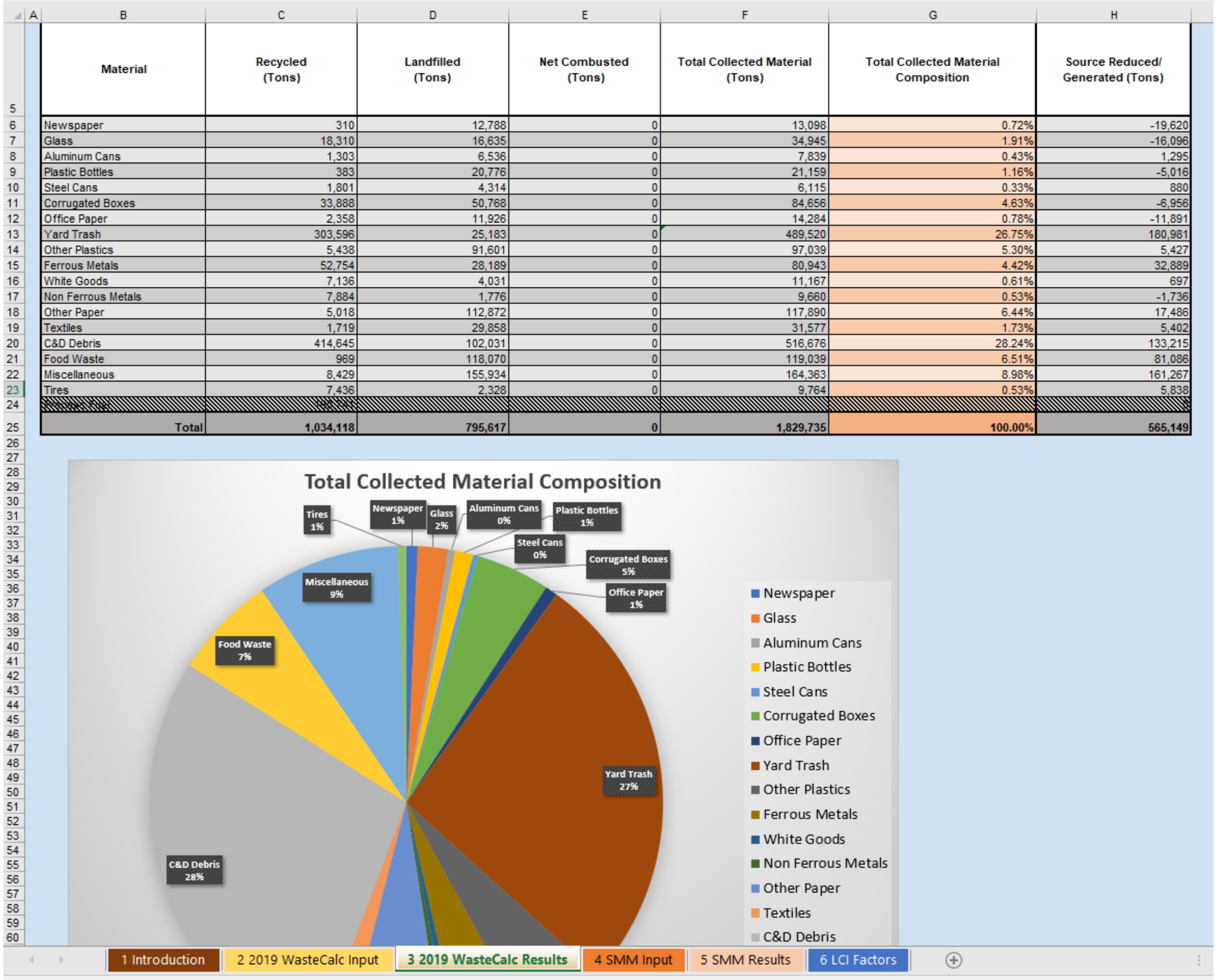
Item #	**2019 WasteCalc**	
1	Data Year (LOCKED):	2017
2	Current Year:	2019
3	Select County:	Brevard
4	Enter County Population:	594,259
5	MSW Landfilled (in tons)	795,617
6	Collected C&D (in tons)	457,800
7	MSW Net Combusted by WTE (in tons)	
8	MSW Net Combusted by Renewable Energy (not WTE) (in tons)	
	Recycling Data (in tons)(from "Recycling Credits")	
9	Newspaper	310
10	Glass	18,310
11	Aluminum Cans	1,303
12	Plastic Bottles	383
13	Steel Cans	1,801
14	Corrugated Boxes	33,888
15	Office Paper	2,358
16	Yard Trash	303,596
17	Other Plastics	5,438
18	Ferrous Metals	52,754

Figure A2. Screenshot of the Tab 2 2019 WasteCalc Input in the 2021 SMM Tool which shows the original WasteCalc inputs.



B	D	E
28	*TOTAL RECYCLED TONNAGE*	*1,034,118*
29	*Reported Total (in tons)*	*1,829,735*
	Recyled C&D Debris Breakdown Mass Data (in tons)	
30	Wood Products	
31	Asphalt Shingles	
32	Gypsum Drywall	
33	Concrete	
34	Reclaimed Asphalt Pavement	
35	Other C&D (LOCKED)	414,645
	Collected Mass Data (in tons)(from older reports)	
36	Previous Year:	**2013**
37	Newspaper	32,718
38	Glass	51,041
39	Aluminum Cans	6,544
40	Plastic Bottles	26,175
41	Steel Cans	5,235
42	Corrugated Boxes	91,612
43	Office Paper	26,175
44	Yard Trash	308,539
45	Other Plastics	91,612
46	Ferrous Metals	48,054
47	White Goods	10,470
48	Non Ferrous Metals	11,396
49	Other Paper	100,404
50	Textiles	26,175
51	C&D Debris	383,461
52	Food Waste	37,953
53	Miscellaneous	3,096
54	Tires	3,926
55	Process Fuel	-
	Donated (in tons)	
56	Textiles (e.g., clothing and footwear)	2,000
57	Furniture	2,000
58	Electronics (e.g., white goods, phones, computers, small appliances)	2,000
59	Food	2,000
60	Books (e.g., textbooks, paper-back books, hard-back books)	2,000

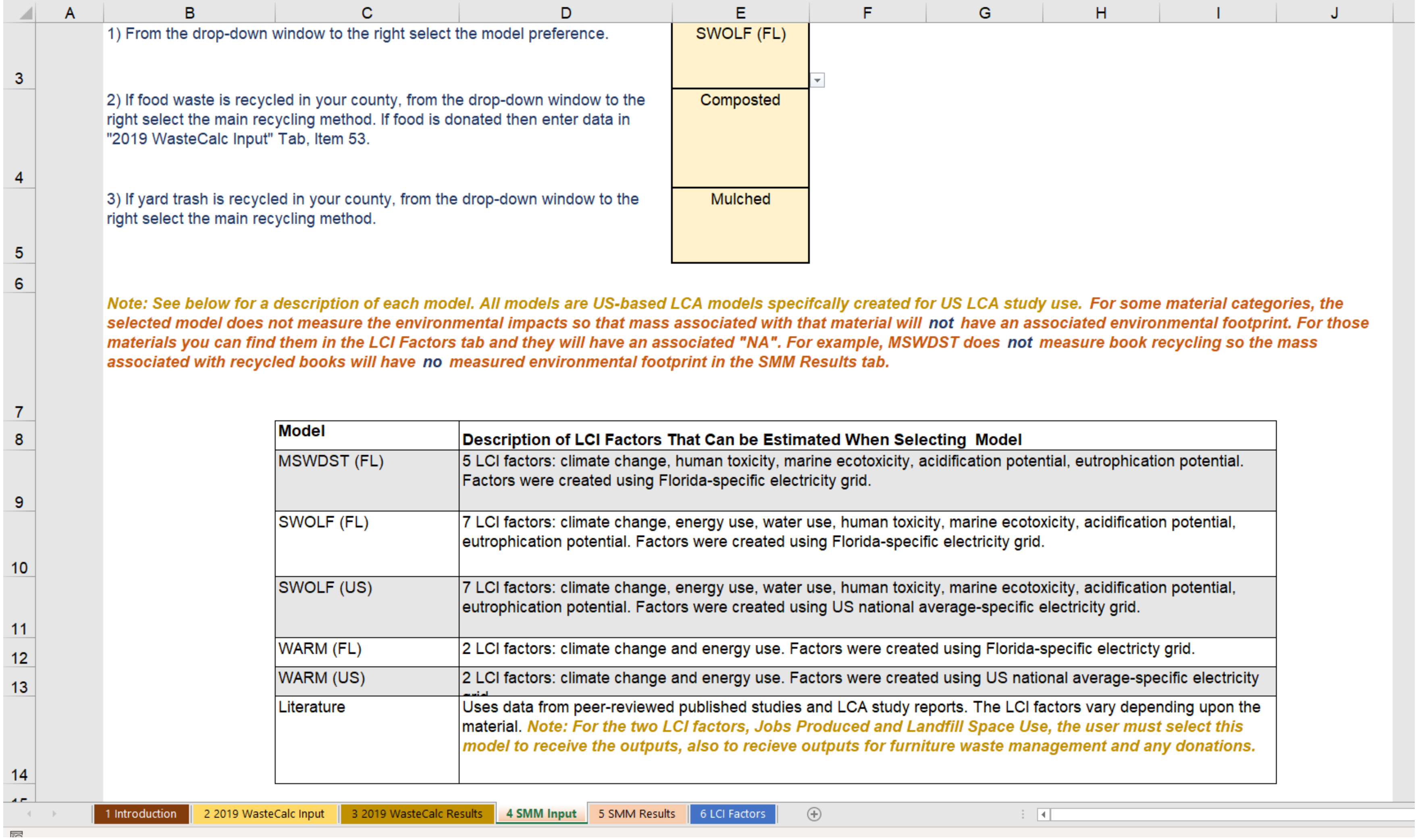
Figure A3. Screenshot of the Tab 2 2019 WasteCalc Input in the 2021 SMM Tool which shows the new refinements to the WasteCalc inputs.



Material	Recycled (Tons)	Landfilled (Tons)	Net Combusted (Tons)	Total Collected Material (Tons)	Total Collected Material Composition	Source Reduced/ Generated (Tons)
Newspaper	310	12,788	0	13,098	0.72%	-19,620
Glass	18,310	16,635	0	34,945	1.91%	-16,096
Aluminum Cans	1,303	6,536	0	7,839	0.43%	1,295
Plastic Bottles	383	20,776	0	21,159	1.16%	-5,016
Steel Cans	1,801	4,314	0	6,115	0.33%	880
Corrugated Boxes	33,888	50,768	0	84,656	4.63%	-6,956
Office Paper	2,358	11,926	0	14,284	0.78%	-11,891
Yard Trash	303,596	25,183	0	489,520	26.75%	180,981
Other Plastics	5,438	91,601	0	97,039	5.30%	5,427
Ferrous Metals	52,754	28,189	0	80,943	4.42%	32,889
White Goods	7,136	4,031	0	11,167	0.61%	697
Non Ferrous Metals	7,884	1,776	0	9,660	0.53%	-1,736
Other Paper	5,018	112,872	0	117,890	6.44%	17,486
Textiles	1,719	29,858	0	31,577	1.73%	5,402
C&D Debris	414,645	102,031	0	516,676	28.24%	133,215
Food Waste	969	118,070	0	119,039	6.51%	81,086
Miscellaneous	8,429	155,934	0	164,363	8.98%	161,267
Tires	7,436	2,328	0	9,764	0.53%	5,838
Process Fuel	[illegible]					[illegible]
Total	1,034,118	795,617	0	1,829,735	100.00%	565,149

Total Collected Material Composition

Figure A4. Screenshot of the Tab 3 2019 WasteCalc Results in the 2021 SMM Tool which shows the original results and the new refinements to the WasteCalc outputs.



1) From the drop-down window to the right select the model preference. — SWOLF (FL)

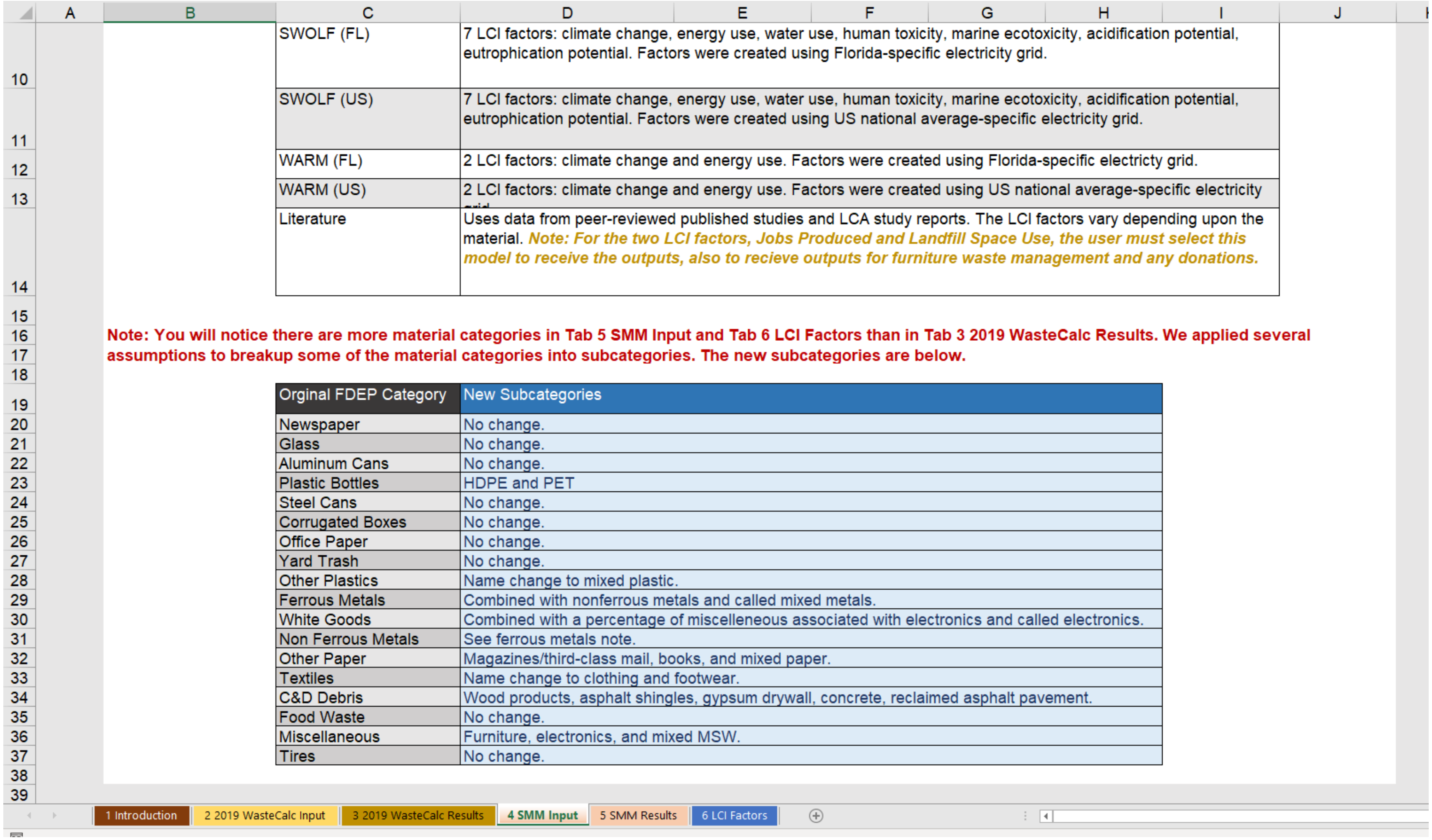
2) If food waste is recycled in your county, from the drop-down window to the right select the main recycling method. If food is donated then enter data in "2019 WasteCalc Input" Tab, Item 53. — Composted

3) If yard trash is recycled in your county, from the drop-down window to the right select the main recycling method. — Mulched

Note: See below for a description of each model. All models are US-based LCA models specfcally created for US LCA study use. For some material categories, the selected model does not measure the environmental impacts so that mass associated with that material will not have an associated environmental footprint. For those materials you can find them in the LCI Factors tab and they will have an associated "NA". For example, MSWDST does not measure book recycling so the mass associated with recycled books will have no measured environmental footprint in the SMM Results tab.

Model	**Description of LCI Factors That Can be Estimated When Selecting Model**
MSWDST (FL)	5 LCI factors: climate change, human toxicity, marine ecotoxicity, acidification potential, eutrophication potential. Factors were created using Florida-specific electricity grid.
SWOLF (FL)	7 LCI factors: climate change, energy use, water use, human toxicity, marine ecotoxicity, acidification potential, eutrophication potential. Factors were created using Florida-specific electricity grid.
SWOLF (US)	7 LCI factors: climate change, energy use, water use, human toxicity, marine ecotoxicity, acidification potential, eutrophication potential. Factors were created using US national average-specific electricity grid.
WARM (FL)	2 LCI factors: climate change and energy use. Factors were created using Florida-specific electricty grid.
WARM (US)	2 LCI factors: climate change and energy use. Factors were created using US national average-specific electricity
Literature	Uses data from peer-reviewed published studies and LCA study reports. The LCI factors vary depending upon the material. ***Note: For the two LCI factors, Jobs Produced and Landfill Space Use, the user must select this model to receive the outputs, also to recieve outputs for furniture waste management and any donations.***

Figure A5. Screenshot of the Tab 4 SMM Input in the 2021 SMM Tool which shows the new refinements developed from this project based on the HC18/19 Tool *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020).

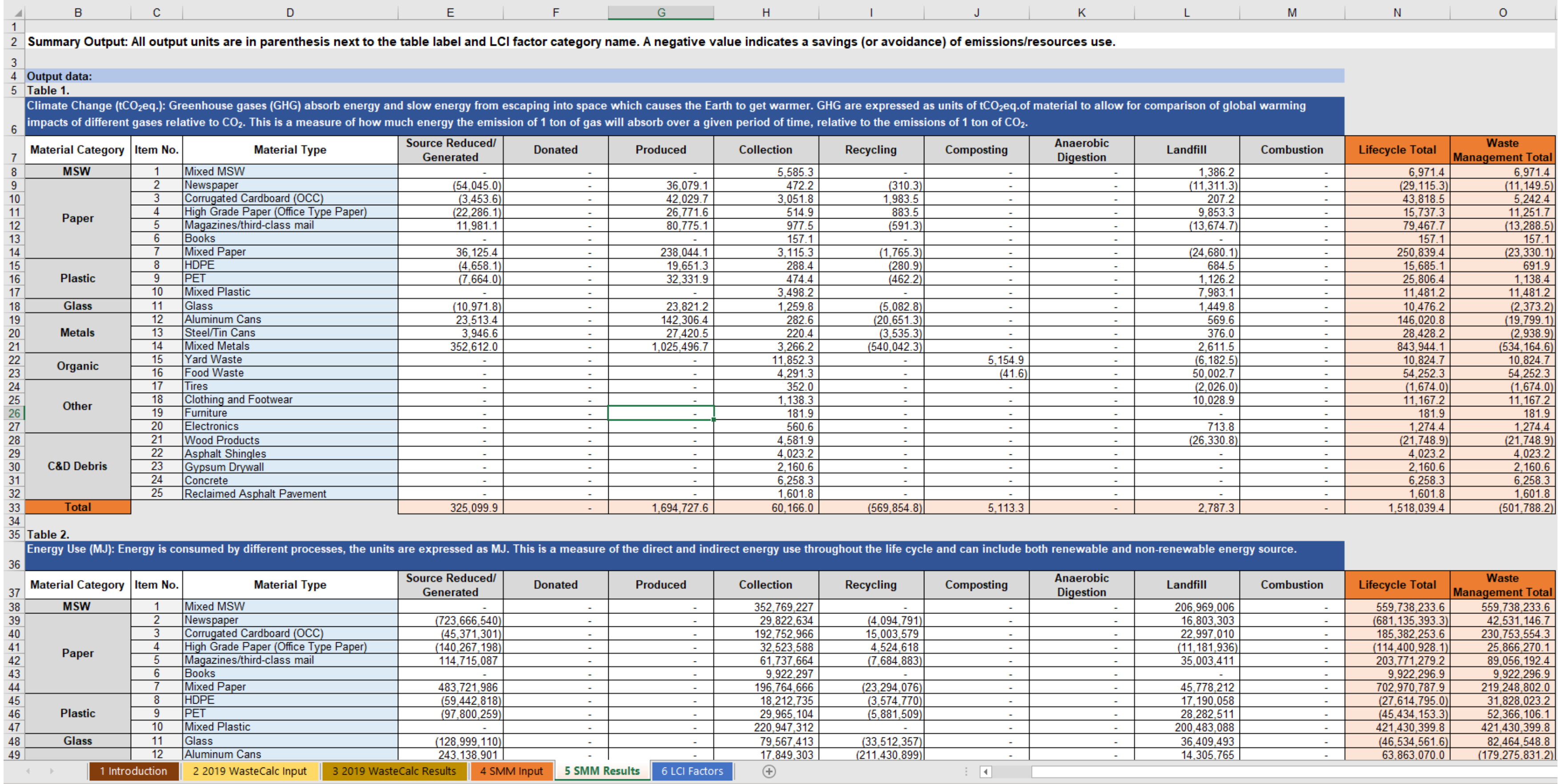


SWOLF (FL)	7 LCI factors: climate change, energy use, water use, human toxicity, marine ecotoxicity, acidification potential, eutrophication potential. Factors were created using Florida-specific electricity grid.
SWOLF (US)	7 LCI factors: climate change, energy use, water use, human toxicity, marine ecotoxicity, acidification potential, eutrophication potential. Factors were created using US national average-specific electricity grid.
WARM (FL)	2 LCI factors: climate change and energy use. Factors were created using Florida-specific electricty grid.
WARM (US)	2 LCI factors: climate change and energy use. Factors were created using US national average-specific electricity
Literature	Uses data from peer-reviewed published studies and LCA study reports. The LCI factors vary depending upon the material. ***Note: For the two LCI factors, Jobs Produced and Landfill Space Use, the user must select this model to receive the outputs, also to recieve outputs for furniture waste management and any donations.***

Note: You will notice there are more material categories in Tab 5 SMM Input and Tab 6 LCI Factors than in Tab 3 2019 WasteCalc Results. We applied several assumptions to breakup some of the material categories into subcategories. The new subcategories are below.

Orginal FDEP Category	New Subcategories
Newspaper	No change.
Glass	No change.
Aluminum Cans	No change.
Plastic Bottles	HDPE and PET
Steel Cans	No change.
Corrugated Boxes	No change.
Office Paper	No change.
Yard Trash	No change.
Other Plastics	Name change to mixed plastic.
Ferrous Metals	Combined with nonferrous metals and called mixed metals.
White Goods	Combined with a percentage of miscelleneous associated with electronics and called electronics.
Non Ferrous Metals	See ferrous metals note.
Other Paper	Magazines/third-class mail, books, and mixed paper.
Textiles	Name change to clothing and footwear.
C&D Debris	Wood products, asphalt shingles, gypsum drywall, concrete, reclaimed asphalt pavement.
Food Waste	No change.
Miscellaneous	Furniture, electronics, and mixed MSW.
Tires	No change.

Figure A6. Screenshot of the Tab 4 SMM Input in the 2021 SMM Tool which shows the new material categories developed from this project (see Figure A5 too).



Summary Output: All output units are in parenthesis next to the table label and LCI factor category name. A negative value indicates a savings (or avoidance) of emissions/resources use.

Output data:

Table 1.

Climate Change ($tCO_2eq.$): Greenhouse gases (GHG) absorb energy and slow energy from escaping into space which causes the Earth to get warmer. GHG are expressed as units of $tCO_2eq.$of material to allow for comparison of global warming impacts of different gases relative to CO_2. This is a measure of how much energy the emission of 1 ton of gas will absorb over a given period of time, relative to the emissions of 1 ton of CO_2.

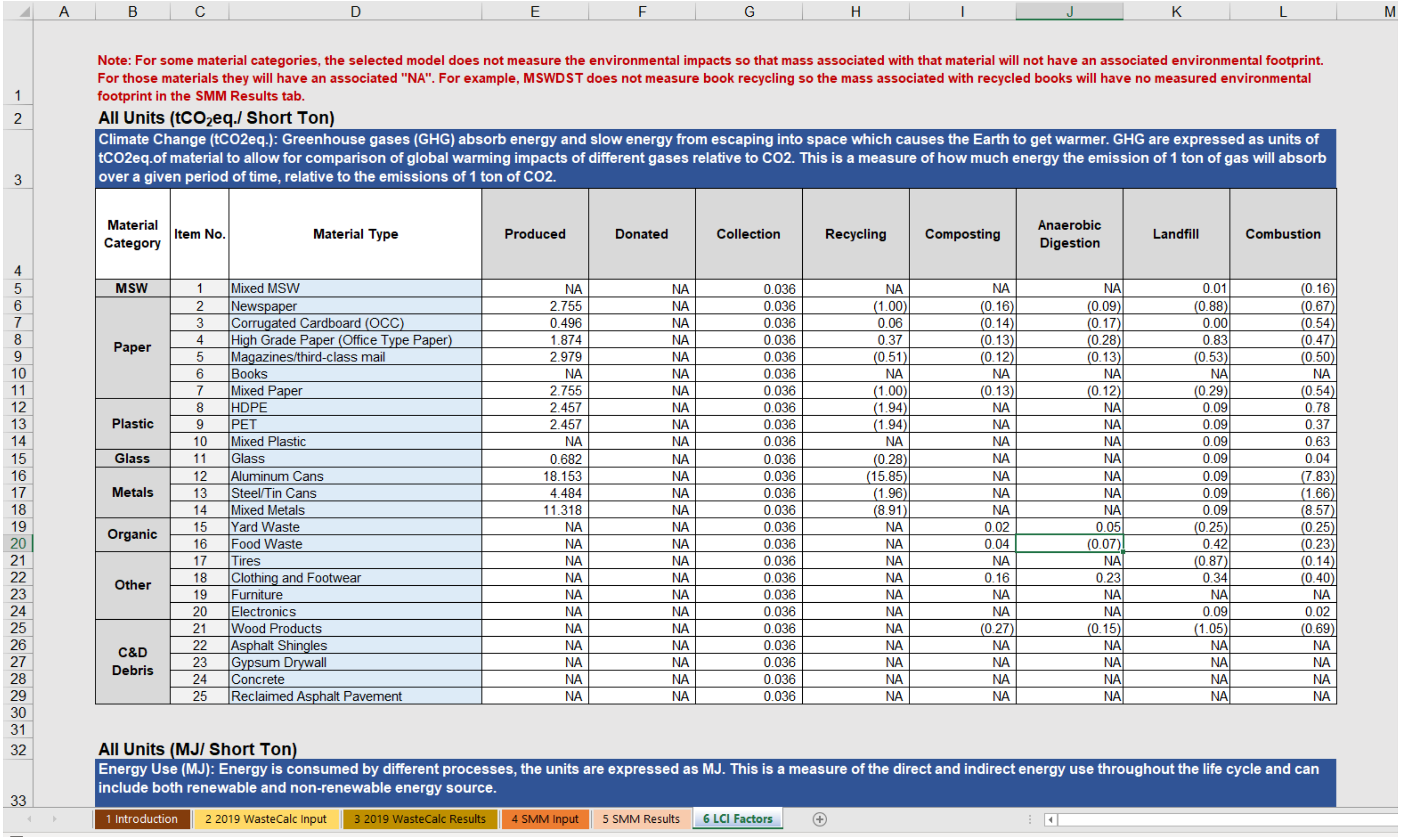
Material Category	Item No.	Material Type	Source Reduced/ Generated	Donated	Produced	Collection	Recycling	Composting	Anaerobic Digestion	Landfill	Combustion	Lifecycle Total	Waste Management Total
MSW	1	Mixed MSW	-	-	-	5,585.3	-	-	-	1,386.2	-	6,971.4	6,971.4
Paper	2	Newspaper	(54,045.0)	-	36,079.1	472.2	(310.3)	-	-	(11,311.3)	-	(29,115.3)	(11,149.5)
	3	Corrugated Cardboard (OCC)	(3,453.6)	-	42,029.7	3,051.8	1,983.5	-	-	207.2	-	43,818.5	5,242.4
	4	High Grade Paper (Office Type Paper)	(22,286.1)	-	26,771.6	514.9	883.5	-	-	9,853.3	-	15,737.3	11,251.7
	5	Magazines/third-class mail	11,981.1	-	80,775.1	977.5	(591.3)	-	-	(13,674.7)	-	79,467.7	(13,288.5)
	6	Books	-	-	-	157.1	-	-	-	-	-	157.1	157.1
	7	Mixed Paper	36,125.4	-	238,044.1	3,115.3	(1,765.3)	-	-	(24,680.1)	-	250,839.4	(23,330.1)
Plastic	8	HDPE	(4,658.1)	-	19,651.3	288.4	(280.9)	-	-	684.5	-	15,685.1	691.9
	9	PET	(7,664.0)	-	32,331.9	474.4	(462.2)	-	-	1,126.2	-	25,806.4	1,138.4
	10	Mixed Plastic	-	-	-	3,498.2	-	-	-	7,983.1	-	11,481.2	11,481.2
Glass	11	Glass	(10,971.8)	-	23,821.2	1,259.8	(5,082.8)	-	-	1,449.8	-	10,476.2	(2,373.2)
Metals	12	Aluminum Cans	23,513.4	-	142,306.4	282.6	(20,651.3)	-	-	569.6	-	146,020.8	(19,799.1)
	13	Steel/Tin Cans	3,946.6	-	27,420.5	220.4	(3,535.3)	-	-	376.0	-	28,428.2	(2,938.9)
	14	Mixed Metals	352,612.0	-	1,025,496.7	3,266.2	(540,042.3)	-	-	2,611.5	-	843,944.1	(534,164.6)
Organic	15	Yard Waste	-	-	-	11,852.3	-	5,154.9	-	(6,182.5)	-	10,824.7	10,824.7
	16	Food Waste	-	-	-	4,291.3	-	(41.6)	-	50,002.7	-	54,252.3	54,252.3
Other	17	Tires	-	-	-	352.0	-	-	-	(2,026.0)	-	(1,674.0)	(1,674.0)
	18	Clothing and Footwear	-	-	-	1,138.3	-	-	-	10,028.9	-	11,167.2	11,167.2
	19	Furniture	-	-	-	181.9	-	-	-	-	-	181.9	181.9
	20	Electronics	-	-	-	560.6	-	-	-	713.8	-	1,274.4	1,274.4
C&D Debris	21	Wood Products	-	-	-	4,581.9	-	-	-	(26,330.8)	-	(21,748.9)	(21,748.9)
	22	Asphalt Shingles	-	-	-	4,023.2	-	-	-	-	-	4,023.2	4,023.2
	23	Gypsum Drywall	-	-	-	2,160.6	-	-	-	-	-	2,160.6	2,160.6
	24	Concrete	-	-	-	6,258.3	-	-	-	-	-	6,258.3	6,258.3
	25	Reclaimed Asphalt Pavement	-	-	-	1,601.8	-	-	-	-	-	1,601.8	1,601.8
Total			325,099.9	-	1,694,727.6	60,166.0	(569,854.8)	5,113.3	-	2,787.3	-	1,518,039.4	(501,788.2)

Table 2.

Energy Use (MJ): Energy is consumed by different processes, the units are expressed as MJ. This is a measure of the direct and indirect energy use throughout the life cycle and can include both renewable and non-renewable energy source.

Material Category	Item No.	Material Type	Source Reduced/ Generated	Donated	Produced	Collection	Recycling	Composting	Anaerobic Digestion	Landfill	Combustion	Lifecycle Total	Waste Management Total
MSW	1	Mixed MSW	-	-	-	352,769,227	-	-	-	206,969,006	-	559,738,233.6	559,738,233.6
Paper	2	Newspaper	(723,666,540)	-	-	29,822,634	(4,094,791)	-	-	16,803,303	-	(681,135,393.3)	42,531,146.7
	3	Corrugated Cardboard (OCC)	(45,371,301)	-	-	192,752,966	15,003,579	-	-	22,997,010	-	185,382,253.6	230,753,554.3
	4	High Grade Paper (Office Type Paper)	(140,267,198)	-	-	32,523,588	4,524,618	-	-	(11,181,936)	-	(114,400,928.1)	25,866,270.1
	5	Magazines/third-class mail	114,715,087	-	-	61,737,664	(7,684,883)	-	-	35,003,411	-	203,771,279.2	89,056,192.4
	6	Books	-	-	-	9,922,297	-	-	-	-	-	9,922,296.9	9,922,296.9
	7	Mixed Paper	483,721,986	-	-	196,764,666	(23,294,076)	-	-	45,778,212	-	702,970,787.9	219,248,802.0
Plastic	8	HDPE	(59,442,818)	-	-	18,212,735	(3,574,770)	-	-	17,190,058	-	(27,614,795.0)	31,828,023.2
	9	PET	(97,800,259)	-	-	29,965,104	(5,881,509)	-	-	28,282,511	-	(45,434,153.3)	52,366,106.1
	10	Mixed Plastic	-	-	-	220,947,312	-	-	-	200,483,088	-	421,430,399.8	421,430,399.8
Glass	11	Glass	(128,999,110)	-	-	79,567,413	(33,512,357)	-	-	36,409,493	-	(46,534,561.6)	82,464,548.8
	12	Aluminum Cans	243,138,901	-	-	17,849,303	(211,430,899)	-	-	14,305,765	-	63,863,070.0	(179,275,831.2)

Figure A7. Screenshot of part of the Tab 5 SMM Results in the 2021 SMM Tool which shows the new outputs developed from this project based on the HC18/19 Tool from the previous project *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020).



Note: For some material categories, the selected model does not measure the environmental impacts so that mass associated with that material will not have an associated environmental footprint. For those materials they will have an associated "NA". For example, MSWDST does not measure book recycling so the mass associated with recycled books will have no measured environmental footprint in the SMM Results tab.

All Units ($tCO_2eq.$/ Short Ton)

Climate Change (tCO2eq.): Greenhouse gases (GHG) absorb energy and slow energy from escaping into space which causes the Earth to get warmer. GHG are expressed as units of tCO2eq.of material to allow for comparison of global warming impacts of different gases relative to CO2. This is a measure of how much energy the emission of 1 ton of gas will absorb over a given period of time, relative to the emissions of 1 ton of CO2.

Material Category	Item No.	Material Type	Produced	Donated	Collection	Recycling	Composting	Anaerobic Digestion	Landfill	Combustion
MSW	1	Mixed MSW	NA	NA	0.036	NA	NA	NA	0.01	(0.16)
Paper	2	Newspaper	2.755	NA	0.036	(1.00)	(0.16)	(0.09)	(0.88)	(0.67)
	3	Corrugated Cardboard (OCC)	0.496	NA	0.036	0.06	(0.14)	(0.17)	0.00	(0.54)
	4	High Grade Paper (Office Type Paper)	1.874	NA	0.036	0.37	(0.13)	(0.28)	0.83	(0.47)
	5	Magazines/third-class mail	2.979	NA	0.036	(0.51)	(0.12)	(0.13)	(0.53)	(0.50)
	6	Books	NA	NA	0.036	NA	NA	NA	NA	NA
	7	Mixed Paper	2.755	NA	0.036	(1.00)	(0.13)	(0.12)	(0.29)	(0.54)
Plastic	8	HDPE	2.457	NA	0.036	(1.94)	NA	NA	0.09	0.78
	9	PET	2.457	NA	0.036	(1.94)	NA	NA	0.09	0.37
	10	Mixed Plastic	NA	NA	0.036	NA	NA	NA	0.09	0.63
Glass	11	Glass	0.682	NA	0.036	(0.28)	NA	NA	0.09	0.04
Metals	12	Aluminum Cans	18.153	NA	0.036	(15.85)	NA	NA	0.09	(7.83)
	13	Steel/Tin Cans	4.484	NA	0.036	(1.96)	NA	NA	0.09	(1.66)
	14	Mixed Metals	11.318	NA	0.036	(8.91)	NA	NA	0.09	(8.57)
Organic	15	Yard Waste	NA	NA	0.036	NA	0.02	0.05	(0.25)	(0.25)
	16	Food Waste	NA	NA	0.036	NA	0.04	(0.07)	0.42	(0.23)
Other	17	Tires	NA	NA	0.036	NA	NA	NA	(0.87)	(0.14)
	18	Clothing and Footwear	NA	NA	0.036	NA	0.16	0.23	0.34	(0.40)
	19	Furniture	NA	NA	0.036	NA	NA	NA	NA	NA
	20	Electronics	NA	NA	0.036	NA	NA	NA	0.09	0.02
C&D Debris	21	Wood Products	NA	NA	0.036	NA	(0.27)	(0.15)	(1.05)	(0.69)
	22	Asphalt Shingles	NA	NA	0.036	NA	NA	NA	NA	NA
	23	Gypsum Drywall	NA	NA	0.036	NA	NA	NA	NA	NA
	24	Concrete	NA	NA	0.036	NA	NA	NA	NA	NA
	25	Reclaimed Asphalt Pavement	NA	NA	0.036	NA	NA	NA	NA	NA

All Units (MJ/ Short Ton)

Energy Use (MJ): Energy is consumed by different processes, the units are expressed as MJ. This is a measure of the direct and indirect energy use throughout the life cycle and can include both renewable and non-renewable energy source.

Figure A8. Screenshot of part of the Tab 6 LCI Factors in the 2021 SMM Tool which shows the new factors developed from this project based on the HC18/19 Tool from the previous project *Looking Beyond Florida's 75% Recycling Goal: Development of a Methodology and Tool for Assessing Sustainable Materials Management Recycling Rates in Florida* (University of Florida, 2020).

Table A1. Data collected from literature for the creation of produced impact factors are discussed in Section 5.4.5.1.

Product	tCO$_2$eq/ton	MJ/ton	Gals Water/ton	CTUh/ton	CTUe/ton	kgNeq/ton	kgSO$_2$eq./ton	Source
Major Appliances								
Refrigerator	5.43	375,555				45	35	(Baxter, 2019)
Walk-in cold room	3.83							(Cascini et al., 2016)
Refrigerator	3.45							(Japan Electrical Manufacturer's Association, 2014)
Washing machine		51,275						(Ciceri et al., 2010)
Refrigerator		47,198						(Ciceri et al., 2010)
Washing machine	3.89	53,536						(WRAP, 2010)
Refrigerator		55,998						(Gonzalez et al., 2012)
Dishwasher		75,997						(Gonzalez et al., 2012)
Washing machine		52,589						(Gonzalez et al., 2012)
Small Appliances								
Electric drill	6.03							(WRAP, 2010)
Vacuum cleaner	4.33	92,945						(Bobba et al., 2015)
Hair dryer		71,757						(Ciceri et al., 2010)
Coffee maker		83,460						(Ciceri et al., 2010)
Furniture								
Office cabinet	1.65		439	4.3E-04	21891.24	2.45	2.4E-03	(Medeiros et al., 2017)
Office chair	1.60	18,929					1.2E-04	(Spitzley et al., 2006)
Office desk	0.74	11,770					7.0E-05	(Spitzley et al., 2006)
Office table	1.72	25,729					1.5E-04	(Spitzley et al., 2006)
Office work surface	2.09	35,243						(Dietz, 2005)
Office lateral file	2.91	32,084						(Dietz, 2005)
Office panel	3.61	58,840						(Dietz, 2005)
Plastic resin set of outdoor furniture	2.31							(Project Learning Tree, 2020)
Cast aluminum set of outdoor furniture	6.13							(Project Learning Tree, 2020)
Pine set of outdoor furniture	0.27							(Project Learning Tree, 2020)
Wardrobe	1.03	1,178				0.71	5.26	(Iritani et al., 2015)
Wardrobe - enchosed space	0.51	13,608						(Wenker et al., 2018)
Wardrobe - surface area	0.76	24,131						(Wenker et al., 2018)
Wooden playground	1.27							(Gonzalez et al., 2012)
Corversible cot into childhood bed	0.73							(Gonzalez et al., 2012)
Kitchen cabinet	2.97							(Gonzalez et al., 2012)
Office table	4.39							(Gonzalez et al., 2012)
Living room furniture	1.37							(Gonzalez et al., 2012)
Headboard	2.20							(Gonzalez et al., 2012)
Youth room accessories	0.80							(Gonzalez et al., 2012)
Wine crate	0.39							(Gonzalez et al., 2012)
Wooden modular playground	1.31							(Gonzalez et al., 2012)

Ventilated wooden wall	0.49						(Gonzalez et al., 2012)
Office chair	2.06						(Linkosalmi et al., 2016)
Student chair	2.67						(Linkosalmi et al., 2016)
Public space chair 1	3.66						(Linkosalmi et al., 2016)
Public space chair 2	2.80						(Linkosalmi et al., 2016)
Public space chair 3	2.83						(Linkosalmi et al., 2016)
Public space chair 4	1.42						(Linkosalmi et al., 2016)
Student desk 1	2.87						(Linkosalmi et al., 2016)
Student desk 2	2.72						(Linkosalmi et al., 2016)
Office desk	1.87						(Linkosalmi et al., 2016)
Office cabinet	1.35						(Linkosalmi et al., 2016)
Kitchen cabinet 1	1.40						(Linkosalmi et al., 2016)
Kitchen cabinet 2	1.36						(Linkosalmi et al., 2016)
Clothing							
T-shirt	0.66	14,845	871,281	1.3E-06	82.45		(Sandin et al., 2019)
Jeans	0.10	1,902	115,531	8.0E-07	950.73		(Sandin et al., 2019)
Dress	1.23	22,395	75,189	2.8E-07	24667.36		(Sandin et al., 2019)
Jacket	0.29	4,291	43,172	5.5E-07	408.56	0.33	(Sandin et al., 2019)
Socks	0.84	21,097	55,721	2.1E-07	421.86		(Sandin et al., 2019)
Hospital Uniform	0.32	11,206	211,414	9.9E-07	2667.65	1.04	(Sandin et al., 2019)
Wool sweater	0.54	2,873	694,846				(Wiedemann et al., 2020)
Electronics							
Desktop Computer (no display)	26.32						(Teehan and Kandlikar, 2013)
Desktop Computer (no display)	13.90						(Teehan and Kandlikar, 2013)
Desktop Computer (no display)	22.38						(Teehan and Kandlikar, 2013)
Desktop Computer (no display)	23.73						(Teehan and Kandlikar, 2013)
Laptop computer	70.38						(Teehan and Kandlikar, 2013)
Laptop computer	34.99						(Teehan and Kandlikar, 2013)
Laptop computer	43.27						(Teehan and Kandlikar, 2013)
Display	52.83						(Teehan and Kandlikar, 2013)
Display	29.88						(Teehan and Kandlikar, 2013)
Ipad	30.24						(Teehan and Kandlikar, 2013)
Ipod	36.29						(Teehan and Kandlikar, 2013)
Kindle	36.85						(Teehan and Kandlikar, 2013)
Server	22.42						(Teehan and Kandlikar, 2013)
Network	39.74						(Teehan and Kandlikar, 2013)
LCD monitor		67,200					(Ciceri et al., 2010)
Digital copier		138,239					(Ciceri et al., 2010)
Laptop computer	27.22	420,321					(WRAP, 2010)