What is the best disposal option for the "Leftovers" on the way to Zero Waste?

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www.ecocycle.org/specialreports/leftovers

INTRODUCTION

Zero Waste communities push for ever-higher resource recovery rates through a strong emphasis on source-separated recycling and composting, waste reduction and reuse programs. While leading communities continue to progress toward 90% recovery and better, there can still remain many thousands of tons of mixed-waste residuals (a.k.a. "leftovers") that need to be 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 and is the preferred option. 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 their 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 "pre-treating" our leftovers before landfilling. The question is, are they the best disposal option for minimizing the negative impacts to public health and our environment from our leftover waste?

There is another method used widely in Europe to pre-treat leftovers before landfilling that could be a viable alternative to WTE. The process first screens the residuals to recover any additional recyclable materials and then stabilizes the organic fraction through either a composting-like process or anaerobic digestion followed by aerobic stabilization. The entire process is known as mechanical biological treatment (MBT). Its goal is to capture any remaining recyclables and then 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 Material 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 main 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?**

And further, are there options that keep the system flexible in order to achieve ever-increasing recycling rates and ever-decreasing amounts of discards while delivering good environmental performance?

OUR APPROACH

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

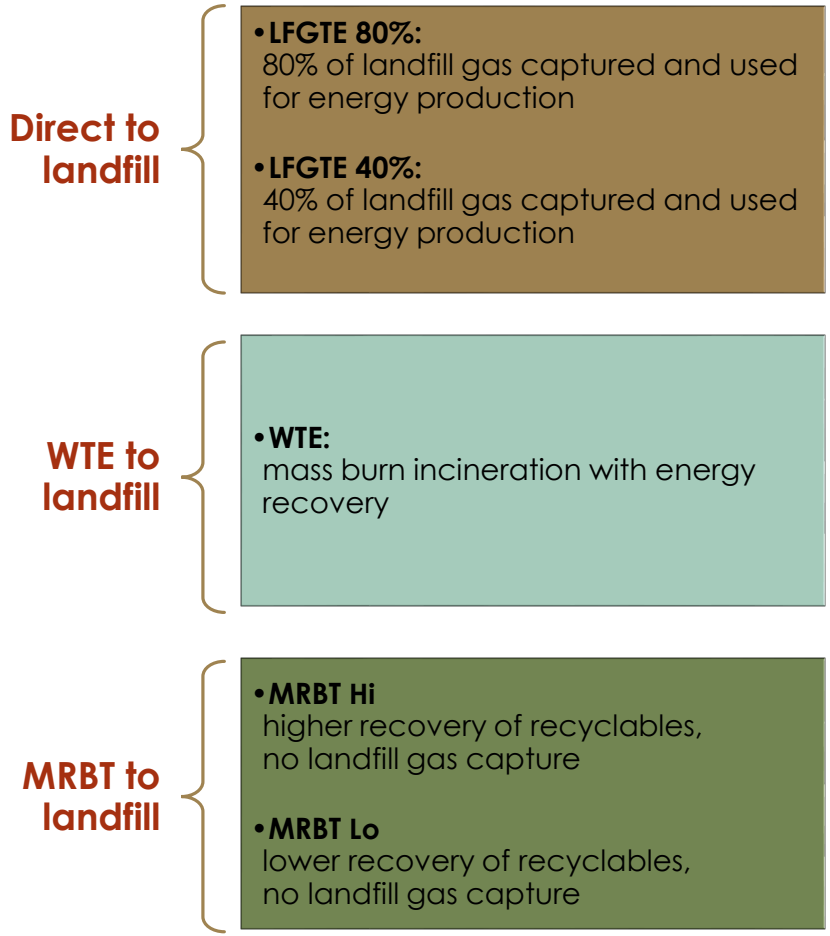
1. **Landfill with landfill-gas-to-energy** (LFGTE) with two different assumptions for gas collection efficiencies;

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

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

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. These environmental impacts are



What is MRBT?

Material 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 7.) 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 leftovers are sent to an MRBT facility.

Step 2: Material 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 assumed the processed leftovers were buried in a landfill with no gas capture system.

MRBT should not be confused with a mixed waste processing facility that relies upon technology to separate recyclables from trash in place of asking residents and businesses to source separate these materials first, such as was proposed recently in Houston, Texas. MRBT can be a complement to source separation efforts to further increase diversion rates and reduce the environmental impacts of a community's leftovers, but it is not a replacement for source separation, which should be given highest priority.

caused by the pollution emitted from the various waste management activities used to handle discarded products, packaging and other materials for recycling, composting or disposal.

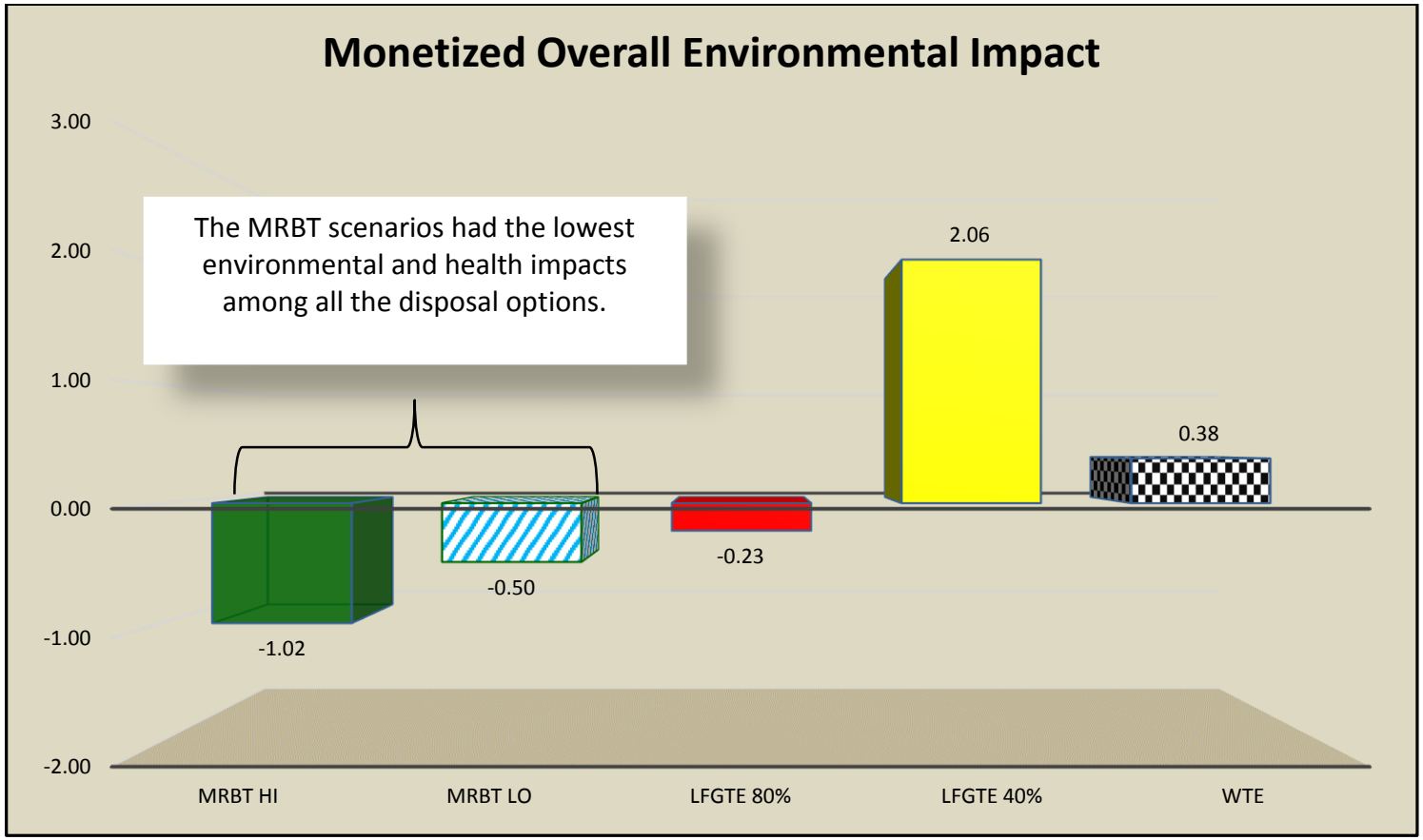
The composition of the residuals in our sample community, Seattle, is an important element in this analysis since most of the recyclables and compostables were removed by source-separation efforts. Single-family households in Seattle, Washington recovered 71% of their discards in 2011, and Seattle has a detailed analysis of the remaining 29% of its leftovers, which was used as the basis for our study. (See Figure 4 on page 12 for more on what is leftover after recycling 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 WTE and LFGTE systems was used to offset energy that would have been produced by natural gas as natural gas 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.

KEY FINDING

The disposal option with the lowest overall environmental impact, as measured by monetized overall score, was MRBT-to-landfill. This held true across both variations on the performance of an MRBT-to-landfill system, the high and low materials recovery rate scenarios for separating recyclables from mixed waste. Our results are detailed in Figure 3 (page 8) and Table 1 (page 9).

Figure 1: The results showed MRBT-to-landfill had the lowest overall environmental and human health impacts.



OTHER KEY FINDINGS

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 fact 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 two 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% gas capture and electricity generation had lower climate impacts than the MRBT-to-landfill scenario that assumed low recovery rates for separating out recyclables. The direct-to-landfill scenarios had lower ecotoxicity impacts than the MRBT-to-landfill scenarios because of the benefits of using landfill gas to generate electricity in place of electricity that would have come from natural gas-fueled power plants. 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 direct landfilling in terms of climate change and ecotoxicity impacts.

3. **MRBT-to-landfill, when utilized by a community with successful recycling and composting programs, can help achieve very high levels of resource recovery.** The MRBT-to-landfill system modeled for Seattle, WA helps achieve an 87% diversion rate for the community—71% recovery from source-separated recycling and composting, and another 16% diversion from MRBT, including the recovery of additional recyclables from mechanically sorting the leftovers and the moisture and carbon reduction from the aerobic composting of the residuals. This remarkable recovery rate demonstrates MRBT can move a community closer to Zero Waste while still supporting source separation as the highest and best priority.

4. **The climate impacts of landfills depended highly upon the effectiveness of the landfill gas capture system**, 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, and cancers—than the non-combustion MRBT-to-landfill scenarios. While these energy sources displace the use of fossil fuels, they still emit pollution and greenhouse gas emissions.

6. **Communities should continue to focus on decreasing the amount of leftovers they produce through recycling, composting and waste reduction programs in order to achieve the greatest environmental and public health benefits.** While MRBT-to-landfill is the best environmental option for disposing of leftovers, it is no substitute for recycling and composting programs that prevent the disposal of leftovers in the first place. The environmental benefits of recycling and composting were estimated at $120 per ton in Portland, Oregon using the MEBCalc model used in this report.[iii] That means the environmental benefits of recycling and composting are nearly ten times greater than the best disposal option, reinforcing that these programs should be the top priority for communities in managing their discards.

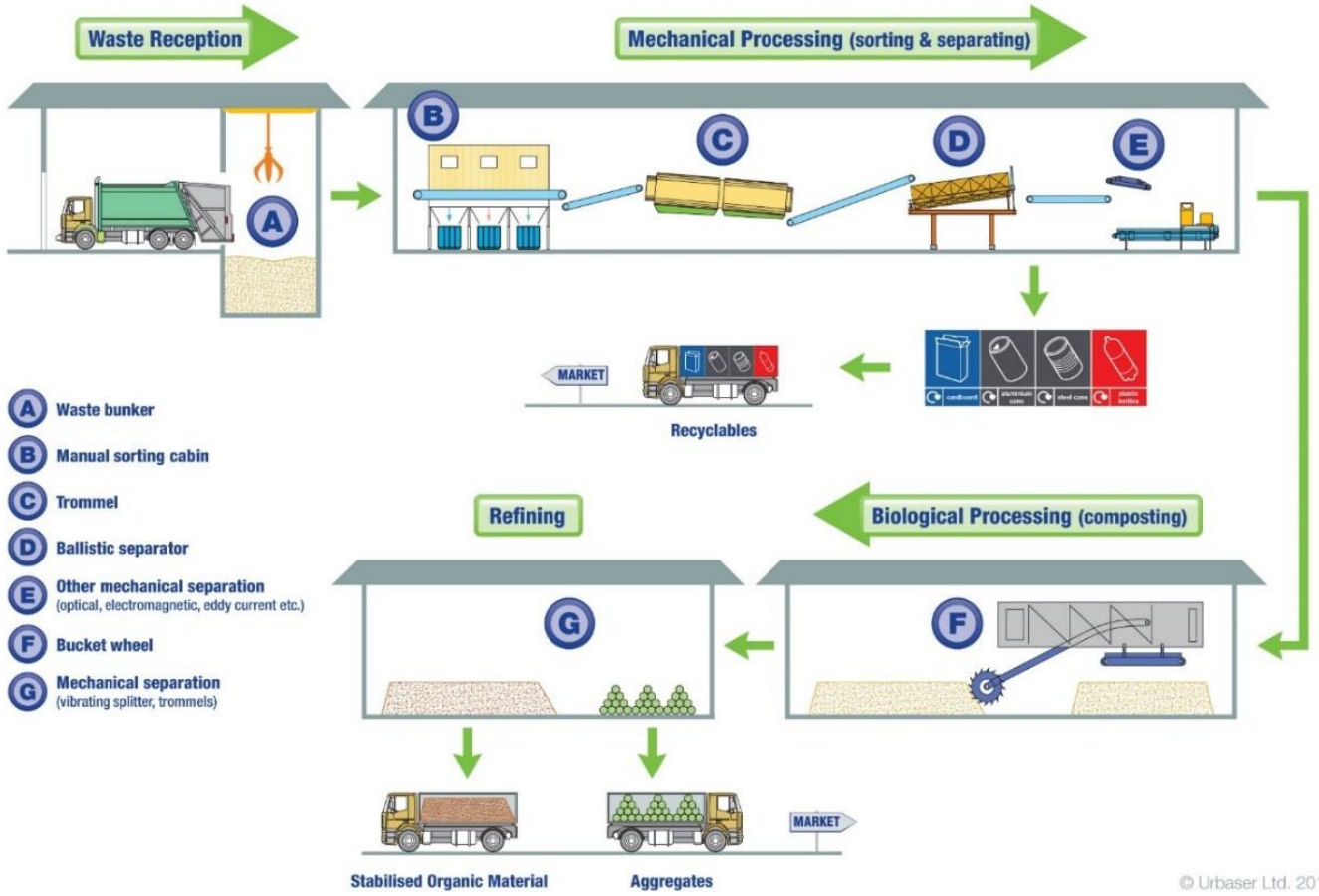
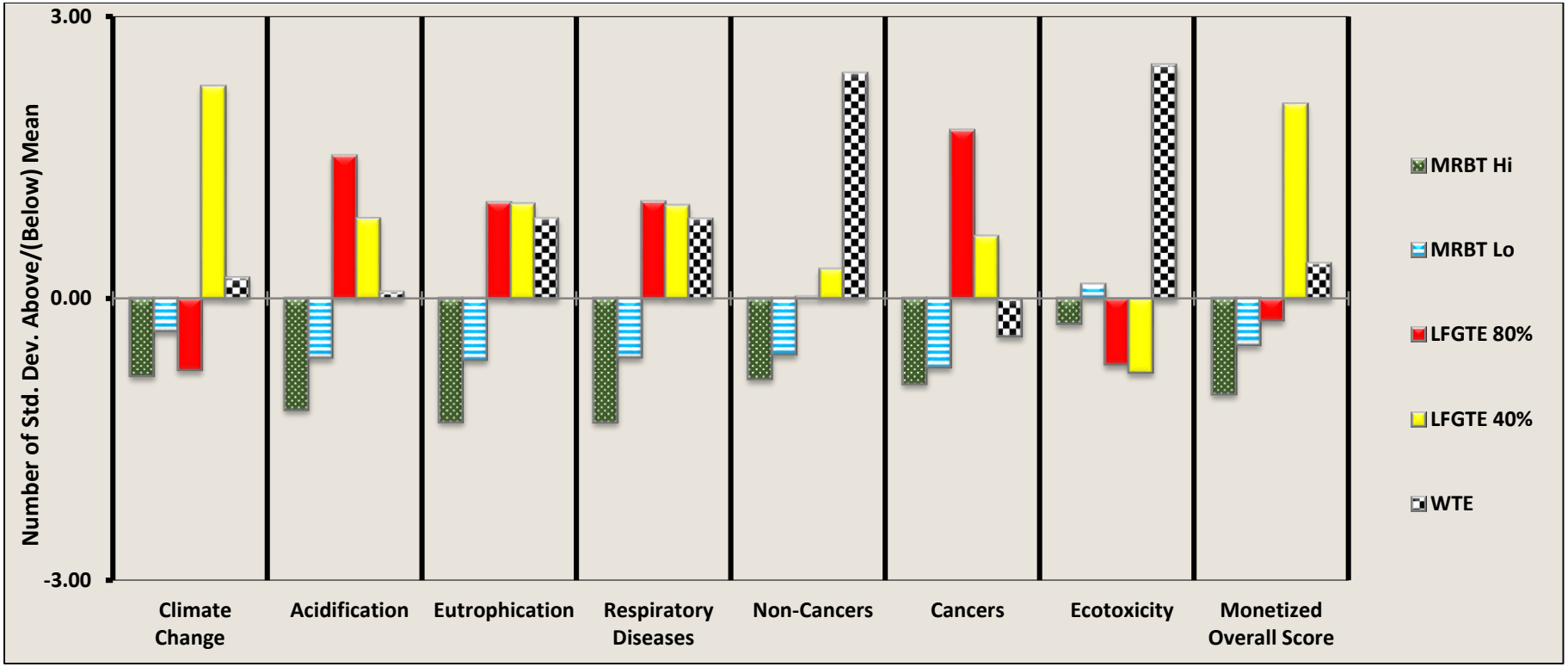


Figure 2: Schematic of an MRBT facility.

Graphic courtesy of Urbaser Ltd.

Figure 3: Standardized Environmental Impact Scores for the Five 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 Hi is 0.9 standard deviations below the average climate impact for all five disposal options, while direct disposal of mixed waste in a landfill with just 40% capture of landfill gas is 2.3 standard deviations above the average climate impact for the five management options.

Table 1: Environmental Impacts for the Five Management Options for Leftover Waste Remaining after 70% Recycling

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)
	MRBT Hi	MRBT Lo	LFGTE 80%	LFGTE 40%	WTE	
Climate Change (eCO_2)	-3.90E+02	-1.50E+02	-3.60E+02	1.10E+03	1.30E+02	**$40**
Acidification (eSO_2)	-2.50E+00	-1.40E+00	2.80E+00	1.50E+00	-3.40E-02	**$290**
Eutrophication (eN)	-1.80E+00	-1.30E+00	1.30E-01	1.20E-01	-1.10E-02	**$4**
Respiratory ($ePM_{2.5}$)	-7.00E-01	-4.90E-01	2.70E-02	1.50E-02	-2.80E-02	**$10,000**
Non-cancer (eT)	-5.20E+01	-4.10E+01	-1.20E+01	1.20E+00	9.70E+01	**$30**
Cancer (eB)	-3.20E-01	-1.50E-01	2.30E+00	1.20E+00	1.70E-01	**$3,030**
Ecotoxicity (e2,4-D)	1.00E-03	1.60E-03	3.60E-04	2.30E-04	5.10E-03	**$3,280**
MONETIZED OVERALL SCORE	**- $13**	**- $7**	**- $3**	**+ $25**	**+ $4**	

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.

EXPLANATION OF RESULTS

Figure 3 on page 8 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 lower 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.

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 depends upon a value-based judgment and personal beliefs. Economists use a technique called 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 translates the seven environmental impacts of the five disposal methods studied into economic benefits or costs. The MRBT-to-landfill scenarios have a negative score, which means there is a net environmental benefit to managing leftovers with

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

MRBT and the economic value of that benefit is between $7 and $13 per ton of MSW leftovers for a community that recycles and composts most of its discards.

This should not be interpreted to mean producing waste is a good thing for the environment. Rather, the results show that the overall environmental pollution reductions and energy savings gained by recovering and marketing the additional recyclable materials through MRBT, and using these recycled materials to replace virgin materials for manufacturing new products, more than offset the negative environmental impacts that occur from landfilling residuals after MRBT.

WTE, by contrast, has a positive monetized score, which means it results in a net environmental cost. Even though WTE facilities create some environmental benefit because the energy they produce replaces electricity generated by natural gas fueled power plants, the overall detrimental impacts of WTE are greater than the benefits from energy production. The result is an overall environmental harm to the

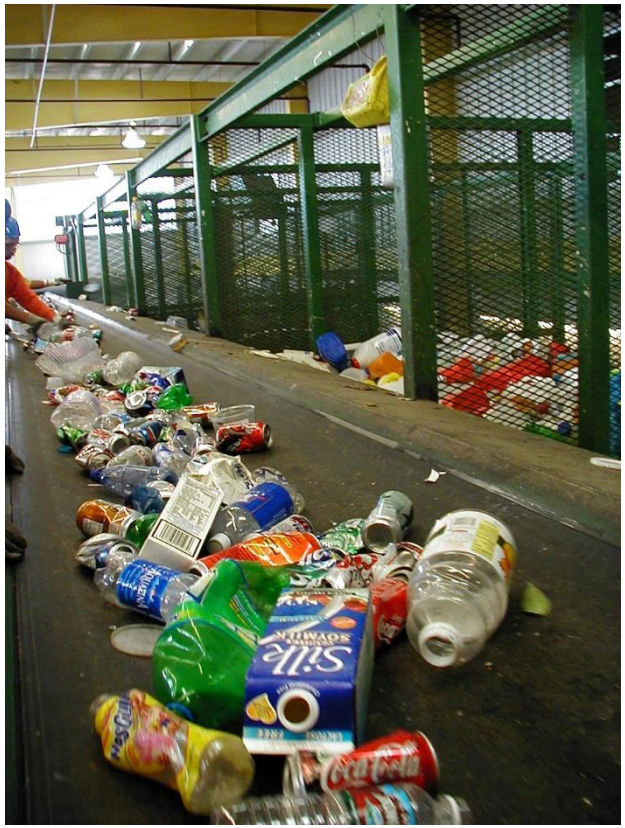
community. This environmental cost is valued at $4 per ton for a community that recycles and composts most of its discards. These negative or positive monetized overall scores can also be considered the environmental externality associated with each technology.

It is counter-intuitive to think that any type of waste disposal has a net environmental "benefit" because it implies that producing waste could be good for the environment. This is not true—producing, consuming and throwing away materials causes harm to our environment. This study only looks at the environmental impacts of waste disposal and not the upstream impacts of creating the products and packaging that end up as leftovers. When the entire cycle of resource extraction, manufacturing and product consumption are also taken into account, there is quite a substantial net cost to our environment from producing and consuming products and packaging.

IMPLICATIONS

Source-separated recycling and composting programs, paired with waste reduction and reuse campaigns, remain the best strategy for managing discarded materials. While leading U.S. communities such as Seattle are pushing 70% recycling rates, there are still more gains to be made along the road to Zero Waste. This report does not pit source separation against MRBT, but rather compares MRBT with other disposal technologies—WTE and landfilling.

While recovery programs should remain the focus, communities are continuously evaluating their disposal infrastructure and capacity, and the impacts of their leftovers. When doing so, it is paramount for the community to keep in mind how its discards stream will change as recovery rates increase. By looking ahead and considering the best options for managing its leftovers in the present and the future, a



MRBT-to-landfill is not a replacement or substitution for source-separated recycling and composting, but it is a valuable tool for helping communities reduce the environmental impacts from the disposal of their leftovers on the way to Zero Waste.

community can find the technology that best fits its goals of increasing recovery, decreasing disposal and reducing environmental risks. The goal is to avoid investing in disposal technologies that are not compatible with a decreasing amount of leftovers or lead to more pollution and detrimental environmental and public health impacts.

In the U.S. today, communities debating future infrastructure investments to dispose of their leftovers are rarely considering the best environmental option—MRBT-to-landfill. This study proves this landfill pre-processing system is environmentally preferable to both WTE facilities and 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. MRBT-to-landfill is still not preferable to recovering materials through recycling and composting programs, but it is the best environmental option for disposal in the interim while recovery efforts and rates improve.

FLEXIBILITY FOR THE FUTURE

The MRBT-to-landfill system provides other important benefits for the community that are harder to quantify. Foremost is the flexibility and dual-purpose of the technology, which allows for the processing of clean or dirty material streams as a 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. By contrast, WTE-to-landfill systems are designed and built for a never-decreasing

What's in the leftovers?

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 of Leftovers	**75.1%**

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.

annual amount of leftovers, often 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 burner, putting the WTE system in direct competition with higher recovery rates. WTE facilities cannot be a bridge to a Zero Waste future when their economic and operational model is dependent upon a constant source of leftover waste. On the other hand, MRBT systems can shift processing capacities to source-separated feedstocks and 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 new WTE or landfill facilities, which translates into a faster reduction in the negative environmental impacts of waste disposal and 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 conventional mass-burn WTE facilities. This allows a community to treat and manage its leftovers locally, helping the 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 and products so that they can be recovered instead of disposed. Once items like this are sorted and clearly identified, the manufacturers can be incentivized (or penalized) in accordance with a community's goals.

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 and recyclables 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.[iv]

CONCLUSIONS

WTE facilities are not the best environmental option for managing leftover waste and they are not a bridge to a Zero Waste future, as claimed by the WTE industry. 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 disposing of residuals, but it is also the best community strategic option as well. MRBT is not a replacement or substitution for source-separated recycling and composting, but it is a valuable tool for helping communities reduce the environmental impacts from the disposal of their leftovers on the way to Zero Waste.

ABOUT THE AUTHORS

Dr. Jeffrey Morris is an economist and lifecycle 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 environmental impacts of different waste management approaches and strategies intended to maximize materials recovery.

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

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