Memorandum

BURNS McDONNELL

Date: August 22, 2019

To: Mr. Steve Hunt, PE, City of Columbia, MO
Mr. Adam White, City of Columbia, MO
Mr. David Sorrell, PE, City of Columbia, MO

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Subject: Organic Waste Management Study, Revision #1

STATE OF MISSOURI
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Burns & McDonnell Engineering Company, Inc. (Burns & McDonnell) has conducted a preliminary study of options for the City of Columbia (City) to manage organic waste (OW). OW from the municipal solid waste stream consists mostly of food waste, wood waste, and yard waste. Three OW management strategies were evaluated:

1. Continue to landfill integrated OW
2. Increase diversion of OW to expand composting of OW
3. Increase diversion of OW and construct an anaerobic digester to process OW

The option of incineration was considered but dismissed due to permitting uncertainties and the lack of any beneficial utilization of the OW. This option is not consistent with resource recovery goals adopted by the City and therefore was not evaluated as part of this study.

Factors considered for the OW strategies include:

- Airspace and long-term liability;
- Energy production potential;
- Potential greenhouse gas (GHG) emissions and other potential environmental impacts;
- Cost and revenue implications; and
- Other ancillary benefits, drawbacks, or considerations.

Further evaluation of certain factors may be warranted at the discretion of the City.

This Revision supersedes the initial issue of this Study, dated March 22, 2019.

EXISTING CONDITIONS

Waste Streams and Composition

Burns & McDonnell assessed OW and the overall waste streams being managed by the City. Data provided by the City for 2018 is summarized below:

- 224,759 tons of municipal solid waste (MSW) was landfilled, including integrated OW;
- 14,647 tons of material (not OW) was recycled at the Materials Recovery Facility (MRF);
- 5,055 tons* of yard waste (OW) was collected separately and diverted for composting;
- 900 tons of food waste (OW) was collected separately and diverted for composting;

- This quantity represents approx. 1/3 of maximum allowable food waste in the City's compost recipe, given the current volume of compost produced.
- Overall 20,600 tons of waste was diverted from the Landfill (approx. 8.4%).

  *A portion of the mulched yard waste (13,500 cubic yards) was used as landfill daily cover, to reduce soil volume in the landfill and improve long term landfill gas production.

A statewide waste composition study (published January 5, 2018) was prepared for the Missouri Department of Natural Resources (MDNR) using data collected from all MSW landfills in Missouri from 2016-2017. The study sorted and quantified the different types of waste in tonnages and as a percentage of total waste, as well as categorized whether the source was residential or commercial. This study is considered representative of the MSW disposed at the Columbia Landfill. Figure 1 shows a clip of the published results for the Columbia Landfill.

Figure 1: Columbia Sanitary Landfill Detailed MSW Composition[1]

Material Category	Est. Percent	Conf. Int (+/-)	Tonnage	Material Category	Est. Percent	Conf. Int (+/-)	Tonnage
Paper	**23.2%**	**3.5%**	**41,720**	**Plastic**	**13.2%**	**1.7%**	**23,820**
OCC/Kraft Paper	7.4%	2.6%	13,304	PET (#1) Bottles/Jars	1.4%	0.4%	2,589
Newsprint	0.7%	0.3%	1,332	PET (#1) Non-Bottle containers	0.3%	0.1%	595
Magazines	1.4%	0.7%	2,485	HDPE (#2) Natural Containers	0.4%	0.1%	669
High Grade Office Paper	1.2%	0.7%	2,240	HDPE (#2) Colored Containers	0.5%	0.2%	835
Mixed Recyclable Paper	3.4%	0.8%	6,112	Clean Film Bags	0.3%	0.1%	536
Compostable Paper	7.4%	1.5%	13,408	Clean Indust'l/Com'l Film	0.1%	0.1%	249
Remainder/Composite Paper	1.6%	0.8%	2,839	Contaminated Film/Other Film	5.2%	1.0%	9,337
Glass	**2.5%**	**0.7%**	**4,506**	Plastic Containers #3 thru #7	0.6%	0.2%	1,106
Clear Glass Containers	1.0%	0.3%	1,777	Expanded Polystyrene #6	0.7%	0.2%	1,306
Brown Glass Containers	1.0%	0.4%	1,803	Bulky Durable Plastic Products	1.9%	0.8%	3,358
Green Glass Containers	0.2%	0.1%	352	Remainder/Composite Plastic	1.8%	0.4%	3,239
Remainder/Composite Glass	0.3%	0.2%	574	**Textiles**	**4.0%**	**1.3%**	**7,231**
Metal	**4.7%**	**1.6%**	**8,377**	Textiles - Clothing	1.0%	0.5%	1,748
Aluminum Cans & Containers	0.4%	0.1%	774	Textiles - Non-Clothing	2.2%	1.0%	4,006
Other Aluminum	0.3%	0.1%	573	Shoes/Belts/Leather	0.8%	0.5%	1,477
Tin/Steel Containers	1.0%	0.2%	1,740	**Inorganics**	**12.1%**	**3.4%**	**21,706**
Other Ferrous - Magnetic	2.7%	1.6%	4,905	Fines	1.9%	0.9%	3,431
Other Non-Ferrous	0.1%	0.0%	127	Drywall/Gypsum Board	0.7%	0.9%	1,198
Oil Filters	0.1%	0.1%	257	Asphalt, Brick, Concrete & Rock	0.8%	0.9%	1,386
Organics	**38.5%**	**5.1%**	**69,334**	Carpet & Carpet Padding	3.1%	2.5%	5,566
Food Waste	17.8%	4.4%	31,977	Other Construction & Demolitior	1.9%	1.3%	3,458
Wood - Clean/Untreated	5.4%	3.6%	9,679	Bulky Items/Furniture	0.7%	0.7%	1,208
Wood - Painted/Stained/Treate	4.4%	1.8%	7,974	Mattresses/Boxsprings	0.4%	0.6%	674
Diapers/Sanitary Products	2.2%	0.8%	3,905	Tires	2.0%	1.7%	3,527
Yard Waste	4.3%	3.4%	7,698	Other/Not Classified	0.7%	0.5%	1,259
Remainder/Composite Organic	4.5%	2.1%	8,102	**HHW**	**0.2%**	**0.1%**	**363**
Electronics	**1.6%**	**2.3%**	**2,921**	Household Hazardous Waste	0.2%	0.1%	363
Electronic Waste	1.6%	1.5%	2,921	**Grand Total**	**100%**		
				No. of Samples	***26***		

Confidence intervals calculated at the 90% confidence level. Percentages for materials may not exactly equal category subtotals due to rounding.

[1] Statewide Waste Composition Study – Final Report. (2018, January). Retrieved from https://dnr.mo.gov/env/swmp/docs/20162017wastesortcharreport.pdf

Collections

The City's fleet currently collects all residential and a portion of commercial waste within the City limits. MSW from outside City limits is collected by independent haulers and may be disposed of at the Columbia landfill or other facility. As apparent from Figure 1, the MSW collected has OW integrated throughout (not separated). The City currently does not offer city-wide separate collection of OW. The food waste being composted currently is collected from area grocery stores and large cafeterias, separately from MSW collection trucks. The City is considering expanding separate food waste collection to include restaurants in the downtown district. From discussions with the City, this expansion would approximately double separated food waste (an additional 900 tons per year).

Potential Additional Organic Waste Diversion

From the statewide study, the largest single type of waste disposed of in the landfill in 2017 was food waste (31,977 tons). Based on the assumptions identified in the composition study, approximately 50% of the waste accepted at the landfill is residential and 50% is commercial. Burns & McDonnell has conducted similar food waste diversion studies for municipalities with similar populations and demographics as the City. Using this experience, it is reasonable to assume 50% of the residential food waste and 30% of the commercial food waste in the landfill waste stream could be separated and diverted from the landfill with a mature source-separated collections program. The table below shows the additional OW that could potentially have been diverted from the landfill in 2017 under these assumptions. Combined, the additional 15,870 tons of OW represents approximately 6.5% of the total waste tonnage. Education and diversion programs could be implemented by the City to potentially increase the percentage of additional OW diverted from the landfill over time, if doing so is thought to be the best apparent option for the City.

Table 1: Potential Additional OW Diversion*

	Residential	**Commercial**	**Residential + Commercial**
Total Food Waste (tons)	15,989	15,988	-
Divertible Food Waste (tons)**	7,994	4,797	12,791
Total Yard Waste (tons)	3,849	3,849	-
Divertible Yard Waste (tons)**	1,924	1,155	3,079
Potential Additional OW Collected (tons)	9,919	5,951	15,870

*Based on 2017 composition study.

**Divertible implies that the waste is separated from MSW and collected at the source.

ORGANIC WASTE MANAGEMENT STRATEGY OPTIONS

1. Continue Landfilling Organic Waste

This strategy generally represents the existing program approach with limited diversion of yard and food wastes, but the majority of these OW materials are disposed of as part of the MSW into the landfill.

Landfilling Decomposition vs. Gas Collection and Control System Installation Timing

Organics degradation is considerably slower in the anaerobic conditions of a landfill (environment lacking free oxygen) when compared with degradation in aerobic conditions (environment containing free oxygen) such as composting. The landfilled waste will begin producing landfill gas (LFG) soon after placement and will increase to moderate production levels after approximately 2 years. A gas collection and control system (GCCS) is typically installed in waste that is at least 2 years old to maximize the amount of LFG captured. The peak generation rate for LFG from typical municipal solid waste occurs approximately 5-7 years after placement[2]. While some decomposition does occur in a landfill prior to the installation of a GCCS, the amount is generally seen as negligible by most industry research.

The City's current practice includes constructing GCCS horizontal collection pipes at various elevation intervals within the landfill cells. This allows early collection of LFG in landfilled waste, as early as 6 months to 1 year after waste placement. For example, the recently constructed Cell 6 incorporated provisions for LFG collection with the construction of the disposal cell (prior to any waste being placed). As cells are brought to intermediate elevations (every 4-6 years), the City installs vertical LFG collection wells to further improve collection efficiency.

Landfill Emissions

The decomposition of municipal solid waste (MSW) under anaerobic (lacking oxygen) conditions produces landfill gas (LFG) approximately 50% methane (CH_4) and 50% carbon dioxide (CO_2) with other compounds present in trace quantities.

Methane is recognized by the USEPA as having a global warming potential (GWP) of 25, meaning methane is approximately 25 times more potent as a greenhouse gas (GHG) than carbon dioxide. When LFG is actively collected by a GCCS and combusted, the methane in the LFG is converted into carbon dioxide and water (water evaporates in process). Therefore, simply by collecting and combusting methane, GHG emissions are greatly

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[2] Cheremisinoff, N. P. (2003) *Handbook of Solid Waste Management and Waste Minimization Technologies.* Burlington, MA. Butterworth-Heinemann/Elsevier Science.

reduced. LFG is also used at the City's LFG to Energy Plant, which serves to displace GHG emissions of fossil fuels, further reducing the overall impact.

A collection efficiency for an average landfill collecting LFG is estimated to be 75%, although intermediate cover operations and GCCS expansion installation phasing, among other factors can increase this collection efficiency. Efficiency rates can be as high as 90-95% with well-maintained cover operations and system maintenance. Additionally, a methane oxidation rate for an average landfill with soil cover is at least 10%[3], meaning 10% of the fugitive methane migrating through a soil cover will be oxidized and converted to carbon dioxide by microorganisms in the soil. The thickness of the cover and moisture content, among other factors, can increase this flux capacity for a landfill, reducing the total GHG emissions for a landfill.

The City's current practice allows for early collection of LFG and GCCS system operation within 2 years of waste placement. It is reasonable to assume, given the City's GCCS practices as well as the ongoing construction of intermediate cover over finished areas, that the City's collection efficiency is in the range of 80-85%.

The Landfill is subject to 40 Code of Federal Regulations (CFR) Part 98 and is required to report GHG emissions annually. In 2017, the City reported an approximate collection efficiency of 80% based on EPA-provided guidance. The GHG annual emissions reduction in 2017 associated with collection and combustion of LFG was calculated to be approximately 94,600 metric tons of CO_2e. The total GHG emissions from all Landfill sources was calculated to be approximately 67,300 metric tons of CO_2e[4].

The LFG to Energy Plant produced a reported 16,676 megawatts hours (MWh) of electricity in 2017. From published carbon intensity values from the California Air Resources Board Low Carbon Fuel Standard, the use of LFG for fuel equates to approximately 12,650 metric tons of CO_2e offset by the beneficial use of the LFG, when compared to natural gas. This equates to net GHG emissions of approximately 54,650 metric tons of CO_2e in 2017.

Other Landfilling Considerations

The City's LFG to Energy Plant is a considerable contributor to the renewable energy portfolio and helps meet the renewable energy goals required by the City's adopted renewable energy ordinance. The presence of OW in the waste mass contributes to the overall quantity and quality of LFG produced. From a renewable energy production perspective, the OW in the landfill waste mass is a benefit to energy production and efficiency.

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[3] 40 CFR 98, Subpart HH

[4] Based on EPA AP-42 calculation methodology and LFG generation / collection amounts from 40 CFR 98 methodology.

The airspace consumed by OW in the landfill comes at a cost to the City. However, OW is typically the quickest waste to degrade and consolidate, particularly in the bioreactor cells; this can potentially free up a portion of the originally consumed airspace, which the City can reclaim years later.

The OW in the landfill represents a portion of the long-term liability of the overall waste mass. After degradation and consolidation over time, the liability represented by the OW is significantly reduced in later years, especially when compared with other components of the waste mass. Leachate management and final cover will be necessary as environmental controls regardless of OW presence in the waste.

For the purposes of this study, the cost of continuing to landfill OW can be considered the current cost of operations, as a baseline for comparison of other options. The costs of continuing the current operations (integrated collection, GCCS expansion, intermediate cover construction, etc.) are accounted for in the City's Solid Waste Utility budget. Cost of disposal at the Columbia Landfill is currently $55 per ton.

2. Expand OW Diversion and Compost Operations

From the OW diverted to the City's compost operation in 2018, approximately 760 cubic yards of compost was distributed from the City's composting operations and utilized locally. Generally, the City's composted material is beneficially used for gardening, lawns, and landscaping. While the City's current operational constraints limit the supply of compost it can produce, City staff indicates that the amount of compost produced appears to meet or exceed the current local demand for their product.

Compost Operation Emissions

Emissions from City's compost operation are not captured, nor are they required to be reported in EPA GHG Emissions Inventory. Most of the off-gas produced by the decomposition of organics via composting is carbon dioxide, while small amounts of methane and even smaller amounts of nitrous oxide are also produced. The process requires oxygen for the aerobic microorganisms to decompose the waste. The most common composting method is using turned windrows, which is the method employed by the City. Windrows are elongated piles of organic materials which are turned using a tractor, or other equipment. The oxygen requirement in windrows is achieved by natural convection through the pile. The actual composition of the off-gas depends heavily on the compost operation recipe, the moisture of the material, and the operational methods, with more aeration (turning) promoting lower emissions from the material. However, the emissions from the operational equipment offset some of the benefit in more active processing.

Independent research comparing GHG emissions of composting vs. landfilling varies greatly. A 2012 study titled "Comparing Greenhouse Gas Emissions from Various

Methods of Organic Waste Disposal"[5] compares OW composting with OW landfilling. The study estimates net GHG emissions for landfilling as approximately 3 to 4 times more than for composting. The landfill conditions in this study assume 75% LFG capture and 47% of the gas captured is beneficially utilized to produce electricity (power production qualifies for emissions offsets). Considering the City may capture up to 85% LFG and in 2017 utilized 75% of captured LFG for energy, the net emissions factor associated with the City's Landfill may be lower than the example in the referenced study, using similar methodology.

Other studies, such as a technical guideline published by the Australian government's Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education titled "National Greenhouse and Energy Reporting System Measurement"[6] in July 2013, and a published summary of a study titled "Evaluating Greenhouse Gas Impacts of Organic Waste Management Options Using Life Cycle Analysis"[7] by the Solid Waste Management Department (SWMD) of Los Angeles County, suggest less difference between emissions of landfilling compared with composting.

The US EPA's Waste Reduction Model (WARM)[8] Version 14, published March 2018, provides an interactive mechanism to estimate the emissions factors associated with various methods of OW management including landfilling, composting, and anerobic digestion. The WARM model is a spreadsheet application which allows users to input certain site-specific information to derive emissions factors for comparison of waste management methods. The WARM Model is issued by EPA along with a published reference document which provides information on many of the calculations embedded in the spreadsheet. Despite the ability to input some site-specific information, the calculated WARM model factors include several embedded assumptions, such as the values for the typical transportation and operational equipment associated with each method, and the offset in composting emissions associated with replacing alternative fertilizers. In the case of the City's waste collection, additional truck routes are necessary to collect separated OW in a manner suitable for composting, similar to the City's recycling program. Therefore, emissions from the additional collection routes are considered and discussed further below.

Another key assumption embedded in the WARM model composting calculation is the end use of the compost. To quantify the emissions benefit of soil carbon storage

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[5] Brockway. A. M. *Comparing Greenhouse Gas Emissions from Various Methods of Organic Waste Disposal*. (2012)
[6] Australian Government, Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education. *National Greenhouse and Energy Reporting System Measurement.* (2013, July)
[7] Kong and Shan. Iacoboni. Maguin; (2012). Evaluating Greenhouse Gas Impacts of Organic Waste Management Options Using Life Cycle Assessment. *Waste Management & Research.* 30(8) 800-812.
[8] ICF International. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM).* (2016, February)

associated with the composting end use, EPA used a separate model known as the CENTURY Soil Organic Matter Model, developed by the USDA-ARS Global Climate Change Research Program. This program assumes an agricultural end use of the compost. For lack of other available methodology or options within the program, EPA used the model assuming a large-scale agricultural use of the compost. EPA recognizes this methodology as a limitation of its model and is researching ways to improve this assumption. The soil carbon storage emissions factor derived from the Century model was calculated by EPA to be 0.24 metric tons CO_2e / ton of material. [8] Since this is based on a scenario in which agricultural activities have depleted soil organic carbon levels, the emissions factor may be overstated when compared with the typical end uses of the City's compost.

The City's current composting customers are approximately 30% landscapers and 70% individuals. It is unknown from EPA's documentation what impact an alternate compost end use would have on the soil carbon storage and the overall composting emissions factor. It is also unknown whether compost spreading and tilling equipment were factored into the soil carbon storage model calculation. Given these uncertainties and other similar assumptions embedded in the model, the City should assume a degree of uncertainty with WARM model scenarios discussed further below.

Another consideration when assuming an agricultural end use is *where* the emissions benefit is realized. In this case, the air quality improvement is realized in rural areas outside the urban core of the City, where air quality is generally not impaired by high traffic volumes and industry. Conversely, the emissions resulting from collection and processing of the material may have an adverse impact on the air quality within the City, where most stakeholders reside.

Compost Contact Water

Another environmental consideration associated with composting is contact water runoff or percolation to groundwater. Compost contact water can be high in BOD, nitrate, phosphorus, and other constituents of concern. The Landfill site currently operates under a National Pollutant Discharge Elimination System (NPDES) permit and is subject to both groundwater monitoring and surface water monitoring. Therefore, like the Landfill, the City's compost operation has environmental controls in place to detect any significant levels of these contaminants and if necessary, address any exceedances to permitted limits. The compost pad is constructed of compacted crushed rock on compacted soil subgrade and is therefore resistant to groundwater percolation. Surface water runoff travels through a series of rock check dams to remove solids before entering a nearby sedimentation basin. The sedimentation basin provides a treatment mechanism prior to discharge from the site. Expansion of the compost area could result in higher concentrations of contaminants in the sedimentation basins and could potentially result in additional cost for compliance with the site NPDES Permit, which should be considered in the overall detailed analysis.

Current Composting Operations

The City utilizes a grinder to process yard waste material before placing into windrows at the compost facility. Approximately half of the permitted compost area is currently constructed and used for the operation at the Landfill site. The City currently produces approximately 700-750 cubic yards of material per batch, and each batch takes approximately 6 months to complete the composting process. Therefore, the City produces approximately 1,400-1,500 cubic yards of compost in a typical year. Currently, approximately 50% is distributed and utilized locally (760 cubic yards in 2018).

Potential Composting Expansion

The City's composting operation could be expanded to increase the amount of material the City produces. The compost pad could be approximately doubled to increase the amount of space available for windrows of materials. Increasing the moisture and oxygen content can significantly increase the rate of decomposition. Assuming twice the area and operational acceleration due to more active turning of material, the City could potentially double or triple their current composting output. A greater degree of production could be achieved if the City implemented City-wide organics separation and further expanded the operation footprint. However, expanding the footprint more than double in the current area may not be feasible due to topography and constraints in the overall site development plan, and thus may require a relocation of the compost operation.

Although the opportunity to expand the compost operation appears to be logistically feasible, key economic factors need to be addressed in more detail to support this plan of action:

1. Demand: The local demand will need to increase with increased compost production. Given the current compost usage rate, the City will need to increase marketing efforts and likely consider new programs to increase use of compost (e.g. requiring compost usage in new City development projects).
2. Cost of Service / Rate Evaluation: Assuming demand is present to expand composting, the City should further analyze the overall costs and revenues of composting to determine benefits and impacts to City finances. A cost of service study may be necessary to set the product price, which may in turn affect demand.
3. Competitive Landscape: Historically the City has offered the composting service as a complimentary service, supplemental to its core service offering of regional waste disposal. Expansion of composting could move the City into a retail product business, which carries an element of risk beyond its core service. Competitors include big box retailers selling compost by the bag, and local/regional private compost operations, selling compost in bulk. More assessment of the market is recommended.
4. Labor: The City estimates that expanding the compost operation and OW collection is estimated to require the addition of 12 collection vehicles and 17

additional staff members. The City's Solid Waste Collection Division currently has multiple unfilled positions. Based on difficulty in finding qualified labor for these positions over several years, the City anticipates further hardships in filling additional positions that would be required to provide this service.

Composting diverts material from the Landfill, thereby increasing its useful life while also deferring some incremental capital costs incurred for landfill expansion and closure projects. Meanwhile, diverting organic materials from the Landfill will reduce tipping fee revenues and reduce quantities of LFG generated and sold for renewable energy production. A future cost of service / rate evaluation should incorporate these provisions.

While the renewable energy production from LFG will be negatively impacted by composting, it is unknown how significantly gas production would decrease. It is reasonable to assume that future production of the City's LFG to Energy Plant would decrease by a factor at least equal to the percent of OW removed from the waste stream over time, 6.5% as previously estimated. Since OW has considerably more methane generation potential than mixed MSW, the actual reduction in power production over time may likely be in the range of 10% to 15%.

Expansion of Organic Waste Diversion

Emissions from collection and hauling operations will increase corresponding to the additional collection routes required for expansion of the City's OW program. The WARM model contains a default transportation emissions factor that can be applied to the waste tonnage. The model appears to assume the waste is transported in bulk between two points rather than by incremental collection along a route. Since this does not accurately represent the City's expansion scenario and given the uncertainty in how the factor was calculated in WARM, the transportation distance was set to zero in the model, and the net change in transportation emissions were calculated outside of the model.

Burns & McDonnell developed emissions estimates associated with the increased hauling routes for OW based on fuel inputs on a per route basis (provided by the City, based on similar routes for recycling), collection vehicle capacities, densities for OW, and the OW diversion rate of 15,870 tons. The expansion of OW hauling would add approximately the equivalent of 82 weekly haul routes. Assuming collection with compressed natural gas (CNG) vehicles, the additional routes would contribute an estimated additional 1,720 metric tons of CO_2e[9].

Removing OW from the existing MSW collection routes would result in a minor reduction in the number of vehicle trips to the landfill. From discussions with the City, a

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[9] Carbon intensity for CNG obtained from California Air Resources Board, Low Carbon Fuel Standard. The carbon intensity (CI) of Compressed Natural Gas is calculated to be 79.21 gCO2e/MJ and is detailed in Table C.1 of *CA-GREET3.0 Lookup Table Pathways Technical Support Documentation* (August 13, 2018).

typical MSW collection vehicle makes two trips to the landfill during its daily route to empty the vehicle's load and then return to the route. It is estimated that by removing OW from the MSW stream, 36 vehicle trips to the landfill per week may be avoided due to the volume decrease accumulated on the MSW routes. These vehicle trips equate to approximately 3.2 weekly haul routes. The estimated emissions reduction from the MSW routes is 70 metric tons of CO_2e, resulting in a *net* collection transportation increase of 1,650 metric tons of CO_2e to separate and collect OW city-wide.

Transportation to the end use location of the compost also adds emissions, as well as spreading the compost with farm equipment. The emissions for an agricultural end use were calculated based on a 50-mile round trip in a typical 20 cubic yard dump truck. The number of trips is specific to the amount of compost utilized, as described in each scenario below.

WARM Model Composting vs. Landfilling Scenarios

The following scenarios are presented to illustrate the impact of applied emissions factors and the range of potential resulting emissions. All scenarios are based on diversion of an additional 15,870 tons of OW to the composting operation, an increase of approximately 270% over current compost feedstock (5,955 tons).

The baseline scenario is provided below assuming no end use of the compost as a point of reference against other scenarios, to illustrate the impact of the soil carbon storage factor.

Table 2: Baseline Scenario

-2,022 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+3,809 metric tons CO_2e	Adjustment for carbon storage factor assuming no end use
+3,437 metric tons CO_2e	Emissions more than landfilling w/ LFG recovery and energy generation

For each scenario below:

- The first line reflects the WARM model output, with landfilling (with LFG recovery and energy generation) as the base case and composting as the alternative management approach (the WARM model inputs and results are provided in Attachment 1).
- The second line applies the net collection transportation increase presented above.
- The third line adds emissions attributed to the transportation of the compost to the end use as described above and adjusted based on the amount utilized.
- The fourth line is an adjustment based on the utilization of the compost for end use (end use is assumed to be agriculture, per WARM model limitations). The end

use adjustment is calculated as 15,870 tons x % unutilized for each scenario x 0.24 metric tons CO_2e per ton of material (soil carbon storage factor for compost end use, per WARM model documentation).

- The fifth line represents the estimated net emissions impact with respect to landfilling with LFG recovery and energy generation.

Scenario A: Assumes 50% of produced compost used for agriculture. This scenario represents the existing utilization of produced compost. Sales/distribution of compost would need to increase by 266% to achieve this scenario.

Table 3: Scenario A

-2,022 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+ 10 metric tons CO2e	End use transportation adjustment
+1,905 metric tons CO_2e	Assumes 50% utilized for agriculture, 50% unutilized
+1,543 metric tons CO_2e	Emissions more than landfilling w/ LFG recovery and energy generation

Scenario B: Assumes 75% of compost used for agriculture. This scenario represents what may be a realistic-optimum scenario. Sales/distribution of compost would need to increase by approximately 400% to achieve this scenario.

Table 4: Scenario B

-2,022 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+ 20 metric tons CO2e	End use transportation adjustment
+ 952 metric tons CO_2e	Assumes 75% utilized for agriculture, 25% unutilized
+ 600 metric tons CO_2e	Emissions more than landfilling w/ LFG recovery and energy generation

Scenario C: Assumes 95% of compost used for agriculture. This scenario represents what may be a stretch-optimum scenario. Sales/distribution of compost would need to increase by over 500% to achieve this scenario.

Table 5: Scenario C

-2,022 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+ 30 metric tons CO2e	End use transportation adjustment
+ 190 metric tons CO_2e	Assumes 95% utilized for agriculture, 5% unutilized
- 152 metric tons CO_2e	Emissions less than landfilling w/ LFG recovery and energy generation

In conclusion, the transformation of OW through composting for beneficial reuse offers environmental benefits. However, before expansion of the OW diversion program for composting is pursued, the compost end use and associated potential emissions reductions should be evaluated further and shown to support the program.

3. Anaerobic Digestion

Anaerobic digestion (AD) is a process that allows for the initial diversion of OW, yard wastes, and some FOG from the Landfill, while producing biogas. While there are various types and sizes of anaerobic digesters available, the general process for each remains similar. OW and a feedstock of anaerobic microorganisms are mixed in a closed vessel for up to several weeks. The time needed to digest OW in an AD varies depending on the type of AD utilized, the amount of waste being digested, and the moisture content of the waste at the beginning of the process. As described below, the AD process is similar to the waste degradation process of landfilling, but with key differences.

AD Emissions

The basic chemistry of an anaerobic digester is almost identical to the anaerobic digestion of MSW in a landfill. The byproducts from an AD are biogas, digestate (a solid waste), and wastewater (similar to leachate). Like LFG, the AD biogas is considered a renewable natural gas that can be used to generate energy and offset fossil fuel-generated energy, and the digestate can be used to amend soil or as feedstock for compost. The biogas produced from an AD is typically higher in methane content than LFG, and the capture rate is near 100%.

From the EPA's WARM model, the net emissions factors associated with dry AD vary depending on whether the digestate is cured (used as compost feedstock) or uncured and directly land applied as a soil amendment. In both cases, the resulting carbon storage factors were derived by similar methods and have similar limitations as the composting scenarios described above. The model assumes that the biogas generated during anaerobic digestion is used in an internal combustion engine to generate electricity. As with the composting scenarios, the diversion of OW for AD would require additional hauling routes, with the net emissions previously calculated as 1,650 metric tons of CO_2e for the given quantity. The WARM model does not provide AD factors/analysis options for the case that the digestate is landfilled.

WARM Model AD vs. Landfilling Scenarios

The following scenarios are presented to illustrate the impact of applied emissions factors for the two possible AD process options described above. The amount of digestate assumed for agricultural use is 75%. As before, the scenarios are based on diversion of 15,870 tons of OW to an AD. For each scenario:

- The first line reflects the WARM model output, with landfilling (with LFG recovery and energy generation) as the base case and AD as the alternative management approach (the WARM model inputs and results are provided in Attachment 2 and 3 for Scenarios D and E, respectively).
- The second line applies the net collection transportation increase presented above.
- The third line adds emissions attributed to the transportation of the digestate to the end use as described above and adjusted based on the amount utilized.
- The fourth line is an adjustment based on the utilization of the compost for end use (end use is assumed to be agriculture, per WARM model limitations). The end use adjustment is calculated as 15,870 tons x 25% unutilized x 0.09 metric tons CO_2e per ton of material for Scenario D, and 15,870 tons x 25% unutilized x 0.22 metric tons CO2e per ton of material for Scenario E (respective soil carbon storage factors, per WARM model documentation).
- The fifth line represents the estimated net emissions impact with respect to landfilling with LFG recovery and energy generation.

Scenario D: Assumes AD digestate is used as feedstock in the onsite compost operation and that compost is utilized in an agriculture application.

Table 6: Scenario D

- 1,047 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+ 20 metric tons CO2e	End use transportation adjustment
+ 357 metric tons CO_2e	Assumes 75% utilized for agriculture, 25% unutilized
+ 980 metric tons CO_2e	Emissions more than landfilling w/ LFG recovery and energy generation

Scenario E: Assumes AD digestate is directly land applied in an agriculture application.

Table 7: Scenario E

- 3,472 metric tons CO2e	WARM model output
+1,650 metric tons CO_2e	Net collection transportation adjustment
+ 20 metric tons CO2e	End use transportation adjustment
+ 873 metric tons CO_2e	Assumes 75% utilized for agriculture, 25% unutilized
- 929 metric tons CO_2e	Emissions less than landfilling w/ LFG recovery and energy generation

Additional scenarios could be developed for AD which would show varying percent utilization of the digestate, similar to the composting scenarios developed. For the purposes of this study, the scenarios above are deemed as adequate to demonstrate the potential range for comparison purposes.

AD Economics

To support the construction of an AD facility, City-wide organics separation would be necessary to produce the volume of feedstock necessary for the process. Implementing City-wide organics separation may provide an OW stream of up to 45 tons per day of food waste to combine with up to 15 tons per day of yard waste (readily available). The City could also explore contracting with local farms to add animal waste to the AD feedstock to increase biogas production. Burns & McDonnell models developed for similar projects have indicated a minimum OW stream of 100 tons per day as being the minimum necessary to support a reasonable payback period for the costs associated with AD development (8 to 10 years). Capital costs alone for small scale AD system infrastructure could be high as $15M, including a new building for separation, piping and processing equipment, digester facility, and other ancillary equipment.

More detailed financial models would need to be developed to determine a payback period for the City to make an informed decision on the development of an AD. The model could examine the additional renewable energy cost margin over alternative renewable energy sources.

The City's Water & Light Department is in the process of studying whether refining LFG to Renewable Natural Gas (RNG) quality is a viable alternative to continuing full scale operation of the LFG to Energy Plant. Renewable Identification Numbers (RINs) are commonly purchased by companies to meet minimum requirements under the Federal Renewable Fuel Standards, which are set by EPA. RIN prices in recent years have been high enough to justify the investment by several similar sized landfills throughout the country. If the study shows a reasonable outlook for the City from the sale of RINs and the RNG project moves forward, the City would need to invest in gas refining system equipment. An AD could immediately improve gas flowrate, methane content, and may reduce the incremental cost of the RNG refining equipment needed and the ongoing operation and maintenance costs of the system. Given the City's unique scenario, it is recommended that the alternative of implementing an AD be evaluated as part of the RNG study discussed above. The State requirement that the bioreactor must produce electricity from the collected gas (per Section 260.250 RSMo) will also need to be considered as part of this study, as this project would utilize the majority of collected biogas for RNG production and would likely involve curtailing or ceasing operations at the existing LFG to Energy Plant.

SUMMARY AND RECOMMENDATIONS

A summary of the considerations examined as part of this organics waste management study are provided in Table 2 below.

Table 8: Summary of OW Strategy Evaluation*

	Continue Landfilling OW with LFG to Energy	Implement City-wide OW Separation and Expand Compost Operation	Implement City-wide OW Separation and Pursue Anaerobic Digestion
Landfill Diversion	No change	Assumes additional OW diversion of 6.5% of overall solid waste stream by weight (15,870 tons)	Assumes additional OW diversion of 6.5% of overall solid waste stream by weight (15,870 tons);
Airspace and Long-term Liability	No change; ~268,000 cubic yards total consumed in 2017; OW stabilizes over 20+ years	Decrease of up to 30,000 cubic yards of airspace consumed annually; no City liability for material sold / donated	Decrease of up to 30,000 cubic yards of airspace consumed annually; byproduct can be composted, directly land applied, or disposed of in landfill
Change in Energy Production Potential	No change; 16,676 MWh renewable power generation in 2017	No energy production for diverted OW; decrease of up to 10 to15% in renewable power production over the life of the applicable future cells.	Increase in LFG flowrate and methane content; potential to increase energy production or quantity of biogas / RINs sold as part of potential RNG project
GHG Reduction Potential	No change; approx. 54,650 metric tons net CO2e (MTCO2e) emissions in 2017 (per assumptions provided)	GHG generation for diverted OW, by WARM Model and applied adjustments ranging from an increase of 1,543 MTCO2e to a decrease of 152 MTCO2e when compared to landfilling, depending on end use of compost, and other factors.	GHG generation for diverted OW by WARM Model and applied adjustments ranging from an increase of 980 MTCO2e to a decrease of 929 MTCO2e when compared to landfilling, depending on end use of digestate, and other factors.
Other Environmental Impact	No change	Positive environmental impact from amending soils; Potentially negative environmental impact from runoff water; Less renewable energy production	Additional renewable power production; Potentially positive environmental impact from amending soils with solids byproduct
General Cost	No change; Capital cost to construct cells every 4 to 6 years; estimated $55 per ton of disposed waste	Moderate capital investment (Est.$3.5M to $4M) in expanding compost pad, 12 new collection vehicles, and potentially more equipment over time; increased operational costs estimated $3.2M annually for labor, fuel, vehicle maintenance	Significant capital investment (Est. $13M to $19M) in new facility, new equipment, 12 new collection vehicles, new infrastructure, new pipelines, etc.; increased operational costs estimated $3.2M to $3.7M annually for labor, fuel, vehicle maintenance
Potential Revenue Impact	No change; OW brings same revenue as other MSW, currently $55 / ton	Additional revenue from compost sales (~ $21 / cubic yard equates to $63K annually if production tripled); Negative revenue impact over time from decreased renewable energy production ($19K to $29K lost annual rev. to Solid Waste Utility from sale of gas; other renewable sources cost more, potentially impact Water & Light rate payers); Results in potential revenue shortfall due to operational cost for the utility; Rate structures likely need additional evaluation	Potential marginal revenue increase from renewable energy (other renewable sources cost more); Potential significant revenue increase from RIN credits and the RNG market (to be further evaluated in RNG study, as well as potential negative rev. impact to Solid Waste from fewer tipping fees and sale of gas revenue)

*Burns & McDonnell's estimates, analyses, and recommendations presented in this study are based on our professional experience and judgment, as well as external sources and assumptions. While we believe the information presented herein is reasonably accurate, Burns & McDonnell does not guarantee that actual values or scenarios will not differ from those presented upon implementation. Further evaluation of certain information, assumptions, and scenarios may be warranted at the discretion of the City.

The OW management strategies examined each have unique advantages, disadvantages, and ancillary impacts. The City's collection and beneficial use of LFG for renewable energy reduces the overall environmental impact of landfilling OW. The increase in emissions associated with the additional truck routes required to collect OW separate from MSW contributes to the overall environmental impact for both composting and AD. Using the WARM model while including collection emissions and end use assumptions, the net emissions from the facility associated with each OW management strategy are estimated as follows:

- Landfilling – 54,650 metric tons CO_2e
- Composting - 54,500 to 56,190 metric tons CO_2e
- Anerobic Digester – 53,720 to 55,630 metric tons CO_2e

While the model used may be the best available method to quantify and compare emissions for the given scenarios, it should be acknowledged that many assumptions, calculations, and variables were used in developing the model and its input values. Each of these carry with it a degree of uncertainty and when compiled, the degree of uncertainty may be compounded. Evaluating the estimated emissions values above with this in consideration may lead stakeholders to imply that no one strategy has a conclusive significant advantage over the others. The specific details of implementation with each option are critical to estimating the environmental impacts.

Given that an AD could have the greatest apparent potential for environmental and financial benefits to the City, it is recommended that an AD be evaluated further as part of an RNG process concept design and pro-forma. If the project proves viable without an AD, the RNG pro-forma should consider the long-term gas generation impact of removing a significant quantity of OW from the landfilled waste stream (i.e., develop a pro-forma scenario showing the impact expanded composting may have on the RNG project financials). If the RNG project proves not viable or carries too much risk and is ultimately not pursued, the City may consider further evaluation of:

- Financial impact of development of an AD to boost renewable energy production in the City's LFG to Energy Plant, as well as potential end uses of digestate; and/or
- Environmental and economic factors associated with increased OW diversion and expansion of composting and specific end uses;
- Alternative OW collection approaches that may further limit vehicle emissions. This could include establishing public OW drop-off locations, utilizing electric collection vehicles as practical technology develops, conforming routes to high participation areas or subscriber locations, or any combination of these approaches.

ATTACHMENT 1

Version 14

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.

1. Describe the baseline generation and management for the waste materials listed below. If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed

2. Describe the alternative management scenario for the waste materials generated in the baseline. Any decrease in generation should be entered in the Source Reduction column. Any increase in generation should be entered in the Source Reduction column as a negative value. Make sure that the total quantity generated equals the total quantity managed.

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Aluminum Cans				NA	NA	0.0					NA	NA
Aluminum Ingot				NA	NA	0.0					NA	NA
Steel Cans				NA	NA	0.0					NA	NA
Copper Wire				NA	NA	0.0					NA	NA
Glass				NA	NA	0.0					NA	NA
HDPE				NA	NA	0.0					NA	NA
LDPE	NA			NA	NA	0.0		NA			NA	NA
PET				NA	NA	0.0					NA	NA
LLDPE	NA			NA	NA	0.0		NA			NA	NA
PP	NA			NA	NA	0.0		NA			NA	NA
PS	NA			NA	NA	0.0		NA			NA	NA
PVC	NA			NA	NA	0.0		NA			NA	NA
PLA	NA				NA	0.0		NA				NA
Corrugated Containers				NA	NA	0.0					NA	NA
Magazines/Third-class Mail				NA	NA	0.0					NA	NA
Newspaper				NA	NA	0.0					NA	NA
Office Paper				NA	NA	0.0					NA	NA
Phonebooks				NA	NA	0.0					NA	NA
Textbooks				NA	NA	0.0					NA	NA
Dimensional Lumber				NA	NA	0.0					NA	NA
Medium-density Fiberboard				NA	NA	0.0					NA	NA
Food Waste (non-meat)	NA					0.0		NA				
Food Waste (meat only)	NA					0.0		NA				
Beef	NA					0.0		NA				
Poultry	NA					0.0		NA				
Grains	NA					0.0		NA				
Bread	NA					0.0		NA				
Fruits and Vegetables	NA					0.0		NA				
Dairy Products	NA					0.0		NA				
Yard Trimmings	NA					0.0	NA	NA				
Grass	NA					0.0	NA	NA				
Leaves	NA					0.0	NA	NA				
Branches	NA					0.0	NA	NA				
Mixed Paper (general)				NA	NA	0.0					NA	NA
Mixed Paper (primarily residential)				NA	NA	0.0					NA	NA
Mixed Paper (primarily from offices)				NA	NA	0.0					NA	NA
Mixed Metals				NA	NA	0.0					NA	NA
Mixed Plastics				NA	NA	0.0					NA	NA
Mixed Recyclables				NA	NA	0.0	NA				NA	NA
Food Waste	NA					0.0		NA				
Mixed Organics	NA	15870.0				15,870.0	NA	NA			15870.0	
Mixed MSW	NA			NA	NA	0.0	NA	NA			NA	NA
Carpet				NA	NA	0.0					NA	NA
Personal Computers				NA	NA	0.0					NA	NA
Clay Bricks	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Concrete			NA	NA	NA	0.0	NA			NA	NA	NA
Fly Ash			NA	NA	NA	0.0	NA			NA	NA	NA
Tires				NA	NA	0.0					NA	NA
Asphalt Concrete			NA	NA	NA	0.0				NA	NA	NA
Asphalt Shingles				NA	NA	0.0					NA	NA
Drywall			NA	NA	NA	0.0				NA	NA	NA
Fiberglass Insulation	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Vinyl Flooring	NA			NA	NA	0.0		NA			NA	NA
Wood Flooring	NA			NA	NA	0.0		NA			NA	NA

Please enter data in short tons (1 short ton = 2,000 lbs.

Please refer to the User's Guide if you need assistance completing this table

3. In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location. Select state for which you are conducting this analysis.

Please select state or select national average:	Missouri
Region Location:	West North Central

4. To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "Current mix" and "100% virgin" inputs are the same.

- (●) Current Mix
- ( ) 100% Virgin

5. The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select "No LFG Recovery" and proceed to question 8. If a LFG system is in place at your landfill, select "LFG Recovery" and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.

- ( ) National Average
- (●) LFG Recovery
- ( ) No LFG Recovery

6a. If your landfill has gas recovery, does it recover the methane for energy or flare it?

- (●) Recover for energy
- ( ) Flare

6b. For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.

- ( ) Typical operation - DEFAULT
- ( ) Worst-case collection
- ( ) Aggressive gas collection
- (●) California regulatory collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
California	*Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill? The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.

- ( ) National average - DEFAULT
- ( ) Dry (k=0.02)
- ( ) Moderate (k = 0.04)
- (●) Wet (k = 0.06)
- ( ) Bioreactor (k = 0.12)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used. Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials. Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

- ( ) Wet Digestion

Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application.
When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultural fields.
Select whether the digestate resulting from your anaerobic digester is cured before land application.

Cured - DEFAULT

Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

Use Default Distances

Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF).
***Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.**

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	0
Combustion	20	0
Recycling	20	0
Composting	20	0
Anaerobic Digestion	20	0

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	
Organization	

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of GHG emissions, see the sheet(s) titled "Analysis Results."

Waste Reduction Model (WARM) -- Results

Total GHG Emissions from Baseline MSW Generation and Management ($MTCO_2E$):	(597.19)
Total GHG Emissions from Alternative MSW Generation and Management ($MTCO_2E$):	(2,619.22)
Incremental GHG Emissions ($MTCO_2E$):	(2,022.03)

$MTCO_2E$ = metric tons of carbon dioxide equivalent

Per Ton Estimates of GHG Emissions for Baseline and Alternative Management Scenarios

Material	GHG Emissions per Ton of Material Source Reduced ($MTCO_2E$)	GHG Emissions per Ton of Material Recycled ($MTCO_2E$)	GHG Emissions per Ton of Material Landfilled ($MTCO_2E$)	GHG Emissions per Ton of Material Combusted ($MTCO_2E$)	GHG Emissions per Ton of Material Composted ($MTCO_2E$)	GHG Emission per Ton of Material Anaerobically Digested
Aluminum Cans	(4.91)	(9.11)	0.02	0.04	NA	NA
Aluminum Ingot	(7.47)	(7.19)	0.02	0.04	NA	NA
Steel Cans	(3.06)	(1.82)	0.02	(1.57)	NA	NA
Copper Wire	(7.01)	(4.71)	0.02	0.03	NA	NA
Glass	(0.53)	(0.28)	0.02	0.03	NA	NA
HDPE	(1.47)	(0.87)	0.02	0.70	NA	NA
LDPE	(1.80)	NA	0.02	0.72	NA	NA
PET	(2.20)	(1.12)	0.02	0.93	NA	NA
LLDPE	(1.58)	NA	0.02	0.71	NA	NA
PP	(1.55)	NA	0.02	0.71	NA	NA
PS	(2.50)	NA	0.02	1.13	NA	NA
PVC	(1.95)	NA	0.02	0.43	NA	NA
PLA	(2.09)	NA	(1.65)	(0.87)	(0.15)	NA
Corrugated Containers	(5.60)	(3.12)	(0.43)	(0.70)	NA	NA
Magazines/third-class mail	(8.60)	(3.07)	(0.64)	(0.51)	NA	NA
Newspaper	(4.77)	(2.75)	(1.09)	(0.79)	NA	NA
Office Paper	(7.97)	(2.86)	0.22	(0.67)	NA	NA
Phonebooks	(6.22)	(2.64)	(1.09)	(0.79)	NA	NA
Textbooks	(9.07)	(3.11)	0.22	(0.67)	NA	NA
Dimensional Lumber	(2.03)	(2.46)	(1.05)	(0.83)	NA	NA
Medium-density Fiberboard	(2.23)	(2.47)	(0.90)	(0.83)	NA	NA
Food Waste (non-meat)	(0.76)	NA	0.22	(0.21)	(0.18)	(0.10)
Food Waste (meat only)	(15.10)	NA	0.22	(0.21)	(0.18)	(0.10)
Beef	(30.05)	NA	0.22	(0.21)	(0.18)	(0.10)
Poultry	(2.47)	NA	0.22	(0.21)	(0.18)	(0.10)
Grains	(0.62)	NA	0.22	(0.21)	(0.18)	(0.10)
Bread	(0.67)	NA	0.22	(0.21)	(0.18)	(0.10)
Fruits and Vegetables	(0.44)	NA	0.22	(0.21)	(0.18)	(0.10)
Dairy Products	(1.74)	NA	0.22	(0.21)	(0.18)	(0.10)
Yard Trimmings	NA	NA	(0.34)	(0.25)	(0.15)	(0.11)
Grass	NA	NA	0.04	(0.25)	(0.15)	(0.01)
Leaves	NA	NA	(0.64)	(0.25)	(0.15)	(0.15)
Branches	NA	NA	(0.87)	(0.25)	(0.15)	(0.25)
Mixed Paper (general)	(6.11)	(3.53)	(0.48)	(0.70)	NA	NA
Mixed Paper (primarily residential)	(6.04)	(3.53)	(0.51)	(0.70)	NA	NA
Mixed Paper (primarily from offices)	(7.41)	(3.59)	(0.37)	(0.64)	NA	NA
Mixed Metals	(3.70)	(4.34)	0.02	(1.01)	NA	NA
Mixed Plastics	(1.92)	(1.03)	0.02	0.85	NA	NA
Mixed Recyclables	NA	(2.83)	(0.46)	(0.62)	NA	NA
Food Waste	(3.66)	NA	0.22	(0.21)	(0.18)	(0.10)
Mixed Organics	NA	NA	(0.04)	(0.23)	(0.17)	(0.10)
Mixed MSW	NA	NA	(0.07)	(0.20)	NA	NA
Carpet	(3.82)	(2.36)	0.02	0.88	NA	NA
Personal Computers	(50.49)	(2.51)	0.02	(0.23)	NA	NA
Clay Bricks	(0.27)	NA	0.02	NA	NA	NA
Concrete	NA	(0.01)	0.02	NA	NA	NA
Fly Ash	NA	(0.87)	0.02	NA	NA	NA
Tires	(4.28)	(0.38)	0.02	0.50	NA	NA
Asphalt Concrete	(0.11)	(0.08)	0.02	NA	NA	NA
Asphalt Shingles	(0.19)	(0.09)	0.02	(0.36)	NA	NA
Drywall	(0.21)	0.02	(0.06)	NA	NA	NA
Fiberglass Insulation	(0.38)	NA	0.02	NA	NA	NA
Vinyl Flooring	(0.61)	NA	0.02	(0.54)	NA	NA
Wood Flooring	(4.05)	NA	(0.86)	(1.06)	NA	NA

ATTACHMENT 2

Version 14

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.

1. Describe the baseline generation and management for the waste materials listed below. If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed

2. Describe the alternative management scenario for the waste materials generated in the baseline. Any decrease in generation should be entered in the Source Reduction column. Any increase in generation should be entered in the Source Reduction column as a negative value. Make sure that the total quantity generated equals the total quantity managed.

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Aluminum Cans				NA	NA	0.0					NA	NA
Aluminum Ingot				NA	NA	0.0					NA	NA
Steel Cans				NA	NA	0.0					NA	NA
Copper Wire				NA	NA	0.0					NA	NA
Glass				NA	NA	0.0					NA	NA
HDPE				NA	NA	0.0					NA	NA
LDPE	NA			NA	NA	0.0		NA			NA	NA
PET				NA	NA	0.0					NA	NA
LLDPE	NA			NA	NA	0.0		NA			NA	NA
PP	NA			NA	NA	0.0		NA			NA	NA
PS	NA			NA	NA	0.0		NA			NA	NA
PVC	NA			NA	NA	0.0		NA			NA	NA
PLA	NA				NA	0.0		NA				NA
Corrugated Containers				NA	NA	0.0					NA	NA
Magazines/Third-class Mail				NA	NA	0.0					NA	NA
Newspaper				NA	NA	0.0					NA	NA
Office Paper				NA	NA	0.0					NA	NA
Phonebooks				NA	NA	0.0					NA	NA
Textbooks				NA	NA	0.0					NA	NA
Dimensional Lumber				NA	NA	0.0					NA	NA
Medium-density Fiberboard				NA	NA	0.0					NA	NA
Food Waste (non-meat)	NA					0.0		NA				
Food Waste (meat only)	NA					0.0		NA				
Beef	NA					0.0		NA				
Poultry	NA					0.0		NA				
Grains	NA					0.0		NA				
Bread	NA					0.0		NA				
Fruits and Vegetables	NA					0.0		NA				
Dairy Products	NA					0.0		NA				
Yard Trimmings	NA					0.0	NA	NA				
Grass	NA					0.0	NA	NA				
Leaves	NA					0.0	NA	NA				
Branches	NA					0.0	NA	NA				
Mixed Paper (general)				NA	NA	0.0					NA	NA
Mixed Paper (primarily residential)				NA	NA	0.0					NA	NA
Mixed Paper (primarily from offices)				NA	NA	0.0					NA	NA
Mixed Metals				NA	NA	0.0					NA	NA
Mixed Plastics				NA	NA	0.0					NA	NA
Mixed Recyclables				NA	NA	0.0	NA				NA	NA
Food Waste	NA					0.0		NA				
Mixed Organics	NA	15870.0				15,870.0	NA	NA				15870.0
Mixed MSW	NA			NA	NA	0.0	NA	NA			NA	NA
Carpet				NA	NA	0.0					NA	NA
Personal Computers				NA	NA	0.0					NA	NA
Clay Bricks	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Concrete			NA	NA	NA	0.0	NA			NA	NA	NA
Fly Ash			NA	NA	NA	0.0	NA			NA	NA	NA
Tires				NA	NA	0.0					NA	NA
Asphalt Concrete			NA	NA	NA	0.0				NA	NA	NA
Asphalt Shingles				NA	NA	0.0					NA	NA
Drywall			NA	NA	NA	0.0				NA	NA	NA
Fiberglass Insulation	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Vinyl Flooring	NA			NA	NA	0.0		NA			NA	NA
Wood Flooring	NA			NA	NA	0.0		NA			NA	NA

Please enter data in short tons (1 short ton = 2,000 lbs.

Please refer to the User's Guide if you need assistance completing this table

3. In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location.

Select state for which you are conducting this analysis.

Please select state or select national average:	Missouri
Region Location:	West North Central

4. To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the "Current mix" and "100% virgin" inputs are the same.

- Current Mix
- 100% Virgin

5. The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select "No LFG Recovery" and proceed to question 8. If a LFG system is in place at your landfill, select "LFG Recovery" and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.

- National Average
- LFG Recovery
- No LFG Recovery

6a. If your landfill has gas recovery, does it recover the methane for energy or flare it?

- Recover for energy
- Flare

6b. For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.

- Typical operation - DEFAULT
- Worst-case collection
- Aggressive gas collection
- California regulatory collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
California	*Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill? The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.

- National average - DEFAULT
- Dry (k=0.02)
- Moderate (k = 0.04)
- Wet (k = 0.06)
- Bioreactor (k = 0.12)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used. Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials. Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

- ○ Wet Digestion
- ● Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application. When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultural fields. Select whether the digestate resulting from your anaerobic digester is cured before land application.

- ● Cured - DEFAULT
- ○ Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

- ○ Use Default Distances
- ● Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF). *Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	0
Combustion	20	0
Recycling	20	0
Composting	20	0
Anaerobic Digestion	20	0

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	
Organization	

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of GHG emissions, see the sheet(s) titled "Analysis Results."

Waste Reduction Model (WARM) -- Results

Total GHG Emissions from Baseline MSW Generation and Management ($MTCO_2E$):	(597.19)
Total GHG Emissions from Alternative MSW Generation and Management ($MTCO_2E$):	(1,644.45)
Incremental GHG Emissions ($MTCO_2E$):	(1,047.27)

$MTCO_2E$ = metric tons of carbon dioxide equivalent

Per Ton Estimates of GHG Emissions for Baseline and Alternative Management Scenarios

Material	GHG Emissions per Ton of Material Source Reduced ($MTCO_2E$)	GHG Emissions per Ton of Material Recycled ($MTCO_2E$)	GHG Emissions per Ton of Material Landfilled ($MTCO_2E$)	GHG Emissions per Ton of Material Combusted ($MTCO_2E$)	GHG Emissions per Ton of Material Composted ($MTCO_2E$)	GHG Emission per Ton of Material Anaerobically Digested
Aluminum Cans	(4.91)	(9.11)	0.02	0.04	NA	NA
Aluminum Ingot	(7.47)	(7.19)	0.02	0.04	NA	NA
Steel Cans	(3.06)	(1.82)	0.02	(1.57)	NA	NA
Copper Wire	(7.01)	(4.71)	0.02	0.03	NA	NA
Glass	(0.53)	(0.28)	0.02	0.03	NA	NA
HDPE	(1.47)	(0.87)	0.02	0.70	NA	NA
LDPE	(1.80)	NA	0.02	0.72	NA	NA
PET	(2.20)	(1.12)	0.02	0.93	NA	NA
LLDPE	(1.58)	NA	0.02	0.71	NA	NA
PP	(1.55)	NA	0.02	0.71	NA	NA
PS	(2.50)	NA	0.02	1.13	NA	NA
PVC	(1.95)	NA	0.02	0.43	NA	NA
PLA	(2.09)	NA	(1.65)	(0.87)	(0.15)	NA
Corrugated Containers	(5.60)	(3.12)	(0.43)	(0.70)	NA	NA
Magazines/third-class mail	(8.60)	(3.07)	(0.64)	(0.51)	NA	NA
Newspaper	(4.77)	(2.75)	(1.09)	(0.79)	NA	NA
Office Paper	(7.97)	(2.86)	0.22	(0.67)	NA	NA
Phonebooks	(6.22)	(2.64)	(1.09)	(0.79)	NA	NA
Textbooks	(9.07)	(3.11)	0.22	(0.67)	NA	NA
Dimensional Lumber	(2.03)	(2.46)	(1.05)	(0.83)	NA	NA
Medium-density Fiberboard	(2.23)	(2.47)	(0.90)	(0.83)	NA	NA
Food Waste (non-meat)	(0.76)	NA	0.22	(0.21)	(0.18)	(0.10)
Food Waste (meat only)	(15.10)	NA	0.22	(0.21)	(0.18)	(0.10)
Beef	(30.05)	NA	0.22	(0.21)	(0.18)	(0.10)
Poultry	(2.47)	NA	0.22	(0.21)	(0.18)	(0.10)
Grains	(0.62)	NA	0.22	(0.21)	(0.18)	(0.10)
Bread	(0.67)	NA	0.22	(0.21)	(0.18)	(0.10)
Fruits and Vegetables	(0.44)	NA	0.22	(0.21)	(0.18)	(0.10)
Dairy Products	(1.74)	NA	0.22	(0.21)	(0.18)	(0.10)
Yard Trimmings	NA	NA	(0.34)	(0.25)	(0.15)	(0.11)
Grass	NA	NA	0.04	(0.25)	(0.15)	(0.01)
Leaves	NA	NA	(0.64)	(0.25)	(0.15)	(0.15)
Branches	NA	NA	(0.87)	(0.25)	(0.15)	(0.25)
Mixed Paper (general)	(6.11)	(3.53)	(0.48)	(0.70)	NA	NA
Mixed Paper (primarily residential)	(6.04)	(3.53)	(0.51)	(0.70)	NA	NA
Mixed Paper (primarily from offices)	(7.41)	(3.59)	(0.37)	(0.64)	NA	NA
Mixed Metals	(3.70)	(4.34)	0.02	(1.01)	NA	NA
Mixed Plastics	(1.92)	(1.03)	0.02	0.85	NA	NA
Mixed Recyclables	NA	(2.83)	(0.46)	(0.62)	NA	NA
Food Waste	(3.66)	NA	0.22	(0.21)	(0.18)	(0.10)
Mixed Organics	NA	NA	(0.04)	(0.23)	(0.17)	(0.10)
Mixed MSW	NA	NA	(0.07)	(0.20)	NA	NA
Carpet	(3.82)	(2.36)	0.02	0.88	NA	NA
Personal Computers	(50.49)	(2.51)	0.02	(0.23)	NA	NA
Clay Bricks	(0.27)	NA	0.02	NA	NA	NA
Concrete	NA	(0.01)	0.02	NA	NA	NA
Fly Ash	NA	(0.87)	0.02	NA	NA	NA
Tires	(4.28)	(0.38)	0.02	0.50	NA	NA
Asphalt Concrete	(0.11)	(0.08)	0.02	NA	NA	NA
Asphalt Shingles	(0.19)	(0.09)	0.02	(0.36)	NA	NA
Drywall	(0.21)	0.02	(0.06)	NA	NA	NA
Fiberglass Insulation	(0.38)	NA	0.02	NA	NA	NA
Vinyl Flooring	(0.61)	NA	0.02	(0.54)	NA	NA
Wood Flooring	(4.05)	NA	(0.86)	(1.06)	NA	NA

ATTACHMENT 3

Version 14

Waste Reduction Model (WARM) -- Inputs

Use this worksheet to describe the baseline and alternative waste management scenarios that you want to compare. The blue shaded areas indicate where you need to enter information.

1. Describe the baseline generation and management for the waste materials listed below.
If the material is not generated in your community or you do not want to analyze it, leave it blank or enter 0. Make sure that the total quantity generated equals the total quantity managed

2. Describe the alternative management scenario for the waste materials generated in the baseline
Any decrease in generation should be entered in the Source Reduction column
Any increase in generation should be entered in the Source Reduction column as a negative value
Make sure that the total quantity generated equals the total quantity managed.

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Aluminum Cans				NA	NA	0.0					NA	NA
Aluminum Ingot				NA	NA	0.0					NA	NA
Steel Cans				NA	NA	0.0					NA	NA
Copper Wire				NA	NA	0.0					NA	NA
Glass				NA	NA	0.0					NA	NA
HDPE				NA	NA	0.0					NA	NA
LDPE	NA			NA	NA	0.0		NA			NA	NA
PET				NA	NA	0.0					NA	NA
LLDPE	NA			NA	NA	0.0		NA			NA	NA
PP	NA			NA	NA	0.0		NA			NA	NA
PS	NA			NA	NA	0.0		NA			NA	NA
PVC	NA			NA	NA	0.0		NA			NA	NA
PLA	NA				NA	0.0		NA				NA
Corrugated Containers				NA	NA	0.0					NA	NA
Magazines/Third-class Mail				NA	NA	0.0					NA	NA
Newspaper				NA	NA	0.0					NA	NA
Office Paper				NA	NA	0.0					NA	NA
Phonebooks				NA	NA	0.0					NA	NA
Textbooks				NA	NA	0.0					NA	NA
Dimensional Lumber				NA	NA	0.0					NA	NA
Medium-density Fiberboard				NA	NA	0.0					NA	NA
Food Waste (non-meat)	NA					0.0		NA				
Food Waste (meat only)	NA					0.0		NA				
Beef	NA					0.0		NA				
Poultry	NA					0.0		NA				
Grains	NA					0.0		NA				
Bread	NA					0.0		NA				
Fruits and Vegetables	NA					0.0		NA				
Dairy Products	NA					0.0		NA				
Yard Trimmings	NA					0.0	NA	NA				
Grass	NA					0.0	NA	NA				
Leaves	NA					0.0	NA	NA				
Branches	NA					0.0	NA	NA				
Mixed Paper (general)				NA	NA	0.0					NA	NA
Mixed Paper (primarily residential)				NA	NA	0.0					NA	NA
Mixed Paper (primarily from offices)				NA	NA	0.0					NA	NA
Mixed Metals				NA	NA	0.0					NA	NA
Mixed Plastics				NA	NA	0.0					NA	NA
Mixed Recyclables				NA	NA	0.0	NA				NA	NA
Food Waste	NA					0.0		NA				
Mixed Organics	NA	15870.0				15,870.0	NA	NA				15870.0
Mixed MSW	NA			NA	NA	0.0	NA	NA			NA	NA
Carpet				NA	NA	0.0					NA	NA
Personal Computers				NA	NA	0.0					NA	NA
Clay Bricks	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Concrete			NA	NA	NA	0.0	NA			NA	NA	NA
Fly Ash			NA	NA	NA	0.0	NA			NA	NA	NA
Tires				NA	NA	0.0					NA	NA
Asphalt Concrete			NA	NA	NA	0.0				NA	NA	NA
Asphalt Shingles				NA	NA	0.0					NA	NA
Drywall			NA	NA	NA	0.0				NA	NA	NA
Fiberglass Insulation	NA		NA	NA	NA	0.0		NA		NA	NA	NA
Vinyl Flooring	NA			NA	NA	0.0		NA			NA	NA
Wood Flooring	NA			NA	NA	0.0		NA			NA	NA

Please enter data in short tons (1 short ton = 2,000 lbs.

Please refer to the User's Guide if you need assistance completing this table

3. In order to account for the avoided electricity-related emissions in the landfilling and combustion pathways, EPA assigns the appropriate regional "marginal" electricity grid mix emission factor based on your location.

Select state for which you are conducting this analysis.

Please select state or select national average:	Missouri
Region Location:	West North Central

4. To estimate the benefits from source reduction, EPA usually assumes that the material that is source reduced would have been manufactured from the current mix of virgin and recycled inputs. However, you may choose to estimate the emission reductions from source reduction under the assumption that the material would have been manufactured from 100% virgin inputs in order to obtain an upper bound estimate of the benefits from source reduction. Select which assumption you want to use in the analysis. Note that for materials for which information on the share of recycled inputs used in production is unavailable or is not a common practice; EPA assumes that the current mix is comprised of 100% virgin inputs. Consequently, the source reduction benefits of both the “Current mix” and “100% virgin” inputs are the same.

- ◉ Current Mix
- ○ 100% Virgin

5. The emissions from landfilling depends on whether the landfill where your waste is disposed has a landfill gas (LFG) control system. If you do not know whether your landfill has LFG control, select "National Average" to calculate emissions based on the estimated proportions of landfills with LFG control in 2012 and proceed to question 7. If your landfill does not have a LFG system, select “No LFG Recovery” and proceed to question 8. If a LFG system is in place at your landfill, select “LFG Recovery” and click one of the options in 6a to indicate whether LFG is recovered for energy or flared.

- ○ National Average
- ◉ LFG Recovery
- ○ No LFG Recovery

6a. If your landfill has gas recovery, does it recover the methane for energy or flare it?

- ◉ Recover for energy
- ○ Flare

6b. For landfills that recover gas, the landfill gas collection efficiency will vary throughout the life of the landfill. Based on a literature review of field measurements and expert discussion, a range of collection efficiencies was estimated for a series of different landfill scenarios. The "typical" landfill is judged to represent the average U.S. landfill, although it must be recognized that every landfill is unique and a typical landfill is an approximation of reality. The worst-case collection scenario represents a landfill that is in compliance with EPA's New Source Performance Standards (NSPS). The aggressive gas collection scenario includes landfills where the operator is aggressive in gas collection relative to a typical landfill. Bioreactor landfills, which are operated to accelerate decomposition, are assumed to collect gas aggressively. The California regulatory collection scenario allows users to estimate and view landfill management results based on California regulatory requirements.

- ○ Typical operation - DEFAULT
- ○ Worst-case collection
- ○ Aggressive gas collection
- ◉ California regulatory collection

	Landfill gas collection efficiency (%) assumptions
Typical	*Years 0-1: 0%; Years 2-4: 50%; Years 5-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Worst-case	*Years 0-4: 0%; Years 5-9: 50%; Years 10-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
Aggressive	*Year 0: 0%; Years 0.5-2: 50%; Years 3-14: 75%; Years 15 to 1 year before final cover: 82.5%; Final cover: 90%*
California	*Year 0: 0%; Year 1: 50%; Years 2-7: 80%; Years 8 to 1 year before final cover: 85%; Final cover: 90%*

7. Which of the following moisture conditions and associated bulk MSW decay rate (k) most accurately describes the average conditions at the landfill? The decay rates, also referred to as k values, describe the rate of change per year (yr-1) for the decomposition of organic waste in landfills. A higher average decay rate means that waste decomposes faster in the landfill.

- ○ National average - DEFAULT
- ○ Dry (k=0.02)
- ○ Moderate (k = 0.04)
- ◉ Wet (k = 0.06)
- ○ Bioreactor (k = 0.12)

	Moisture condition assumptions
Dry (k=0.02)	*Less than 20 inches of precipitation per year*
Moderate (k=0.04)	*Between 20 and 40 inches of precipitation per year*
Wet (k=0.06)	*Greater than 40 inches of precipitation per year*
Bioreactor (k=0.12)	*Water is added until the moisture content reaches 40 percent moisture on a wet weight basis*
National average	*Weighted average based on the share of waste received at each landfill type*

8a. For anaerobic digestion of food waste materials (including beef, poultry, grains, bread, fruits and vegetables, and dairy products), please choose the appropriate type of anaerobic digestion process used. Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials. Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

Wet Digestion

Dry Digestion

8b. WARM assumes that digestate resulting from anaerobic digestion processes will be applied to land. In many cases, the digestate is cured before land application.
When digestate is cured, the digestate is dewatered and any liquids are recovered and returned to the reactor (when using a wet digester). Next, the digestate is aerobically cured in turned windrows, then screened and applied to agricultural fields.
Select whether the digestate resulting from your anaerobic digester is cured before land application.

Cured - DEFAULT

Not cured

9a. Emissions that occur during transport of materials to the management facility are included in this model. You may use default transport distances, indicated in the table below, or provide information on the transport distances for the various MSW management options.

Use Default Distances

Provide Information

9b. If you have chosen to provide information, please fill in the table below. Distances should be from the curb to the landfill, combustor, or material recovery facility (MRF).
***Please note that if you chose to provide information, you must provide distances for both the baseline and the alternative scenarios.**

Management Option	Default Distance (Miles)	Distance (Miles)
Landfill	20	0
Combustion	20	0
Recycling	20	0
Composting	20	0
Anaerobic Digestion	20	0

10. If you wish to personalize your results report, input your name & organization, and also specify the project period corresponding to the data you entered above.

Name	
Organization	

Project Period	From		to	

Congratulations! You have finished all the inputs.
A summary of your results awaits you on the sheet(s) titled "Summary Report."
For more detailed analyses of GHG emissions, see the sheet(s) titled "Analysis Results."

Waste Reduction Model (WARM) -- Results

Total GHG Emissions from Baseline MSW Generation and Management ($MTCO_2E$):	(597.19)
Total GHG Emissions from Alternative MSW Generation and Management ($MTCO_2E$):	(4,069.66)
Incremental GHG Emissions ($MTCO_2E$):	(3,472.47)

$MTCO_2E$ = metric tons of carbon dioxide equivalent

Per Ton Estimates of GHG Emissions for Baseline and Alternative Management Scenarios

Material	GHG Emissions per Ton of Material Source Reduced ($MTCO_2E$)	GHG Emissions per Ton of Material Recycled ($MTCO_2E$)	GHG Emissions per Ton of Material Landfilled ($MTCO_2E$)	GHG Emissions per Ton of Material Combusted ($MTCO_2E$)	GHG Emissions per Ton of Material Composted ($MTCO_2E$)	GHG Emission per Ton of Material Anaerobically Digested
Aluminum Cans	(4.91)	(9.11)	0.02	0.04	NA	NA
Aluminum Ingot	(7.47)	(7.19)	0.02	0.04	NA	NA
Steel Cans	(3.06)	(1.82)	0.02	(1.57)	NA	NA
Copper Wire	(7.01)	(4.71)	0.02	0.03	NA	NA
Glass	(0.53)	(0.28)	0.02	0.03	NA	NA
HDPE	(1.47)	(0.87)	0.02	0.70	NA	NA
LDPE	(1.80)	NA	0.02	0.72	NA	NA
PET	(2.20)	(1.12)	0.02	0.93	NA	NA
LLDPE	(1.58)	NA	0.02	0.71	NA	NA
PP	(1.55)	NA	0.02	0.71	NA	NA
PS	(2.50)	NA	0.02	1.13	NA	NA
PVC	(1.95)	NA	0.02	0.43	NA	NA
PLA	(2.09)	NA	(1.65)	(0.87)	(0.15)	NA
Corrugated Containers	(5.60)	(3.12)	(0.43)	(0.70)	NA	NA
Magazines/third-class mail	(8.60)	(3.07)	(0.64)	(0.51)	NA	NA
Newspaper	(4.77)	(2.75)	(1.09)	(0.79)	NA	NA
Office Paper	(7.97)	(2.86)	0.22	(0.67)	NA	NA
Phonebooks	(6.22)	(2.64)	(1.09)	(0.79)	NA	NA
Textbooks	(9.07)	(3.11)	0.22	(0.67)	NA	NA
Dimensional Lumber	(2.03)	(2.46)	(1.05)	(0.83)	NA	NA
Medium-density Fiberboard	(2.23)	(2.47)	(0.90)	(0.83)	NA	NA
Food Waste (non-meat)	(0.76)	NA	0.22	(0.21)	(0.18)	(0.16)
Food Waste (meat only)	(15.10)	NA	0.22	(0.21)	(0.18)	(0.16)
Beef	(30.05)	NA	0.22	(0.21)	(0.18)	(0.16)
Poultry	(2.47)	NA	0.22	(0.21)	(0.18)	(0.16)
Grains	(0.62)	NA	0.22	(0.21)	(0.18)	(0.16)
Bread	(0.67)	NA	0.22	(0.21)	(0.18)	(0.16)
Fruits and Vegetables	(0.44)	NA	0.22	(0.21)	(0.18)	(0.16)
Dairy Products	(1.74)	NA	0.22	(0.21)	(0.18)	(0.16)
Yard Trimmings	NA	NA	(0.34)	(0.25)	(0.15)	(0.36)
Grass	NA	NA	0.04	(0.25)	(0.15)	(0.08)
Leaves	NA	NA	(0.64)	(0.25)	(0.15)	(0.54)
Branches	NA	NA	(0.87)	(0.25)	(0.15)	(0.75)
Mixed Paper (general)	(6.11)	(3.53)	(0.48)	(0.70)	NA	NA
Mixed Paper (primarily residential)	(6.04)	(3.53)	(0.51)	(0.70)	NA	NA
Mixed Paper (primarily from offices)	(7.41)	(3.59)	(0.37)	(0.64)	NA	NA
Mixed Metals	(3.70)	(4.34)	0.02	(1.01)	NA	NA
Mixed Plastics	(1.92)	(1.03)	0.02	0.85	NA	NA
Mixed Recyclables	NA	(2.83)	(0.46)	(0.62)	NA	NA
Food Waste	(3.66)	NA	0.22	(0.21)	(0.18)	(0.16)
Mixed Organics	NA	NA	(0.04)	(0.23)	(0.17)	(0.26)
Mixed MSW	NA	NA	(0.07)	(0.20)	NA	NA
Carpet	(3.82)	(2.36)	0.02	0.88	NA	NA
Personal Computers	(50.49)	(2.51)	0.02	(0.23)	NA	NA
Clay Bricks	(0.27)	NA	0.02	NA	NA	NA
Concrete	NA	(0.01)	0.02	NA	NA	NA
Fly Ash	NA	(0.87)	0.02	NA	NA	NA
Tires	(4.28)	(0.38)	0.02	0.50	NA	NA
Asphalt Concrete	(0.11)	(0.08)	0.02	NA	NA	NA
Asphalt Shingles	(0.19)	(0.09)	0.02	(0.36)	NA	NA
Drywall	(0.21)	0.02	(0.06)	NA	NA	NA
Fiberglass Insulation	(0.38)	NA	0.02	NA	NA	NA
Vinyl Flooring	(0.61)	NA	0.02	(0.54)	NA	NA
Wood Flooring	(4.05)	NA	(0.86)	(1.06)	NA	NA