# What's best to do with the "Leftovers" on the way to Zero Waste?

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www.ecocycle.org/specialreports/leftovers

## INTRODUCTION

Whether a community is recycling and composting 50%, 70% or 90% of its discards, there still remain thousands of tons of mixed-waste residuals (a.k.a. "leftovers") that need to be managed and disposed of, most commonly in landfills. Lately, there has been renewed interest in burning the leftovers in waste incinerators with the capacity for energy recovery, typically referred to as waste-to-energy (WTE) plants, in order to create energy and reduce the amount of waste going to landfills. Proponents of WTE claim that this residuals management method reduces the environmental impacts of waste disposal. According to the president and CEO of Covanta Holding Corp., one of the world's largest owners and operators of WTE infrastructure,

> *"We think [our clients should] absolutely [be] pushing the recycling, but then looking to do the best with what´s leftover after that recycling. And clearly, the answer, whether you listen to the [European Union], the U.S. EPA or any kind of policy initiative, the best environmental answer after you´ve recycled is to convert what´s left over into energy."*[i]

But communities do not have the choice to just replace landfills with incinerators because incinerators still need landfills: WTE facilities send 10% of their residuals by volume to landfills, or up to 25% of residuals by weight.[ii] Even with a well-run incinerator, there is no such thing as "zero waste to landfill." This means incinerators are really just a pre-treatment option for our leftovers before landfilling. The question is, are they the best option for minimizing the negative impacts to public health and our environment?

There is another process used widely in Europe to pre-treat leftovers before landfilling that first screens the residuals to recover any additional recyclable materials and then stabilizes the organic fraction of the materials through biological treatment via a composting-like process or anaerobic digestion followed by aerobic stabilization. The process is known as mechanical biological treatment (MBT). Its goal is to create an inert mass of residuals that produces little to no landfill gas when buried, thus greatly reducing the environmental impact of landfilling the materials. This report considers a similar pre-processing scenario we call Mechanical Recovery, Biological Treatment (MRBT) to emphasize the recovery of recyclable materials in the process. See more on our MRBT scenario in the sidebar on page 4.

The question taken up by this study is this:

> **What is the best method for managing our residual waste in order to reduce the harm and risks to public health and our environment?**

**Find more details on our analysis and results at www.ecocycle.org/specialreports/leftovers.**

## OUR APPROACH

To find the answer, we took the residual waste from a leading recycling and composting community, Seattle, Washington, and ran it through eight different residual management scenarios based on the leading technologies in the marketplace today (see figure at right):

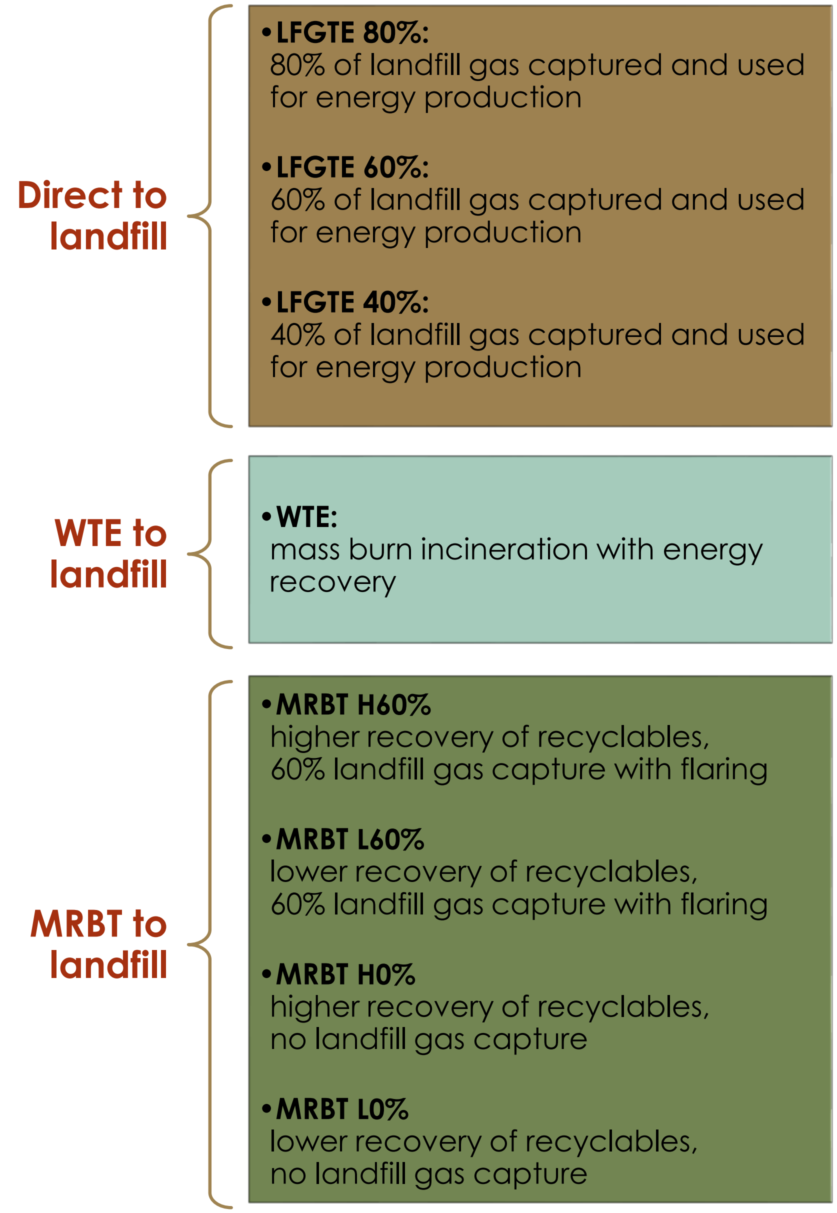
1. **Landfill with landfill-gas-to-energy** (LFGTE) with three different assumptions for gas collection efficiencies;

2. **Waste-to-energy** followed by landfilling (WTE-to-landfill) as practiced by Covanta and others in the WTE industry;

3. **Mechanical Recovery, Biological Treatment** followed by landfilling (MRBT-to-landfill) with two different assumptions for recovery of recyclables and two different assumptions for gas collection efficiencies.

These technologies were chosen to represent commercial technologies available on the market today in the U.S. and Europe. Conversion technologies, such as pyrolysis, gasification and plasma arc, were not considered since these technologies do not have commercial scale facilities with real emissions data to model in this analysis.

We then used the Measuring Environmental Benefits Calculator (MEBCalc™), created by Dr. Jeffrey Morris, to assess each leftovers management scenario across seven lifecycle environmental impacts: climate change, acidification, eutrophication, respiratory diseases, non-cancers, cancers, and ecotoxicity. The environmental impacts are caused by the pollution emitted from the various waste management



## What is MRBT?

Mechanical Recovery, Biological Treatment is a process to pre-treat leftover waste before landfilling in order to recover additional materials for recycling and minimize the impacts from landfilling. (See a schematic of the process on page 6.) MRBT can involve different methods, but for this study we assumed the following steps:

**Step 1: Source separation:** After extensive source separation for recycling and composting in the community, the remaining community waste is sent to an MRBT facility.

**Step 2: Mechanical Recovery:** The leftovers are sorted by machines and by hand to recover and market additional recyclable materials, primarily mixed paper, PET and HDPE plastics, metals and small appliances, and cardboard.

**Step 3: Biological Treatment**: The leftovers are then sent through a composting-like system where the organic fraction biodegrades and reduces in total volume due to moisture and carbon losses. The resulting stabilized output is often too dirty to market as a soil amendment, so this study assumes the residual output is landfilled. However, in some MRBT processes, the stabilized residuals may be used for restricted applications, such as land reclamation of old mines and landfills or landscaping along railways and highways, which increases the environmental benefits of using MRBT.

**Step 4: Landfill:** The remaining inert leftovers are then trucked to a landfill for burial. Because the residuals have been stabilized and produce little to no landfill gas when buried, we modeled one scenario where the gas capture rate for the buried residuals was 0%. We also ran a scenario assuming 60% gas capture with flaring in order to measure the difference in impacts versus the landfill with no gas capture. In the end, there is so little landfill gas being generated from the MRBT-processed leftovers that the environmental impacts for the 60% and 0% methane capture scenarios are nearly identical.

This MRBT-to-landfill system helps achieve an 87% landfill diversion rate for the community, combining the 70% recovery rate from source separated recycling and composting with another 17% diversion from the recovery of additional recyclables from mechanically sorting the leftovers and moisture and carbon reduction from the aerobic composting of the residuals.

activities used to handle discarded products, packaging and other materials for recycling, composting or disposal.

The composition of the residuals of our sample community, Seattle, is an important element in this analysis since most of the recyclables and compostables will have been removed by source separation efforts that have achieved a 70% residential diversion rate. Single-family households in Seattle, Washington recovered 71% of their discards in 2011, and Seattle has a detailed analysis of the remaining 29% of their leftovers, which was used as the basis for our study. (See Figure 4 on page 10 for more on what is leftover in Seattle.) While Seattle's high recycling rate makes it a national leader, much of its remaining leftovers could have been recycled or composted, leaving room for Seattle to continue to expand its recovery efforts and push for Zero Waste.

The study also assumed the energy generated from waste-to-energy and LFGTE systems was used to offset energy that would have been produced by natural gas as it is the predominant source of new electricity on the market today in the U.S. Further assumptions about the recovery rates of materials in the MRBT process and other details from the analysis can be found at www.ecocycle.org/specialreports/leftovers.

## RESULTS

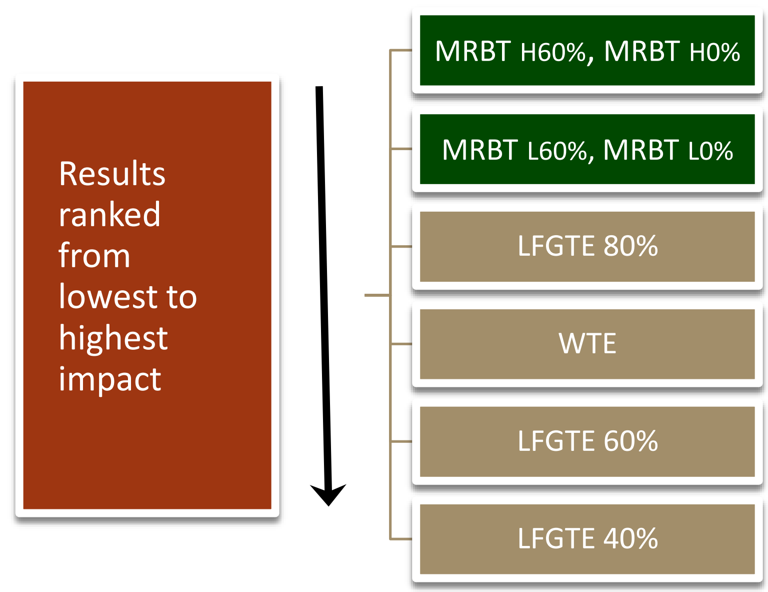
Our results are detailed in Figure 3 (page 7) and Table 1 (page 8). Highlights include:

1. **All of the options studied to manage leftover waste resulted in increased pollution in at least one of the seven public health and environmental impact categories included in this study.** This reinforces the idea that waste disposal is not beneficial and should be minimized, and priority should be given to waste reduction, reuse and separate collections of recyclables and compostables.

2. **The disposal option with the lowest overall environmental impact, as measured by monetized overall score, was MRBT-to-landfill.** In fact, MRBT-to-landfill had a net environmental benefit in all categories except ecotoxicity. This held true across all the variations on the performance of an MRBT-to-landfill system, including the high and low-recovery rate scenarios for separating recyclables from mixed waste and the two different landfill scenarios, one with 60% capture of landfill methane and one with no gas capture.

3. **The four MRBT-to-landfill scenarios had the lowest environmental impacts across five of the seven public health and environmental categories**—acidification, eutrophication, respiratory diseases, non-cancers and cancers. In terms of climate impacts, landfilling with 80% methane capture and electricity generation had lower climate impacts than the two MRBT-to-landfill scenarios that assumed low recovery rates for separating our recyclables. All three straight to landfill scenarios had lower ecotoxicity impacts than all four MRBT-to-landfill scenarios because of the benefits of displacing natural gas generated electricity with electricity generated from landfill gas. In the cases where anaerobic digestion is used for biological stabilization in MRBT-to-landfill systems, the energy production from anaerobic digestion may further (and remarkably) improve the environmental performance of MRBT-to-landfill compared with straight landfilling.

Figure 1: The results showed MRBT-to-landfill had the lowest overall environmental and human health impacts. Here is a ranking of all the assessed disposal technologies from lowest to highest overall environmental impact.



4. **The climate impact of landfills depended highly upon the effectiveness of the landfill gas capture rates**, with higher capture rates leading to a lower climate impact and lower overall environmental impact.

5. **The combustion of waste for energy, either directly through WTE plants or by burning the methane generated by organic materials in the landfill, had higher relative human health impacts**—respiratory diseases, non-cancers  cancers—than the non-combustion MRBT-to-landfill scenarios. While these energy sources displace the use of fossil fuels, they still do emit pollution and greenhouse gas emissions.

## Summary of Results

Figure 3 on page 7 summarizes the relative impacts of each leftovers management approach as they compare to each other. Any impact above the midline is "relatively worse" when compared to the other options. Likewise, impacts below the midline are relatively better in terms of less environmental impact. For example, looking at the category for "acidification," the results show that burying waste directly in landfills causes more acidification than pre-processing leftovers through MRBT or WTE.

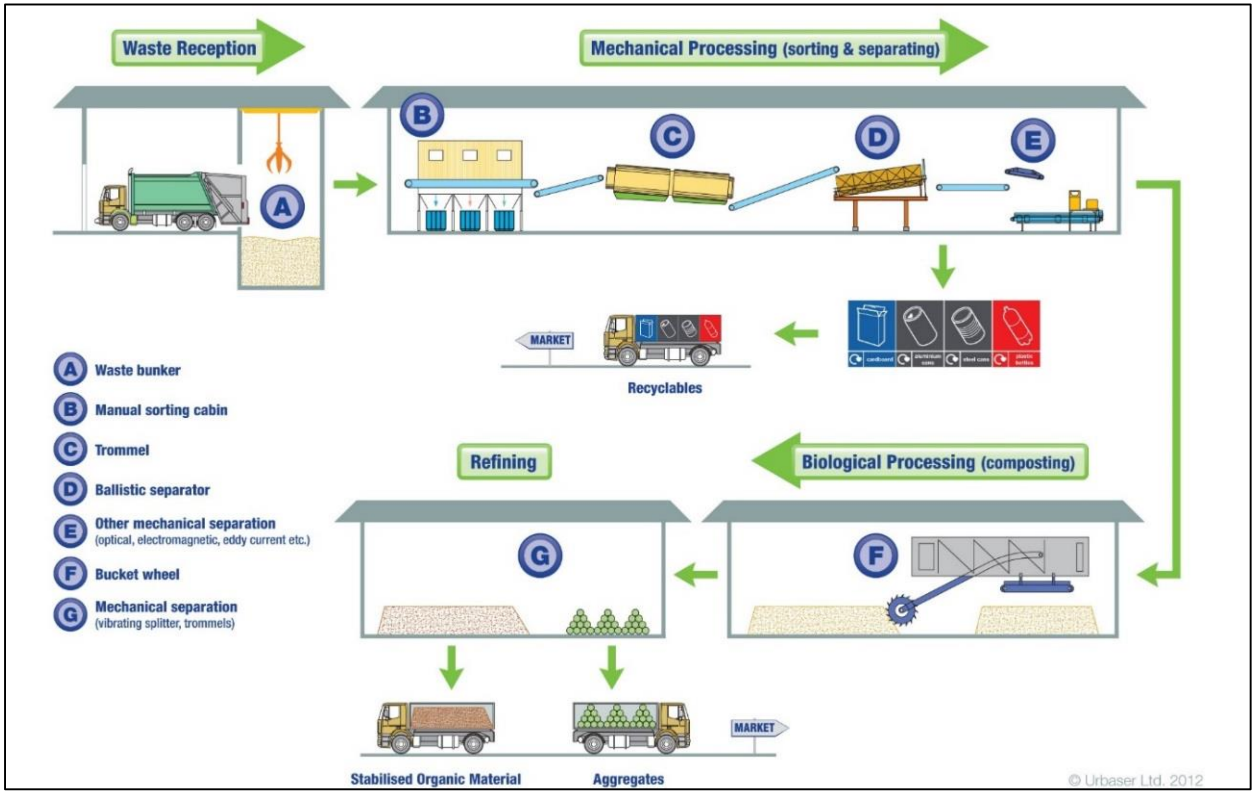
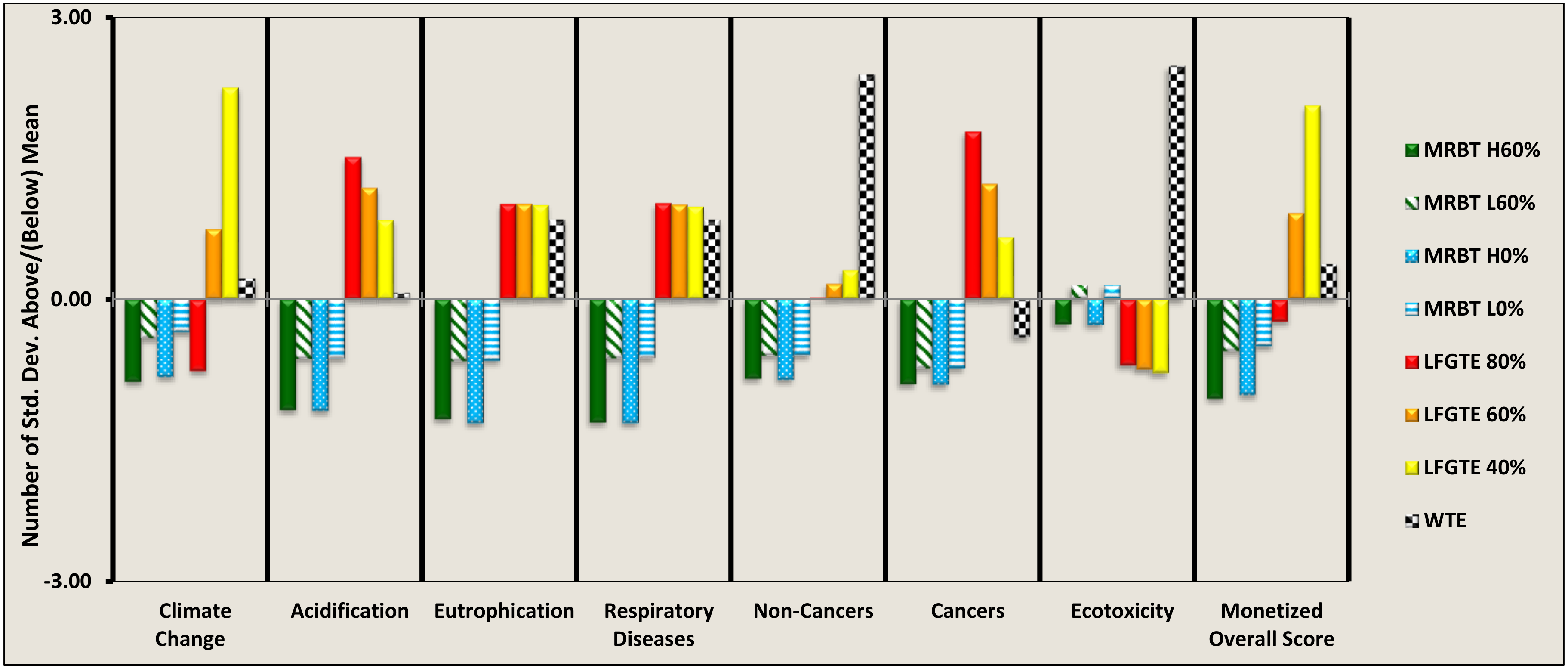



Figure 2: Schematic of an MRBT facility.

Graphic courtesy of Urbaser Ltd.

## Figure 3: Standardized Environmental Impact Scores for the Eight Management Options for Leftover Waste Remaining after 70% Recycling




Bar lengths in Figure 3 represent the number of standard deviations above or below the average impact. For example, the potential climate impact for MRBT—highly efficient processing of mixed waste to recover recyclables, biological treatment of remaining mixed waste, and disposal of treated wastes in a landfill with 60% landfill gas capture—is 0.9 standard deviations below the average climate impact for all eight management options. Straight disposal of mixed waste in a landfill with just 40% capture of landfill gases is 2.3 standard deviations above the average climate impact for the eight management options.

Table 1 compares the actual environmental impacts of each leftovers management strategy and then expresses the total environmental impact as an economic cost in the bottom row through a technique called monetization.

**Table 1: Environmental Impacts for Post 70% Diversion Discards Management Options**

| Impact Category | Increase/Decrease in Environmental Impact Potential (measured in pounds of each impact category's indicator pollutant per incoming ton) | | | | | | | | Monetized Impact ($/Ton of Emissions) |
|---|---|---|---|---|---|---|---|---|---|
| | MR(Hi)BT 60% | MR(Lo)BT 60% | MR(Hi)BT 0% | MR(Lo)BT 0% | LFGTE 80% | LFGTE 60% | LFGTE 40% | WTE | |
| **Climate Change ($eCO_2$)** | -4.2E+02 | -1.9E+02 | -3.9E+02 | -1.5E+02 | -3.6E+02 | 3.9E+02 | 1.1E+03 | 1.3E+02 | **$40** |
| **Acidification ($eSO_2$)** | -2.5E+00 | -1.4E+00 | -2.5E+00 | -1.4E+00 | 2.8E+00 | 2.1E+00 | 1.5E+00 | -3.4E-02 | **$290** |
| **Eutrophication (eN)** | -1.8E+00 | -1.3E+00 | -1.8E+00 | -1.3E+00 | 1.3E-01 | 1.2E-01 | 1.2E-01 | -1.1E-02 | **$4** |
| **Respiratory ($ePM_{2.5}$)** | -7.0E-01 | -4.9E-01 | -7.0E-01 | -4.9E-01 | 2.7E-02 | 2.1E-02 | 1.5E-02 | -2.8E-02 | **$10,000** |
| **Non-cancer (eT)** | -5.2E+01 | -4.1E+01 | -5.2E+01 | -4.1E+01 | -1.2E+01 | -5.5E+00 | 1.2E+00 | 9.7E+01 | **$30** |
| **Cancer (eB)** | -3.2E-01 | -1.5E-01 | -3.2E-01 | -1.5E-01 | 2.3E+00 | 1.8E+00 | 1.2E+00 | 1.7E-01 | **$3,030** |
| **Ecotoxicity (e2,4-D)** | 1.0E-03 | 1.6E-03 | 1.0E-03 | 1.6E-03 | 3.6E-04 | 2.9E-04 | 2.3E-04 | 5.1E-03 | **$3,280** |
| **MONETIZED OVERALL SCORE** | **- $13** | **- $7** | **- $13** | **- $7** | **- $3** | **+ $11** | **+ $25** | **+ $4** | |

It can be difficult to objectively assess if it is more important to reduce greenhouse gas emissions, cancer risks or water pollution because the answer varies by individual and community, and it depends upon a value-based judgment and personal beliefs. Economists use monetization to apply a dollar value to environmental impacts in order to provide a more objective comparison across different impacts. According to Dr. Morris,

> *"Monetization provides a method for evaluating trade-offs between the different types of environmental impacts and is a standard approach within the field of environmental economics. One difficulty is that monetization is controversial, especially regarding the issue of placing a dollar value on human and non-human lives. The benefit of monetization is that it summarizes and aggregates the environmental impacts into a single indicator for each management option."*

The monetized score in Table 1 shows the environmental benefits or additional costs of managing our leftovers by each of the eight methods studied. A negative monetized overall score indicates that the option's environmental impacts are offset through avoidance of environmental impacts by replacing virgin materials used for manufacturing products with recycled materials and/or by replacing electricity generated by natural gas fueled power plants with electricity generated from waste. These negative or positive monetized overall scores can also be considered the environmental externality benefits or costs associated with each technology. **The MRBT-to-landfill scenarios produce the highest reductions in overall environmental impacts and in fact yield an externality benefit between $7 and $13 per ton of MSW leftovers for a community that recycles and composts most of its discards.**

Curbside composting programs in cities such as Portland, OR (above) and Seattle, WA are helping households recover 70% of their discards.

## IMPLICATIONS

In the U.S. today, communities debating future infrastructure investments to manage their leftovers are rarely considering the best environmental option—MRBT-to-landfill. This study proves this landfill pre-processing system is environmentally preferable to WTE facilities or direct landfilling because it recovers the greatest amount of additional recyclables, stabilizes the organic fraction of the residuals, reduces the amount of material to be disposed of in a landfill, and minimizes the negative environmental and public health impacts of landfilling leftovers compared to the available alternatives.

Unfortunately, communities often see only the capital and operating costs per ton of operating disposal facilities, and they do not account for the costs incurred from damages to public health and the environment. This can lead to poor decision making and investments in technologies that result in higher environmental and public health risks and higher overall system costs. Communities can use the monetized environmental impact costs per ton in Table 1 to understand the full economic impact of their investment choices on their community's health, the health of our ecosystems and their bottom line.

The MRBT-to-landfill system provides other important benefits for the community, as well. Foremost is the flexibility and dual-purpose of the technology, which allows for the processing of clean or dirty material streams as community's needs change. For example, as a community diverts more and more of its discards, getting closer to Zero Waste, the biological stabilization component of an MRBT facility can shift to receiving and processing source-separated organics (SSO) and producing valuable soil amendments. This solves the problem faced by the WTE-to-landfill systems, which are designed and built for a minimum annual amount of leftovers and negotiated through a "put or pay" contract where the community is liable to fuel the plant for 20-30 years. As communities recover more resources and generate fewer leftovers, WTE facilities must find alternative waste to fuel the system, putting the WTE system in direct competition with higher recovery rates. By contrast, the MRBT system will not suffer financially as a community keeps going all the way to 90% diversion or higher.

MRBT facilities require a markedly shorter time to be designed, built and put into operation than WTE, which translates into a faster reduction of the negative environmental impacts of waste disposal and of the volume of waste headed to landfills, which could quickly extend the life of existing landfills. MRBT is also scalable and can be designed to serve much smaller waste management districts than any type of WTE installation. This allows a community to treat and manage its leftovers locally, helping a community be more self-reliant and best fulfilling the proximity principle.

Finally, MRBT facilities can facilitate further materials recovery in the future if paired with a research component to understand the composition of the remaining dry residuals and evaluate strategies to target additional recovery of these items. For example, the mechanical sorting system may also pull many non-recyclable dry items from the mixed waste and use this as a starting point to work with industry to redesign their packaging, so that it will no longer be considered a leftover. Once items like this are sorted and clearly identified, the producers can be incentivized (or penalized) in accordance with a community's goals.

Figure 4: Top ten materials in household leftovers in Seattle, WA after recycling and composting. Find the full study at http://www.seattle.gov/util/Documents/Reports/SolidWasteReports/CompositionStudies/index.htm.

| Material | Percentage of leftovers |
|---|---|
| Food | 28.8% |
| Animal byproducts | 12.8% |
| Disposable diapers | 9.9% |
| Compostable/soiled paper | 7.3% |
| Mixed low-grade paper | 4.9% |
| Other plastic film | 4.4% |
| Textiles/clothing | 3.2% |
| Mixed/other paper | 1.4% |
| Durable plastic products | 1.3% |
| Mixed textiles | 1.2% |
| **Total** | **75.1%** |

Managing residuals through MRBT should always be second to increasing source-separation efforts which deliver higher quality recyclables and compost and result in the highest environmental benefits. MRBT is not a replacement or substitution for source separation, but it is a valuable tool for helping communities reduce their environmental impact on the way to Zero Waste.

## ECONOMIC ANALYSIS

While this study does not compare the economic impacts of managing leftovers across these three leading disposal technologies, we believe MRBT-to-landfill does hold a significant economic advantage over WTE, and this could be the focus of a future study. The MRBT option is a much less expensive system to build than WTE, and it can be more quickly implemented in order to reduce the amount of waste headed to landfills and reduce the associated negative impacts. It also offers a flexible processing approach that can be repurposed to handle increasing levels of source-separated organics as the amount of mixed waste decreases. The lower upfront facility costs and process flexibility from MRBT are significant positives considering that the amount of mixed waste residuals needing disposal will be a moving target over time as communities steadily increase their recycling/composting rates and decrease their total waste amounts.

Experience from the European Union with similar MBT facilities supports all of the evidence in favor of MRBT-to-landfill identified above:

- MBT is inherently more flexible than incineration
- There is less public opposition to these technologies than to larger, less flexible technologies, like incineration, so it is generally far quicker to achieve planning and environmental permitting.
- It is quicker to build and start operating facilities.
- MBT is cheaper to build and operate facilities.[iii]

## CONCLUSIONS

After maximizing their source separated recycling and composting efforts, communities looking to minimize the environmental impacts of their remaining waste should pursue an MRBT-to-landfill system because it recovers the greatest amount of additional recyclables, stabilizes the organic fraction of the residuals, reduces the amount of material to be disposed of in a landfill, and minimizes the negative environmental and public health impacts of landfilling leftovers compared to the available alternative technologies. This study shows that it is reasonable to conclude that the MRBT option is not only the best environmental practice for managing residuals, but it is also the best community strategic option, as well.

**Read more about MEBCalc™ and lifecycle analysis, learn about our assumptions around capture and efficiency rates, and more at www.ecocycle.org/specialreports/leftovers.**

## ABOUT THE AUTHORS

Dr. Jeffrey Morris is an economist and life cycle assessment expert with Sound Resource Management Group based in Olympia, Washington. Dr. Enzo Favoino is a Senior Researcher at Scuola Agraria del Parco di Monza in Milan, Italy. Eric Lombardi is the Executive Director of Eco-Cycle, a Zero Waste Social Enterprise based in Boulder, Colorado. Kate Bailey is the Senior Analyst for Eco-Cycle. We all work professionally on the issue of the environmental impacts from different waste management approaches and strategies intended to maximize materials recovery.

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