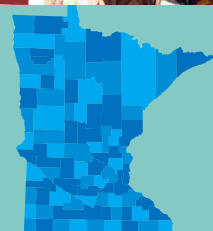
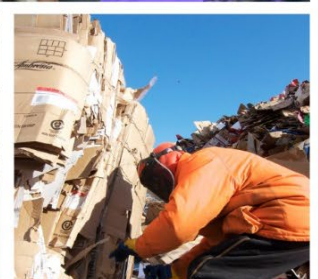


May 2026

DRAFT

Minnesota Resource Management Report



Legislative charge

170.27 Sec. 35. RESOURCE MANAGEMENT; REPORT. By January 15, 2026, the commissioner of the Pollution Control Agency must conduct a study and prepare a report that includes a pathway to implement resource management policies, programs, and infrastructure. The commissioner must submit the report to the chairs and ranking minority members of the senate and house of representatives committees with jurisdiction over environmental policy and finance and energy policy. The report must include: (1) an overview of how municipal solid waste is currently managed, including how much material is generated in the state and is reused, recycled, composted, digested, or disposed of; (2) a summary of infrastructure, programs, policies, and resources needed to reduce the amount of materials disposed of in landfills or incinerators statewide by more than 90 percent over a 2021 baseline by 2045 or sooner. The summary must include analysis and recommendations of scenarios above Waste-to-Energy on the state's Waste Hierarchy that maximizes the environmental benefits when meeting the 90 percent reduction target; (3) an analysis of: (i) waste prevention program impacts and opportunities; (ii) how much additional capacity is needed after prevention for reuse, recycling, composting, and anaerobic digestion systems to achieve that goal; and (iii) what steps can be taken to implement that additional capacity, including working collaboratively with local governments, industry, and community-based organizations to invest in such facilities and to work together to seek additional state and federal funding assistance; (4) strategic programmatic, regulatory, and policy initiatives that will be required to produce source reduction, rethink and redesign products and packaging to more efficiently use resources, and maximize diversion from disposal of materials in a way that prevents pollution and does not discharge to land, water, or air or threaten the environment or human health; (5) recommendations for reducing the environmental and human health impacts of waste management, especially across environmental justice areas as defined under Minnesota Statutes, section 115A.03, and ensuring that the benefits of these resource management investments, including the creation of well-paying green jobs, flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution and that land, water, air, and climate impacts are considered; and (6) a review of feasibility, assumptions, costs, and milestones necessary to meet study goals. (b) The commissioner must obtain input from counties and cities inside and outside the seven-county metropolitan area; reuse, recycling, and composting facilities; anaerobic digestion facilities; waste haulers; environmental organizations; community-based organizations; Tribal representatives; and diverse communities located in environmental justice areas that contain a waste facility. The commissioner must provide for an open public comment period of at least 60 days on the draft report. Written public comments and commissioner responses to all those comments must be included in the final report.

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Executive Summary

To be added once report content is finalized.

Introduction

In 2023, the Minnesota Legislature directed the Minnesota Pollution Control Agency (MPCA) to prepare a comprehensive Resource Management Report. The Legislature charged the MPCA with conducting a study and preparing a report that identifies pathways to implement resource management policies, programs, and infrastructure across Minnesota.

In 2024, the MPCA contracted Resource Recycling Systems (RRS) to develop waste reduction scenarios and recommendations. This work includes analysis of a scenario in which Minnesota reduces disposal of municipal solid waste (MSW) in landfills and waste-to-energy (WTE) facilities by more than 90 percent compared to a 2021 baseline by 2045 or sooner, using management methods higher on the waste management hierarchy. This scenario is not a mandated target, but rather an analytical framework used to understand the scale of system changes, investments, and policy approaches that would be required to achieve such an outcome. The analysis also includes a comparison of system pathways with and without reliance on waste-to-energy.

As directed by the Legislature, the Resource Management Report:

- Describes how MSW is currently being managed across Minnesota.
- Analyzes prevention, reuse, recycling, composting, and anaerobic digestion (AD), including the capacity needed to achieve these outcomes.
- Recommends infrastructure, programs, policies, investments, and milestones to support implementation.
- Incorporates environmental justice considerations by identifying opportunities to reduce disproportionate pollution burdens and improve access to benefits, including the creation of well-paying green jobs, are accessible to historically marginalized communities.

This report does not evaluate or make recommendations regarding any single facility. Instead, it examines statewide systems and identifies opportunities for transformation and innovation across Minnesota's waste and materials management system.

The findings indicate that progress would depend on sustained system-wide changes, including policy development, infrastructure investment, and community engagement. Achieving these outcomes would require long-term coordination across state agencies, local governments, industry, and residents, and would occur incrementally over multiple decades. These outcomes depend on a range of factors, including technological feasibility, market conditions, policy decisions, and sustained funding over time.

RRS and the MPCA thank the hundreds of stakeholders who contributed to this report through meetings, interviews, surveys, and public comments, including counties and cities, Tribes, environmental justice communities, waste facilities, haulers, environmental organizations, and community-based partners.

This Resource Management Report presents a statewide analysis of waste and materials management systems, informed by stakeholder engagement and scenario modeling.

Overview of Municipal Solid Waste Generated in Minnesota

Minnesota generated approximately 5.86 million tons of MSW in 2021, equivalent to approximately 5.63 pounds per person per day. These figures are based on county-reported data through Minnesota's statewide SCORE reporting system, which requires counties to report both disposal and diversion annually. This section presents Minnesota's 2021 data on waste management, including reuse, recycling, and disposal, which serve as the baseline for evaluating system performance and measuring progress toward statewide diversion outcomes. These data provide the foundation for the modeling and scenario analysis presented in subsequent sections. In 2021, municipal solid waste in Minnesota was managed through a combination of recycling, organics management, mixed waste processing, and disposal. Of the total waste generated, approximately 42 percent was recycled or composted, while the remaining 58 percent was managed as disposal through landfilling and WTE. Disposal in Minnesota refers to the management of waste through landfilling and WTE facilities.

Data Limitations

The tonnage data presented in this report are based on counties and facilities reporting through the SCORE system. While this provides a consistent statewide baseline, it does not capture all waste management activities. Data quality depends on consistent reporting practices across counties and facilities, and while the SCORE system provides a standardized framework, reporting methods and levels of detail may vary.

Waste delivered through private self-haul to permitted landfills, waste-to-energy facilities, or transfer stations is generally included in reported disposal totals. However, certain activities (e.g. informal reuse, private sector donations, or burning of yard waste in a few counties) fall outside formal reporting channels. As a result, reported data likely underestimates the full scale of reuse and certain diversion activities occurring across Minnesota.

Despite these limitations, the SCORE system provides the most comprehensive and consistent statewide dataset available for evaluating waste generation and management trends.

For the purposes of this report:

- **reuse:** materials kept in use through repair, resale, rental, donation, or community exchange, preventing entry into the MSW stream; prioritized in Minnesota's waste hierarchy; avoids manufacturing and downstream waste management impacts
- **recycling:** includes traditional recyclable materials (e.g., paper, glass, metals, plastics) and composting of source-separated organics (SSO) counted toward Minnesota's recycling rate; AD included only when digestate is beneficially used in a manner consistent with statutory definitions; AD systems that recover energy are classified as resource recovery and excluded from the recycling rate
- **disposal:** the management of MSW through landfills or WTE facilities
- **diversion:** a planning term used in this report to describe materials managed outside of disposal (landfill and WTE), including reuse, recycling, and organics management; term is used for analytical purposes and is distinct from Minnesota's official recycling rate
- **mixed waste processing (MWP):** the mechanical and/or manual processing of MSW to recover recyclable materials; materials recovered may contribute to recycling or resource recovery, depending on processing outcomes and end uses

These definitions are used consistently throughout this report to distinguish between material recovery, diversion, and disposal pathways.

Reuse and Recycling

In 2021, Minnesota reused, recycled, and composted approximately 2.49 million tons of material statewide across Minnesota's 87 counties, including communities served by Resource Renew. Of this total, 72% consisted of recyclable materials (approximately 1.78 million tons), while 28% consisted of organic materials (approximately 710,000 tons). The following sections describe how reuse, recycling, and organics recovery function within Minnesota's current materials management system, highlighting the materials captured, management pathways, and key factors influencing performance.

Reuse

Reuse includes activities that extend the life of products and materials by keeping them in use and out of the waste stream, such as resale, repair, redistribution, and donation. Reuse spans a wide range of materials, including textiles, furniture, electronics, construction and demolition materials, and edible food recovered for people.

More than 4,000 tons of material was reported as being reused in Minnesota in 2021. More than half of the reused tons are office and residential furniture, predominantly from the residential sector. Wood and textiles make up the next two largest reuse categories, again with the residential sector surpassing the commercial, industrial, and institutional waste (CII) sector significantly (Figure 1).

Reuse is a high-priority strategy in Minnesota's waste management hierarchy because it prevents waste generation, extends product lifespans, and reduces environmental impacts compared to downstream management options.

Documented reuse is included in statewide reporting and contributes to Minnesota's overall recycling rate, though measurement of reuse activity remains limited. Reuse is not comprehensively measured in Minnesota. The SCORE reporting system captures only the portion of reuse activity documented by counties, while much of the informal reuse economy, such as household-to-household exchanges, peer-to-peer resale platforms, nonprofit redistribution, and community-based repair, is not tracked. As a result, the 4,000 tons reported here significantly underestimates the true scale of reuse activity occurring statewide. Despite these measurement limitations, expanding reuse systems presents a major opportunity to prevent waste, conserve resources, and reduce environmental impacts across Minnesota.

Figure 1. Reused materials in Minnesota, 2021

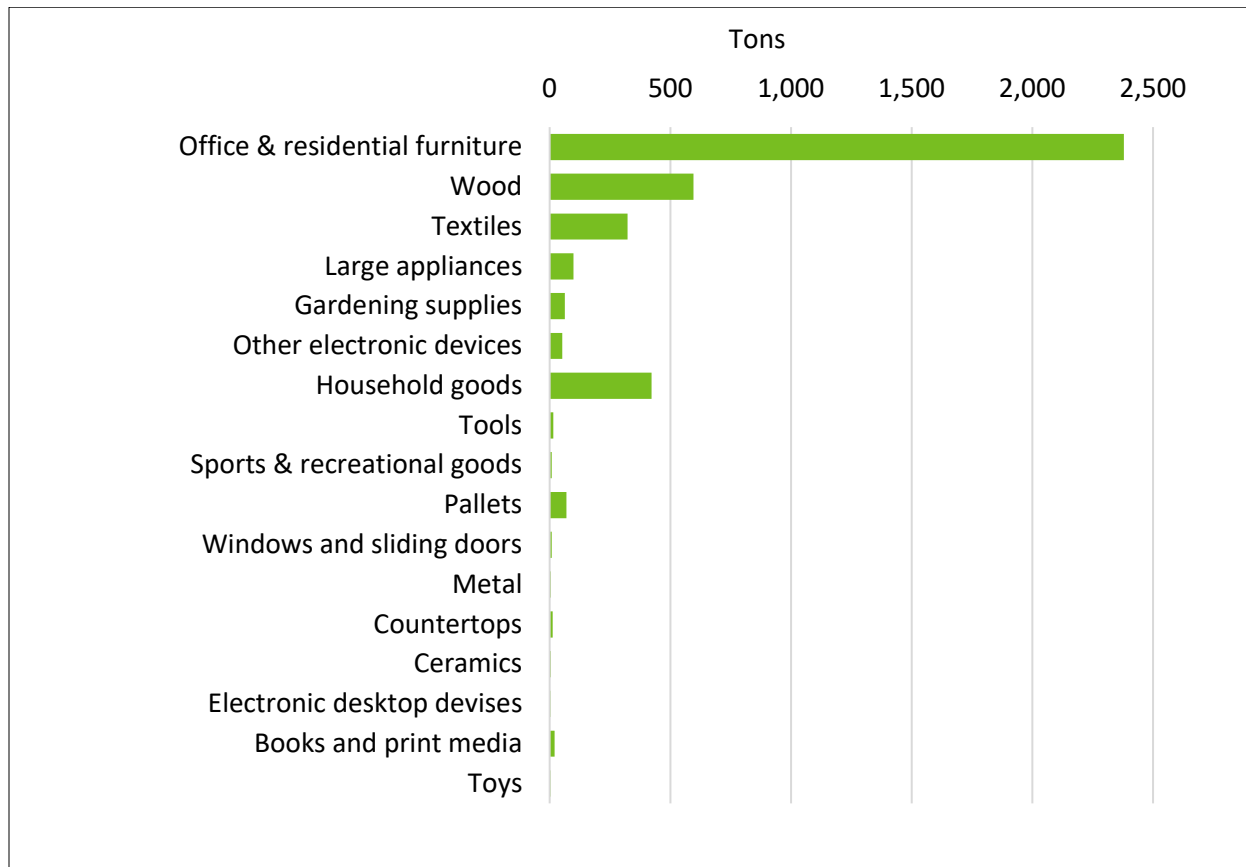


Table 1. Share of reuse activity attributable to residential vs. commercial sources (tons, 2021)

Material	Residential	CII	Total
Office & residential furniture	2,289	90	2,379
Wood	467	128	595
Textiles	283	40	323
Large appliances	80	19	99
Gardening supplies	63	0	63
Other electronic devices	52	0	52
Household goods	29	392	422
Tools	12	3	15
Sports & recreational goods	7	1	8
Pallets	5	65	70
Windows and sliding doors	4	4	8
Metal	4	0	4
Countertops	4	8	12
Ceramics	2	3	5
Electronic desktop devices	2	2	4
Books and print media	2	19	20
Toys	0	3	3
Total	3,306	776	4,082

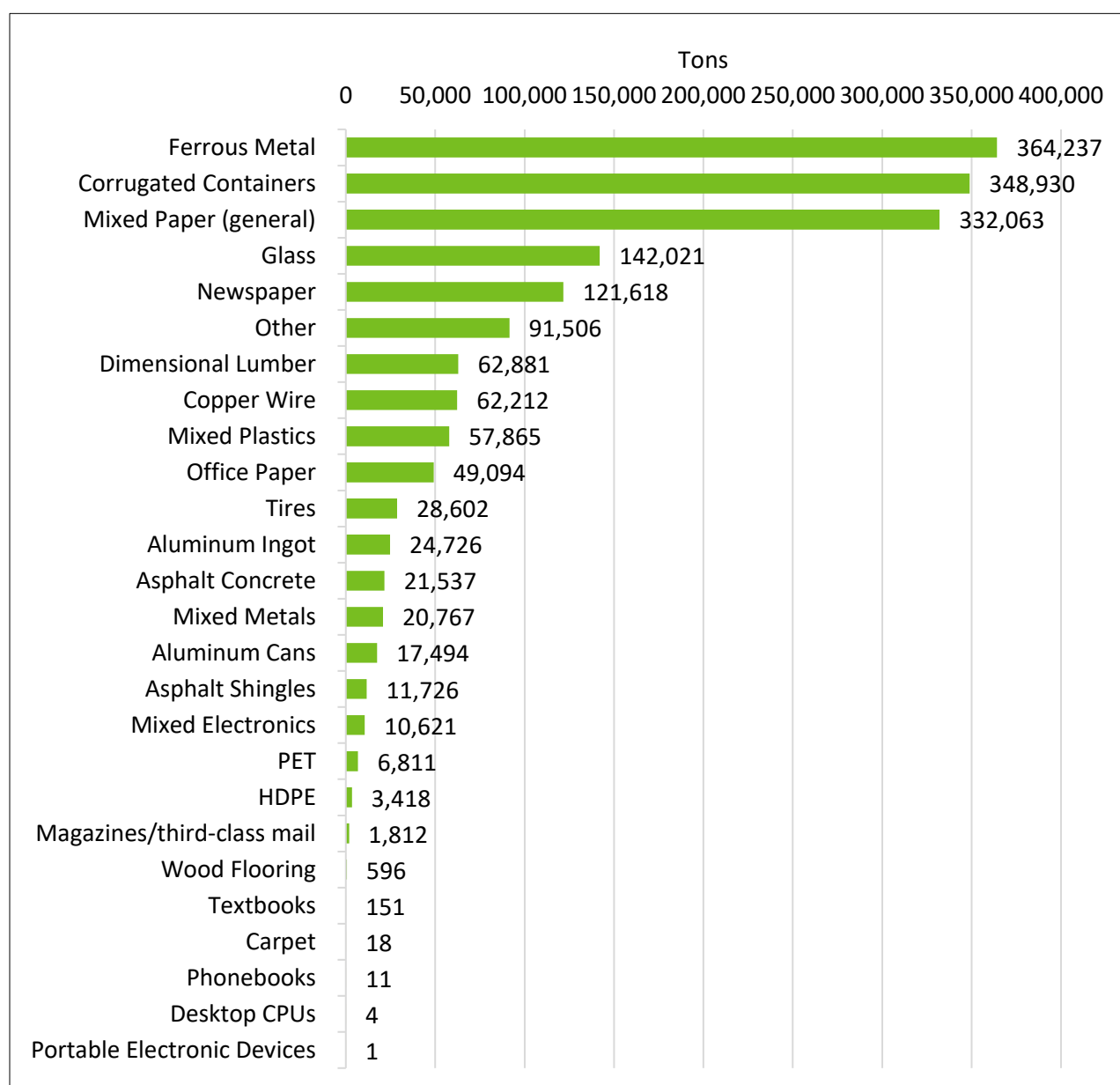
Recycling

Recycling

Minnesota's recycling system is driven by a relatively small number of high-volume materials with established markets, particularly ferrous metal, corrugated cardboard, and mixed paper. Together, these materials account for more than 58% of all recyclable material collected statewide (Figure 2).

Corrugated cardboard and mixed paper are widely recyclable, with established collection systems, mature processing technologies, and strong end markets, yet significant quantities end up in disposal. This reflects gaps in participation, uneven access to services, and system design limitations. Targeting these materials represents a relatively low-cost opportunity to increase recycling rates using existing infrastructure. However, improving capture rates depends on participation, service design, and material quality, including contamination levels.

Figure 2. Recycled materials in Minnesota, 2021



Organics

In 2021, Minnesota managed approximately 709,500 tons of organic material. Yard waste accounted for more than half of the total (approximately 418,300 tons), with nearly two-thirds generated by the residential sector. Wasted food made up the remainder (approximately 291,200 tons), with approximately 90% of wasted food recovery coming from the CII sector (Figure 3). This reflects a clear difference in material flows by sector: residential organics recovery is dominated by yard waste, while CII recovery is driven primarily by wasted food.

Existing recovery data show that yard waste is already captured at high levels, while wasted food remains a larger opportunity for additional recovery, particularly in the CII sector and in areas without widespread organics collection. Despite these efforts, wasted food and other organic materials remain a significant portion of the disposal stream. Expanding organics diversion will depend on prevention, food rescue, source-separated collection, contamination control, and processing capacity.

The state also tracks how organic materials are managed. Most yard waste is composted statewide, which is the only management method that counts toward Minnesota's recycling rate. In a small number of counties, yard waste is burned; because this is not considered beneficial use, those tons are not reported to the MPCA.

Figure 3. Organics recovery by residential and CII sectors (tons, 2021)

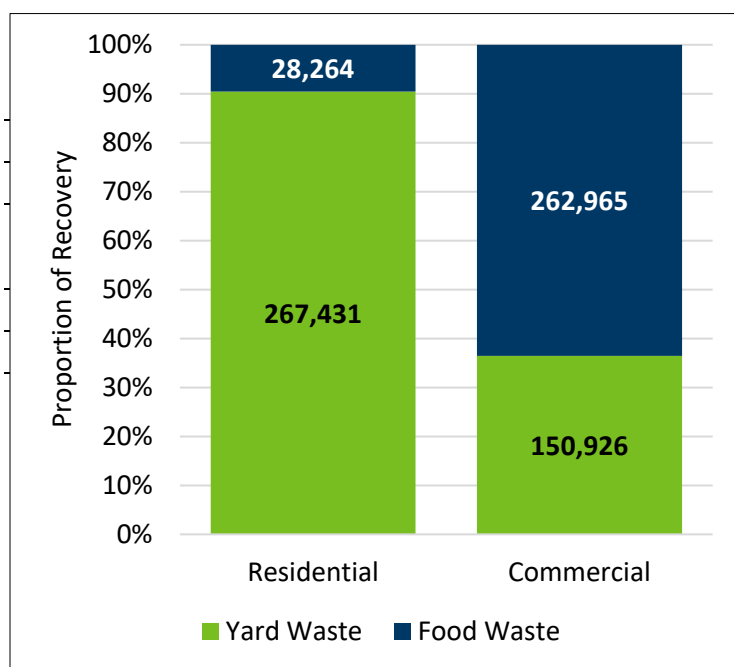


Table 2. Organics recovery by residential and CII sectors (tons, 2021)

Material	Residential	CII	Total
Yard Waste	267,431	150,926	418,357
Wasted Food	28,264	262,965	291,229
Total	295,695	413,891	709,586

Management methods in Minnesota follow the Wasted Food Scale established in Minn. Stat. § 115A.02(c), which prioritizes higher-value uses of food before lower-value recovery or disposal pathways. The scale emphasizes preventing waste at the source and directing surplus food to feed people first, followed by animal feed, industrial uses, composting, and other recovery methods.

In 2021:

- nearly 32,000 tons of edible food were donated to feed people
- more than 159,300 tons were diverted to livestock feed
- approximately 3,200 tons of fats, oils, and greases recovered more than 96,600 tons of wasted food composted (Table 3)

Minnesota's statutory scale aligns with the U.S. EPA Wasted Food Scale and provides a framework for prioritizing prevention and higher-value recovery pathways before composting or disposal.

Table 3. Organics management within Minnesota (tons, 2021)

Organics management	Wasted food	Yard waste	Total
Food to People	31,960	-	31,960
Food to Livestock	159,372	-	159,372
Fats, Oils & Greases	3,214	-	3,214
Composting	96,683	418,357	515,040
Total	291,229	418,357	709,586

Disposal

Current MSW Disposal

In 2021, Minnesota disposed of nearly 3.4 million tons of MSW. Of this total, approximately 2.3 million tons were landfilled (68%) and 1.1 million tons (32%) were disposed of via WTE facilities. A breakdown of landfill versus WTE tonnage is provided in Figure 4, and a county-level table is included in Appendix A.1 MSW Disposal by County.

Figure 4. Disposal by method in Minnesota (landfill vs. WTE, tons, 2021)

MSW Landfilled: 2,293,084

MSW to WTE: 1,075,440

Generation and Disposal Comparison

In 2021, Minnesotans generated approximately 5.86 million tons of MSW (5.63 pounds per person per day), based on county-reported data through Minnesota's statewide SCORE reporting system.

While comprehensive generation data are not published in standardized formats in all neighboring states, available disposal data and diversion rates indicate that overall waste generation levels across the Upper Midwest are broadly comparable.

Although Minnesota's per capita waste generation is similar to neighboring states, its disposal rate is substantially lower. Table 4 demonstrates this difference by presenting both generation and disposal per capita for each state.

Table 4. MSW generation and disposal per capita

State	Disposal lbs./person/day ¹	Generation lbs./person/day ²
MN	3.23	5.63 (reported)
WI	4.16	5.9 – 6.4 (estimated)
IA	5.98	7.0 – 7.5 (estimated)
MI	4.42	5.4 – 5.9 (estimated)

The difference is not primarily driven by lower waste generation, but is strongly influenced by diversion policies and infrastructure established through the Waste Management Act of 1980. These long-standing policies and investments have enabled Minnesota to achieve lower disposal rates than neighboring states and highlight the role of sustained policy direction in driving diversion outcomes.

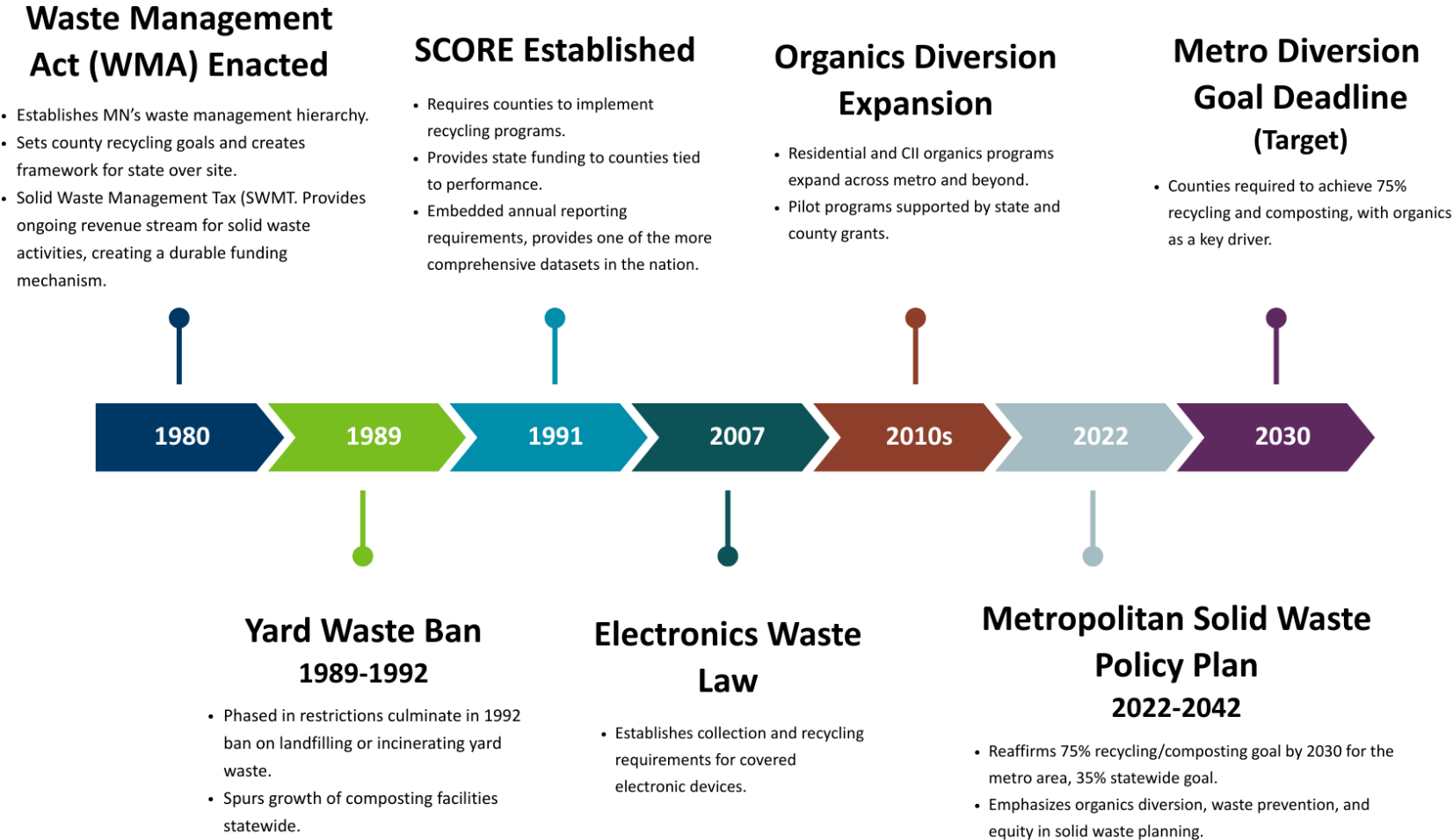
Minnesota's lower disposal rate reflects more than short-term programmatic efforts; it is the result of decades of statutory direction, investment, and accountability. By establishing a waste management hierarchy, setting measurable recycling goals, banning yard waste from disposal, and creating the SCORE reporting system, the state built both the infrastructure and the data systems necessary to track and drive diversion performance over time.

Figure 5 illustrates the progression, highlighting key legislative milestones and diversion targets that have shaped Minnesota's materials management system since 1980.

¹ Per capita rates were calculated using landfilled MSW tonnage reported for the baseline year of 2021 in all states, except for Iowa, which was calculated using MSW tonnages 2022. 2020 US Census population data was used. Data sources are as follows: (Wisconsin Department of Natural Resources 2022), (Iowa Department of Natural Resources 2024), (Michigan Department of Environment 2022).

² Minnesota's per capita generation rate is calculated using tonnage reported through the statewide SCORE system, established under the Waste Management Act of 1980, which provides consistent annual reporting of both disposal and diversion. Neighboring states publicly report landfill tonnage but do not publish equivalent comprehensive generation datasets in standardized formats for 2021. Accordingly, generation values for Wisconsin, Iowa, and Michigan were estimated using disposal tonnage and publicly reported diversion rate ranges.

Figure 5. Minnesota's waste management policy timeline



MSW Characterization

Understanding the composition of the MSW stream is essential for identifying opportunities to prevent, recover, and better manage materials. Minnesota has not conducted a complete statewide waste characterization study since 2013. MPCA received an EPA Solid Waste Infrastructure for Recycling (SWIFR) grant for States and Territories to conduct a waste characterization study. The study evaluates the types and volume of materials generated and discarded by residents, businesses, and organizations in Minnesota. Results will support assessment of Minnesota's waste stream, current trends, and opportunities to improve waste reduction, reuse, and recycling. The project and results will be summarized in a final report that will be available after the project completion date, September 30, 2026.

To reflect current conditions, this report draws on multiple datasets:

- **Minnesota studies:** Burnsville MSW Landfill (2019), Polk County Solid Waste Resource Recovery Facility (2024), and Pope/Douglas Solid Waste Management (2024); provide metro landfill data and rural WTE facility data to approximate statewide conditions
- **Statewide comprehensive studies from neighboring states:** Iowa Department of Natural Resources (2022) and Wisconsin Department of Natural Resources (2021); provide statistically robust data on residential and commercial disposal streams not available from Minnesota regional studies

While each state has different disposal regulations, they share common features such as bans on landfilling yard waste, lead-acid batteries, and tires. Some states go further:

- **Iowa bottle redemption law:** redemption rates declined to 49% in 2022
- **Wisconsin landfill bans:** broad restrictions covering yard waste, aluminum cans, certain plastics, paper, cardboard, steel cans, electronics, and glass containers

These regulatory differences can influence waste stream composition and diversion outcomes. Table 5 outlines the aggregate summary results from the comparison studies. Because each study represents a single point in time, variation in results cannot be attributed to specific causes. To account for seasonal and regional fluctuations, average values across the studies were used to estimate Minnesota's MSW composition.

This composite view provides a practical baseline for identifying materials that are highly recyclable but still landfilled and for targeting strategies that move Minnesota closer to its statutory recycling and waste prevention goals.

Table 5. Waste characterization study comparison for key categories (based on weight)

General category	Specific category	BSL 2019	Pope Douglas	Polk County	IA – residential	IA – CII	WI – residential	WI – CII	Residential average	Commercial average
Glass	Glass Bottles and Jars	0.9%	1.3%	1.4%	0.3%	0.4%	0.6%	0.9%	0.9%	1.0%
Metal	Aluminum Cans	0.6%	1.3%	1.4%	1.0%	0.8%	1.2%	1.0%	1.1%	1.0%
Metal	Steel Cans	2.1%	0.7%	1.3%	0.6%	0.4%	0.6%	0.5%	1.1%	1.0%
Paper	Corrugated Cardboard	3.6%	3.4%	6.4%	3.9%	9.8%	2.0%	5.1%	3.9%	5.6%

General category	Specific category	BSL 2019	Pope Douglas	Polk County	IA – residential	IA – CII	WI – residential	WI – CII	Residential average	Commercial average
Paper	Mixed Paper	1.6%	1.5%	1.7%	4.7%	4.3%	4.5%	6.0%	2.8%	3.0%
Plastic	Plastic PET #1 Bottle	0.8%	1.6%	1.5%	1.1%	1.0%	1.5%	1.6%	1.3%	1.3%
Plastic	Plastic HDPE #2	1.9%	1.2%	1.7%	1.0%	0.9%	0.8%	0.8%	1.3%	1.3%
Organics	Leaves and Grass	1.2%	2.3%	2.0%	3.5%	1.5%	2.9%	1.1%	2.4%	1.6%

Residential

Residential MSW is categorized into two components: single-family and multi-family units. For the purposes of this report, single-family refers to housing with four units or fewer, whereas multi-family refers to housing with five or more units; however, definitions vary by city and county. Some ordinances classify up to fourplexes as single-family, while others base the distinction on billing structure or whether each unit has its own collection container. Manufactured/mobile homes are also included in the residential stream. When billed individually, mobile homes may be treated as single-family, but when located in parks with shared dumpsters or association billing, they are often grouped with multi-family or even CII waste streams. These distinctions arise primarily from different collection methods used across Minnesota communities.

According to the 2020 U.S. Census, Minnesota had 1.7 million single-family households in Minnesota (85% of residential units) and 481,000 multi-family households (15%). In the baseline year of 2021, single-family households disposed of approximately 1.24 million tons of MSW, while multi-family households disposed of about 337,100 tons. These figures represent materials found in the garbage (disposal stream) and do not include what was already captured through recycling or organics diversion programs.

These figures reflect materials remaining in the disposal stream in 2021:

- **organics (654,500 tons, 41%):** wasted food, yard waste, compostable paper and packaging, and wood waste
- **plastics (265,800 tons, 17%):** PET, HDPE, and PP bottles and jars, expanded polystyrene, plastic film, and bulky plastics
- **paper (222,400 tons, 14%):** corrugated cardboard, newsprint, magazines, office paper, mixed paper, and cartons

Figure 6. Residential MSW composition by general category, 2021

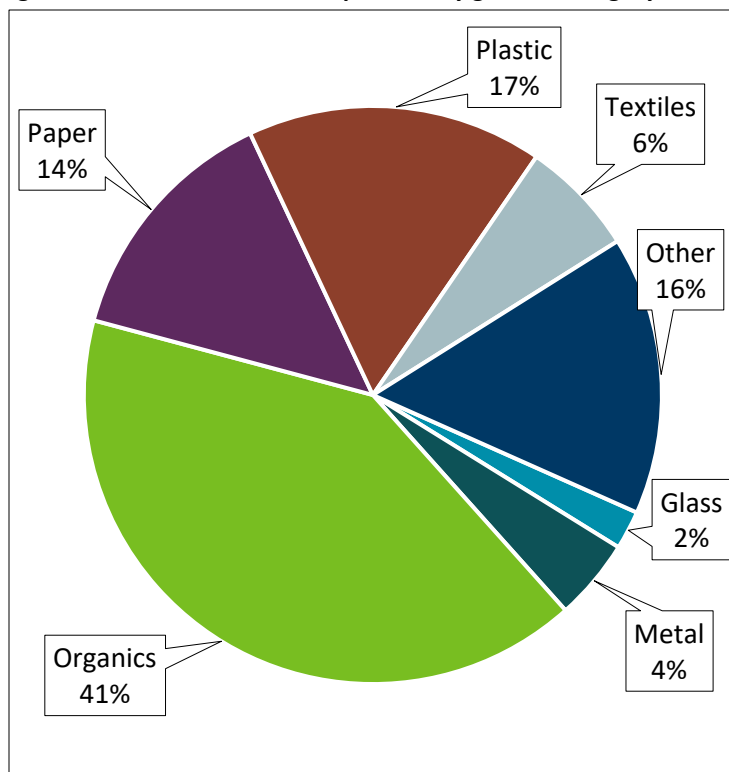


Table 6. Residential MSW composition by general category (tons, 2021)

General category	Single-family	Multi-family
Glass	27,364	7,420
Metal	57,451	15,578
Organics	514,896	139,613
Paper	174,983	47,446
Plastic	209,101	56,697
Textiles	81,929	22,215
Other	196,995	53,415
Total	1,262,719	342,383

Figure 7 illustrates Minnesota's estimated residential waste composition by potential management strategy. These figures represent materials found in the disposed stream in 2021 and show what could be diverted if appropriate programs and infrastructure were available. They do not include materials already captured through recycling or organics programs. Diversion estimates reflect theoretical potential; actual

recovery is constrained by access, contamination, and market demand.

- **MRF-compatible Recycling (345,300 tons, 22%):** materials recoverable using existing MRF technology through curbside or drop-off systems, including corrugated cardboard, mixed paper, aluminum and steel cans, glass bottles and jars, and plastic bottles and tubs
- **drop-off / special collection recycling (479,300 tons, 30%):** materials not efficiently processed by MRFs, including plastic film, scrap metal, bulky plastics, electronics, C&D debris, HHW, carpet, and tires
- **source separated organics (SSO) (607,500 tons, 38%):** wasted food, yard waste, and compostable paper that could be diverted through curbside or drop-off organics collection programs

- **non-recyclable (173,000 tons, 11%):** materials not currently feasible for recovery under existing technologies or markets, including heavily contaminated items and inert materials such as rocks, dirt, and fines

Taken together, these categories indicate that approximately 89% of disposed residential MSW (1.4 million tons) is theoretically divertible under existing technologies and with expanded program implementation, while the remaining 11% (173,000 tons) represents a persistent challenge. This estimate reflects technical potential based on material composition and available recovery pathways. Actual diversion rates are constrained by access to services, participation, contamination, market conditions, and processing capacity.

It is important to note that not all MRF-compatible materials must be processed at MRFs. If those items are collected separately, they often can be baled and sold directly to end markets. Similarly, certain materials currently designated for drop-off recycling could potentially be incorporated into specialty curbside collection programs, such as bag-in-bag plastic film recycling. Likewise, organics collection can be implemented through both curbside and drop-off programs, depending on local infrastructure and participation.

Figure 7. Residential MSW composition by potential management strategy, 2021

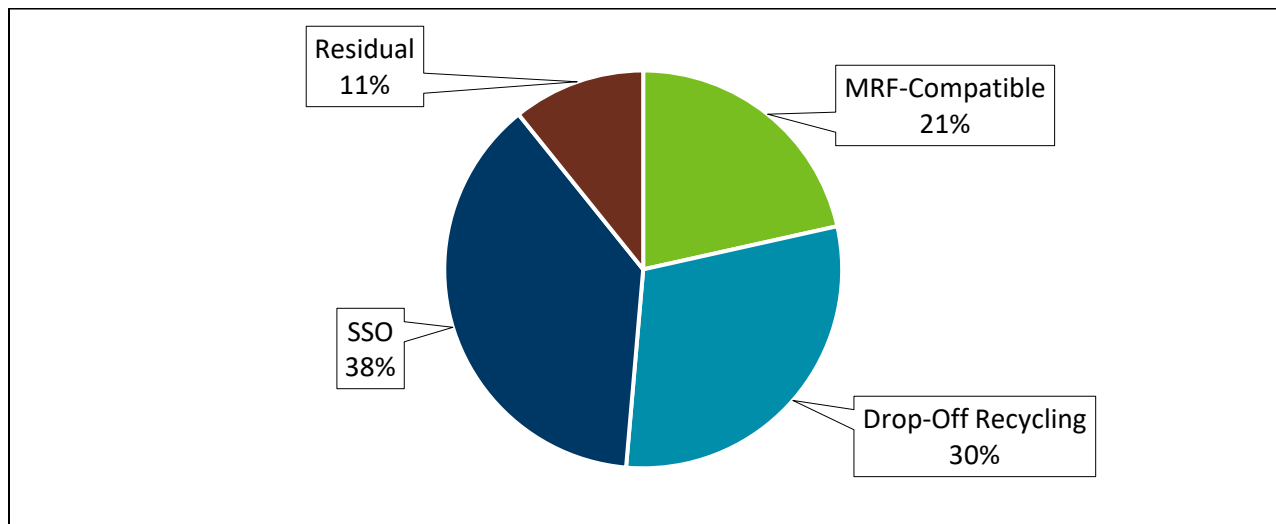


Table 7. Residential MSW composition by potential management strategy (tons, 2021)

Potential management strategy	Single-family (SF)	Multi-family (MF)	Combined SF & MF
MRF-Compatible	271,667	73,662	345,329
Drop-Off/Special Collection	377,057	102,238	479,295
SSO	477,909	129,584	607,493
Total Divertible MSW	1,126,633	305,484	1,432,117
Remaining non-divertible	136,086	36,899	172,985
Total Divertible and Non-Divertible MSW	1,262,719	342,383	1,605,102

Figure 8 highlights the top seven single material categories in the residential MSW disposal stream. Target categories are defined as materials comprising more than 5% of disposed tonnage and for which viable or emerging diversion pathways exist, including drop-off or special pick-up collection programs, and SSO programs). All figures reflect materials remaining in the disposal stream in 2021.

- **wasted food (327,200 tons, 20%), other organics (162,500 tons, 10%), and compostable paper (104,100 tons, 6%):** largest diversion opportunity in the residential waste stream; prevention

prioritized under Minn. Stat. § 115A.02, with composting, anaerobic digestion, and animal feed as downstream recovery pathways; “other organics” includes materials not otherwise captured in composition studies and is not further disaggregated

- **plastic film (143,200 tons, 9%)**: dominated by polyethylene (PE) film (e.g., grocery bags and packaging) with established retail takeback programs and relatively stable end markets; multi-laminate films (e.g., chip bags) lack scalable recovery pathways
- **textiles (118,400 tons, 7%)**: growing share of the residential disposal stream, near-term diversion through donation and reuse systems, with long-term potential dependent on expanded collection and market development
- **mixed paper (91,000 tons, 6%) and corrugated cardboard (78,800 tons, 5%)**: highly recoverable through existing MRF infrastructure with well-established supply chains and strong end markets; continued presence in the disposal stream indicates gaps in participation, access, or service availability

Figure 8. Top MSW disposal categories from residential sources, 2021

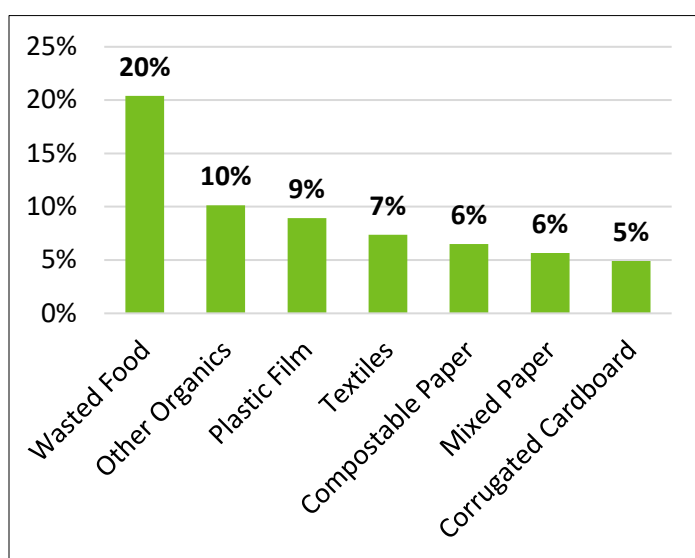


Table 8. Top MSW disposal categories from residential sources (tons, 2021)

Specific category	Single-family	Multi-family	Total
Wasted Food	257,442	69,805	327,246
Other Organics	127,845	34,665	162,510
Plastic Film	112,668	30,550	143,218
Textiles	93,119	25,249	118,368
Compostable Paper	81,929	22,215	104,143
Mixed Paper	71,650	19,428	91,078
Corrugated Cardboard	61,984	16,807	78,791

Commercial, Industrial, and Institutional (CII)

CII MSW includes waste generated by businesses and institutions, such as office buildings, retail, wholesale trade, health care facilities, educational facilities, accommodation and food services. It excludes industrial byproducts from manufacturing, mining, and construction. In Minnesota, the largest CII sectors by employment include health care, manufacturing, retail trade, accommodation and food services, and professional, scientific, and technical services, collectively employing more than 1.5 million Minnesotans (US Census Bureau 2017).

Following a similar pattern to residential MSW, the largest three categories were:

- **organics (723,200 tons, 41%):** Wasted food accounts for 47% of this category, followed by other organics (18%), recyclable wood (17%), and compostable paper (14%)
- **paper (308,100 tons, 17%):** Corrugated cardboard accounts for 41% of CII paper disposal
- **plastic (298,400 tons, 17%):** Plastic film accounts for 48% of all CII plastic disposal

Figure 9. CII MSW composition by material category

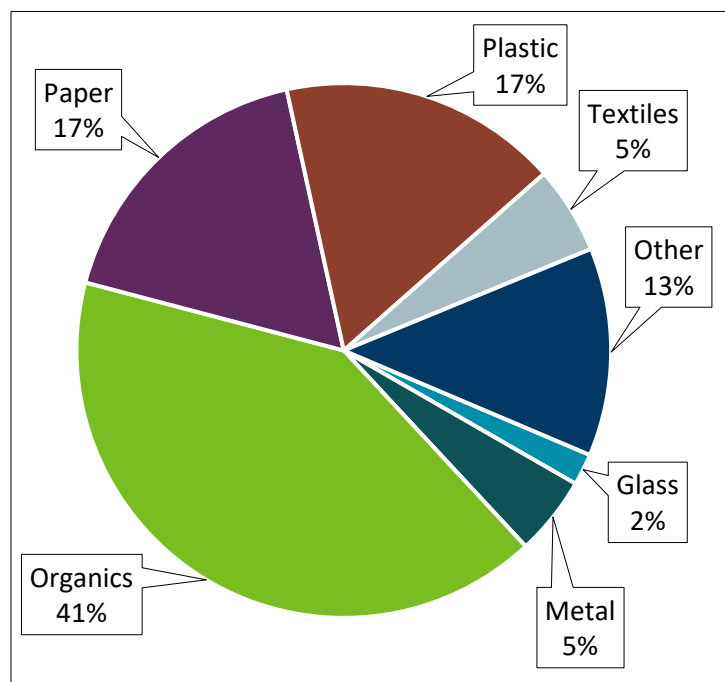


Table 9. CII MSW composition by material category

General category	Tons disposed (2021)
Glass	33,757
Metal	84,352
Organics	723,246
Paper	308,052
Plastic	298,372
Textiles	93,556
Other	222,088
Total	1,763,422

Diversion Potential

Of the total CII waste disposed in 2021, approximately 93% is theoretically divertible under existing or expanded program structures (Figure 10). As with residential waste, this estimate reflects technical potential. Actual diversion depends on access to services, operational constraints, market demand, contamination, and enforcement capacity.

- **MRF-compatible recycling (434,200 tons, 25%):** high-value materials like corrugated cardboard, mixed paper, and beverage containers; large businesses often capture corrugated cardboard

through onsite baling and backhaul systems, while smaller businesses may lack access to robust recycling services.

- **drop-off / special collection recycling (624,900 tons, 35%):** includes plastic film as the largest single material; large retailers commonly recycle shrink wrap and pallet film, while smaller operations frequently lack access
- **organics recovery (601,200 tons, 34%):** significant opportunity associated with wasted food; Hennepin County’s requirement for large generators to separate organics provides a model for broader statewide expansion

Figure 10. CII MSW composition by potential management strategy

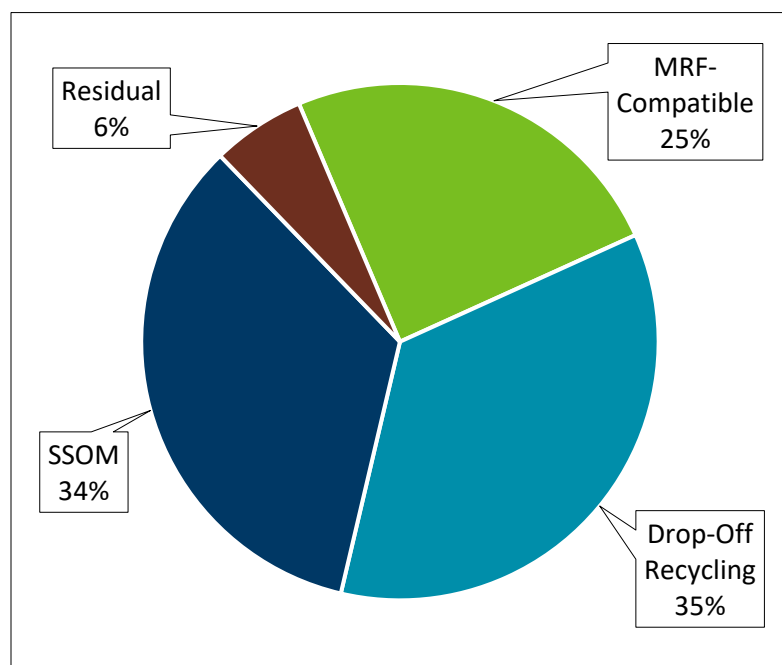


Table 10. CII MSW composition by strategy

Potential management strategy	Tons disposed (2021)
MRF-Compatible	434,194
Drop-off/Special Collection	624,941
SSO	601,250
Non-Recyclable	103,037
Divertible MSW	1,660,386
Total MSW	1,763,422

The top CII disposal categories (Figure 11):

- **wasted food (341,700 tons, 19%), other organics (129,800 tons, 7%) and compostable paper (104,400 tons, 6%):** largest diversion opportunity in the CII sector; includes unsold perishables, kitchen preparation waste, and expired goods, creating opportunities for prevention and donation; ; composting and anaerobic digestion of source-separated organics as preferred downstream pathways; barriers include liability concerns, storage constraints, staff turnover, and limited enforcement capacity

- **plastic film (143,700 tons, 8%):** pallet wrap and polyethylene packaging represent a major share of CII plastics; recovery dependent on clean, dry material; challenges include storage limitations, contamination, and operational constraints across generators; limited recovery despite existing end markets
- **corrugated cardboard (124,900 tons, 7%):** efficiently recovered by large chains through established systems; smaller businesses often rely on landlord-provided services and may lack access; self-hauled recyclables not consistently reported, leading to undercounting of diversion activity
- **recyclable wood (122,000 tons, 7%):** includes treated and untreated materials such as pallets, dimensional lumber, fencing, shingles, and construction offcuts; clean wood has established end markets, while contamination (e.g., paint, preservatives, fasteners, mixed debris) limits recovery; smaller generators often lack space or capacity for source separation
- **textiles (93,600 tons, 5%):** growing share of the CII waste stream, including apparel and institutional linens; reuse and recycling markets exist, particularly for sorted materials; diversion constrained by contamination, inconsistent sorting, and limited collection infrastructure

Figure 11. Top MSW disposal categories from CII

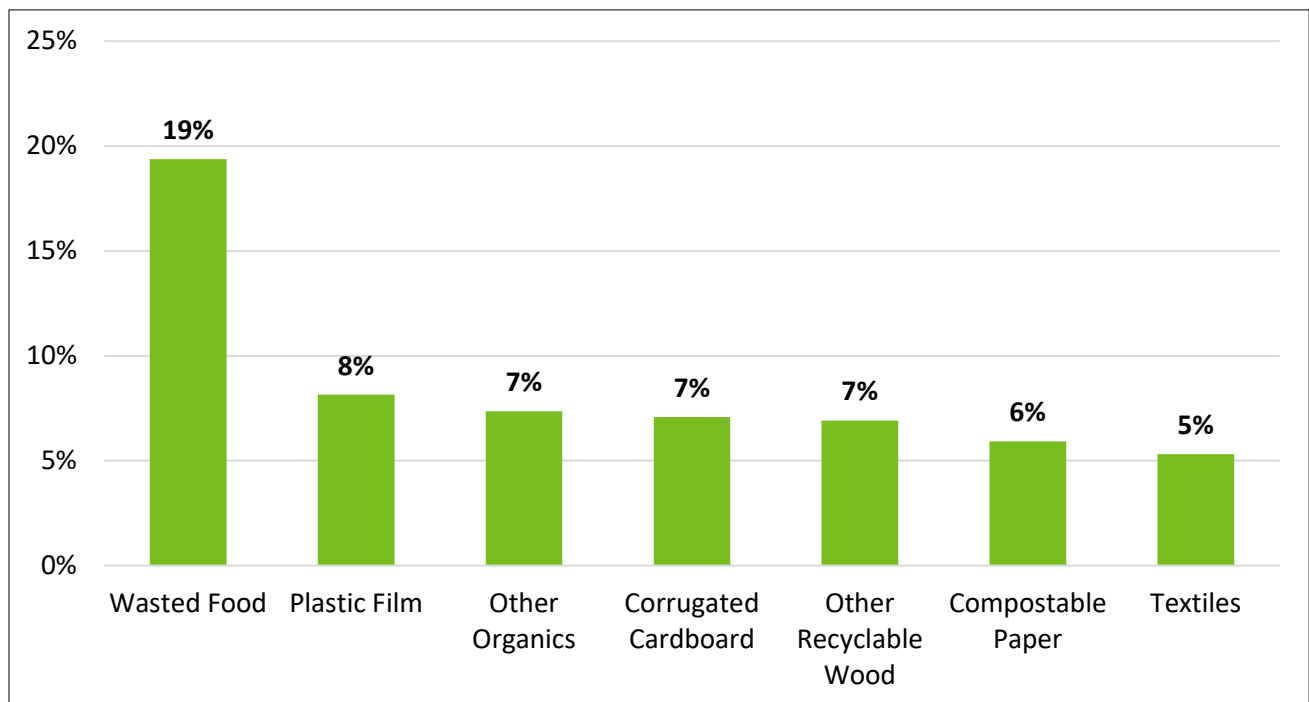


Table 11. Top MSW disposal categories from CII

Specific category	Tons disposed (2021)
Wasted food	341,695
Plastic film	143,700
Other organics	129,797
Corrugated cardboard	124,948
Other recyclable wood	121,996
Compostable paper	104,357
Textiles	93,556

Recycling Rate

Table 12 summarizes materials reused, recycled, and composted to calculate Minnesota's recycling rate, defined in this report as the sum of reuse, recycling, and organics recovery divided by total MSW generation. Minnesota's overall 2021 recycling rate is 43%. The Twin Cities Metro Area (TCMA), which includes the counties of Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington, had a slightly higher rate than Greater Minnesota, which covers the remaining 80 counties plus Resource Renew. The rate for the TCMA was 45%, compared to 39% for Greater Minnesota.

The persistence of large volumes of readily divertible material in the disposal stream, despite existing infrastructure and end markets, indicates that Minnesota's recycling rate is primarily constrained by system design and implementation rather than by absence of technical solutions.

Table 12. Total disposal and recycling by Minnesota region (tons, 2021)

Region	Reused & rescued ³	Recyclable recovery	Organics recovery ⁴	Total diverted	WTE	Landfill	Total disposal	Diversion rate
TCMA	25,693	944,968	524,347	1,495,008	707,268	1,102,165	1,809,433	45%
Greater MN	10,349	835,755	153,279	999,383	368,173	1,190,919	1,559,091	39%
Total	36,042	1,780,723	677,626	2,494,391	1,075,440	2,293,084	3,368,524	43%

³ Reused and Rescued include material goods that were reused and surplus food that was rescued in Minnesota in 2021

⁴ Organics Recovery includes wasted food, yard trimmings, food sent to livestock, and fats, oils, and greases

Current MSW Waste Management Infrastructure

Prevention and Reuse

Waste prevention and reuse are foundational components of Minnesota's waste management hierarchy, as they extend product lifespans, conserve resources, and delay or prevent material from entering the MSW stream altogether. Stakeholders consistently emphasized that achieving long-term statutory recycling goals will require greater investment in prevention, reuse, and repair systems, rather than continued reliance on end-of-life strategies such as recycling and disposal alone.

For this analysis, the scope was intentionally limited to businesses most directly tied to reuse activities involving materials and products that would otherwise enter the MSW stream. This includes repair, resale, and rental activities that extend the useful life of consumer goods and reduce demand for new product manufacturing. Activities that fall outside the MSW stream, such as automotive parts and tires, industrial machinery, boats, and raw-material remanufacturing, were excluded from the analysis.

This approach differs from the broader *Reuse Minnesota* study (2022), which included sectors such as automotive parts, recreational equipment, and vehicle sales. As such, this analysis represents a focused subset of reuse activities directly relevant to MSW generation and diversion, consistent with the report's focus on modeling a 90% diversion scenario.

Incidental reuse activities embedded within retail settings (e.g., jewelry repair at a jewelry store) were excluded due to data and measurement limitations. While not captured here, these activities remain important contributors to Minnesota's broader reuse system.

This screening identified 3,167 businesses statewide that can be classified as reuse and prevention businesses:

- **53% repair services:** e.g., electronics repair shops, appliance repair, furniture restoration, tailoring and shoe repair, bicycle repair
- **34% resale businesses:** e.g., thrift stores, antique stores, used bookshops, consignment stores, nonprofit reuse organizations
- **12% rental businesses:** e.g., tool and equipment rental, event and party rental, furniture rental, recreational gear rental

Figures 12-16 illustrate the distribution of reuse and prevention businesses category and NAICS code, highlighting the dominance of repair and resale activities within the MSW-relevant reuse sector. Most repair businesses concentrate on electronics and appliances, resale businesses are dominated by thrift/antique stores, and the rental market is split between broad general rental centers and material-specific categories such as office machinery or recreational goods. It is worth noting that some NAICS categories, such as video rental, no longer represent significant reuse activity but remain in the classification system. Similarly, community redistribution services (labeled "community food services" in NAICS) play a meaningful role in reuse by redistributing food, clothing, and household goods.

Stakeholders consistently emphasized that reuse and prevention deliver greater environmental benefits than recycling and should play a central role in achieving long-term diversion goals. However, Minnesota lacks consistent tools to measure the full scale of reuse activity, making these estimates a conservative snapshot of a much larger system. Reuse activity is inherently difficult to measure, as it occurs across a wide range of formal and informal markets that are not consistently tracked through existing data systems. As a result, these estimates should be understood as a conservative representation of a

broader system. These limitations highlight the need for improved measurement approaches alongside continued development of reuse-related programs and policies.

While prevention and reuse reduce the amount of material entering the waste stream, a substantial volume of material still requires collection and processing. Minnesota's recycling and organics infrastructure plays a central role in managing these materials.

Figure 12. Prevention and reuse industries in Minnesota

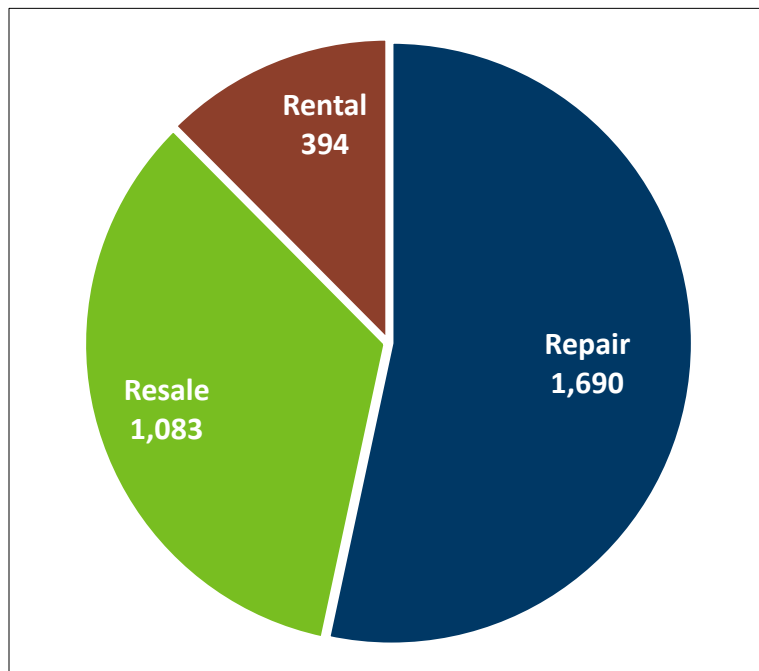


Figure 13. Repair, resale/redistribution, and rental stores in Minnesota

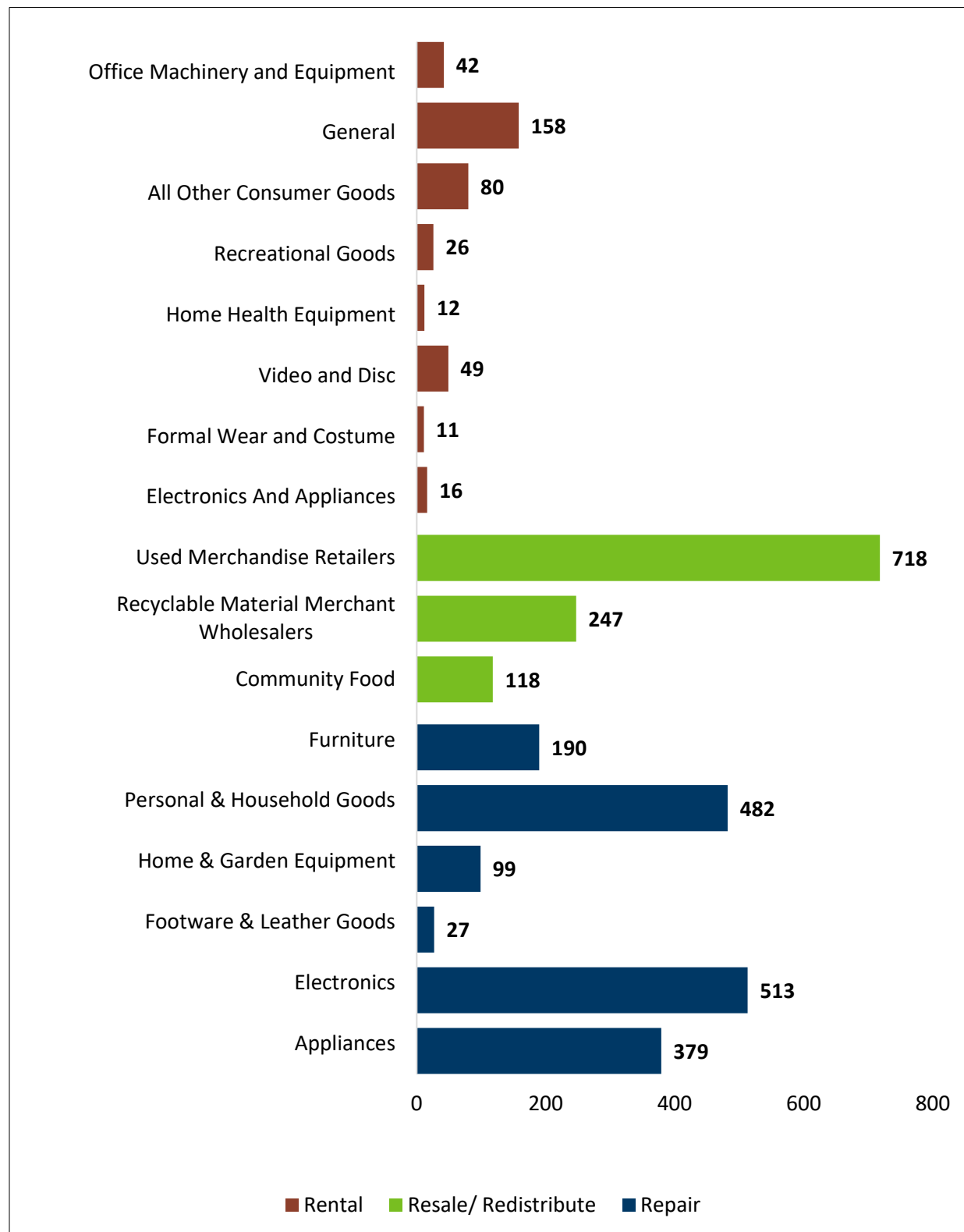
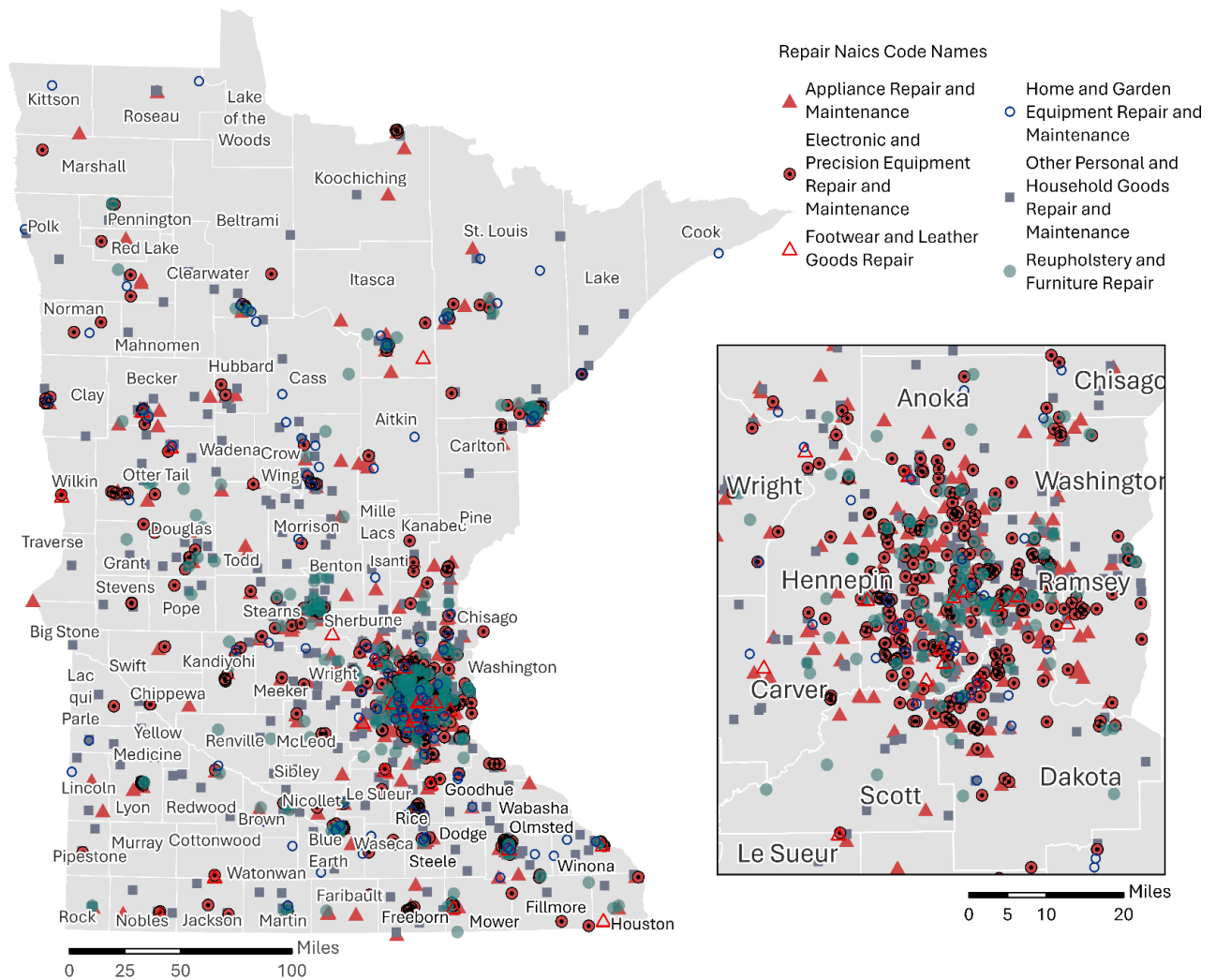


Figure 14. Repair centers by NAICS code name⁵



⁵Reuse centers” includes repair shops, resale businesses, rental companies, and nonprofit redistribution organizations.

Figure 15. Reuse centers by NAICS code name

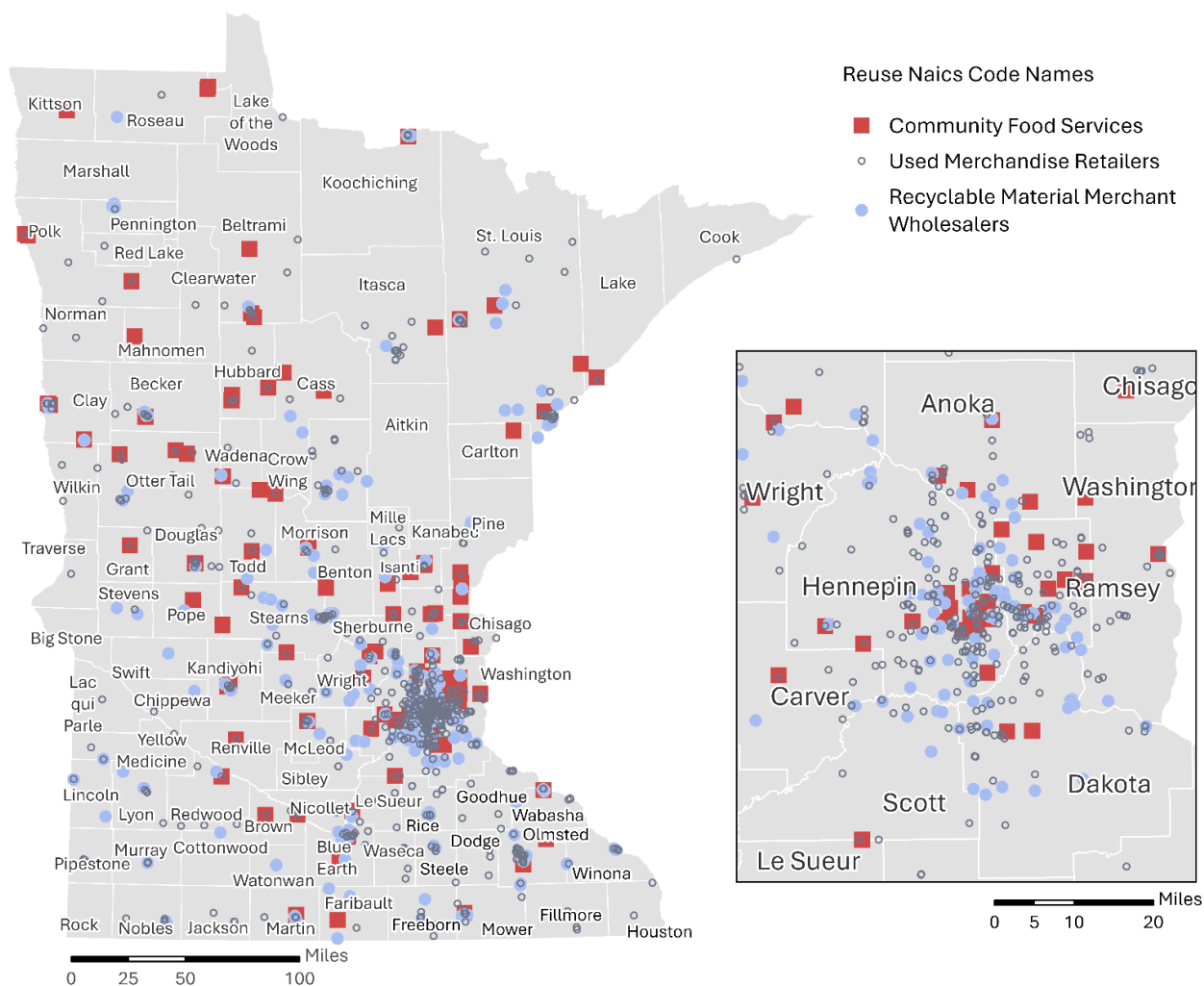
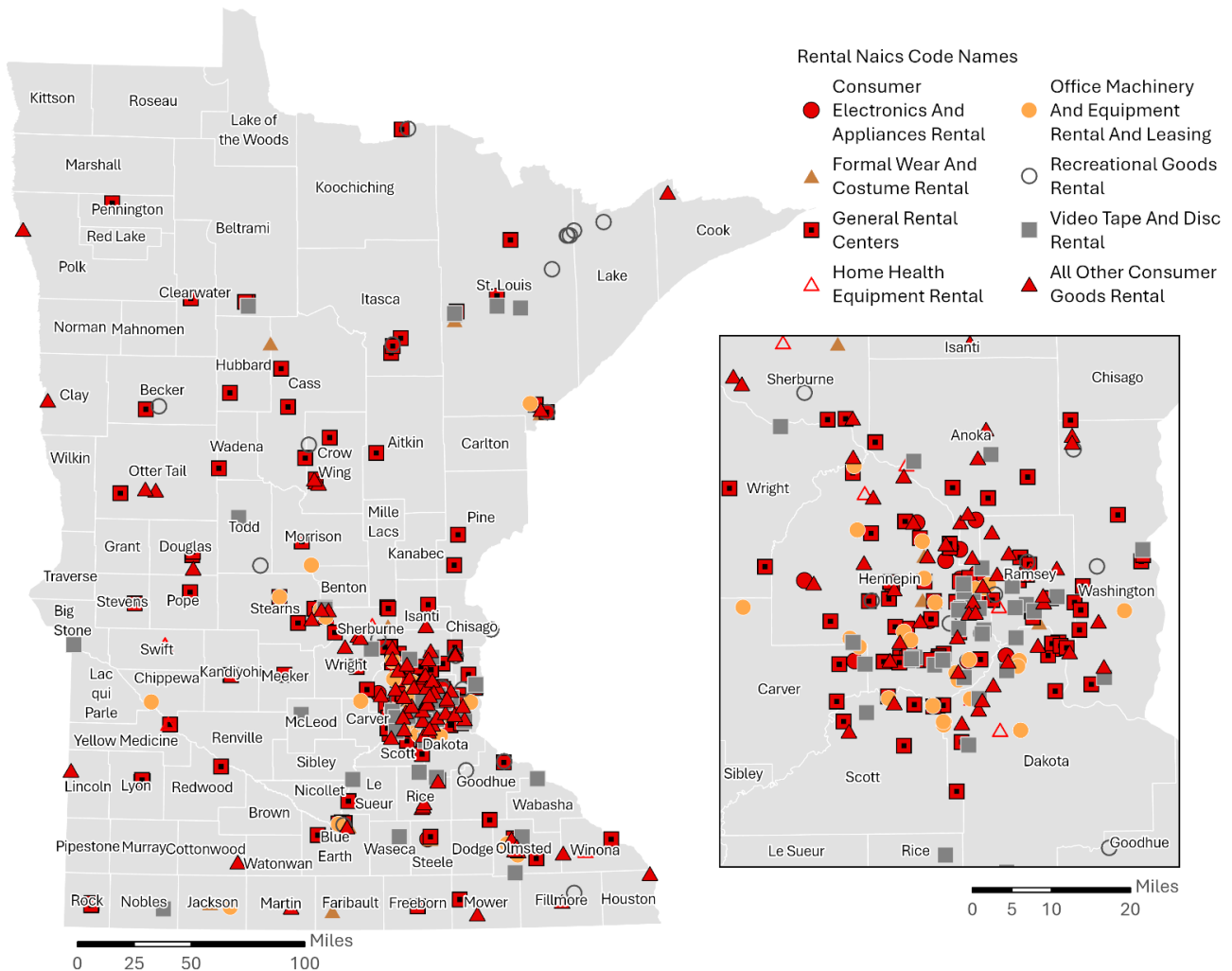


Figure 16. Rental centers by NAICS code name



Recycling and Organics Infrastructure

Minnesota has a diverse network of facilities that manage recyclable and organic materials, including materials recovery facilities (MRFs) and organics processing sites. For this analysis, organics facilities were grouped into two main categories based on available MPCA data:

- **yard waste facilities:** sites that mulch or compost yard debris (e.g., brush, wood waste, leaves, and grass clippings); prevalence reflects Minnesota's yard waste landfill ban; site counts likely underrepresented due to small, private, or seasonal operations not captured in available data; significant volumes of wood waste also managed through biomass energy systems (e.g., District Energy St. Paul, approximately 260,000–300,000 tons annually), which are not counted toward Minnesota's recycling rate under SCORE reporting
- **SSO facilities:** large-scale composting or anaerobic digestion sites processing food scraps, non-recyclable paper, and compostable packaging; identified based on MPCA classification or reported processing activity; facilities concentrated in the TCMA with limited coverage in Greater Minnesota, resulting in regional disparities in access
- **MRFs:** facilities that receive and sort recyclable materials using mechanical and/or manual processes to meet end-market specifications defined in Minn. R. 7035.2860, subp. 1 and 2; 19

facilities statewide with approximately 636,300 tons of throughput in 2021; largest facilities include Waste Management – Minneapolis (179,000 tons), Dem-Con – Shakopee (112,700 tons), and Eureka Recycling – Minneapolis (110,200 tons); statewide network includes large, medium, and small facilities, though coverage remains uneven with gaps in Greater Minnesota and reliance on long-haul transport

Even with an established network of recycling and organics facilities, not all materials are captured through source-separated systems. Some materials remain in the mixed waste stream or are generated as residuals during processing, requiring additional management pathways.

Mixed Waste Processing

MWP facilities attempt to recover recyclables and organics from unsorted MSW. In some regions domestically and internationally, MWP systems have been implemented as a strategy to reduce land disposal and increase material recovery. A facility is currently under development in Minnesota based in part on demonstrated performance in other jurisdictions.

However, MWP faces practical and systemic limitations that constrain its role within Minnesota’s materials management system:

- **manual intervention:** reliance on labor-intensive sorting to remove contaminants and recover materials; generally less effective and more costly than source-separated collection
- **material quality:** high contamination reduces quality and market value of recovered materials compared to source-separated streams, limiting end-market viability
- **organics contamination:** food and paper recovered through MWP typically unsuitable for composting; anaerobic digestion technically possible but requires extensive and costly pre-processing
- **behavioral risk:** perception that “it all gets sorted anyway” may reduce source separation, increasing contamination across the system

Consistent with the diversion scenarios modeled in this report, MWP is treated as a supplemental recovery strategy that captures residual recoverable material remaining after upstream prevention, reuse, and source-separated recycling and organics programs have been fully applied.

Some stakeholders view MWP as a strategy that could further reduce disposal by increasing recovery from mixed waste streams. In the modeled pathways to higher diversion, MWP contributes incremental recovery from remaining mixed waste. However, the analysis assumes that the most durable and cost-effective diversion gains are achieved through upstream waste reduction and high-quality source-separation systems, with MWP playing a secondary role in managing material that escapes higher-priority pathways.

Accordingly, this report does not position MWP as a replacement for source-separated systems or upstream strategies, but as a limited, secondary tool that can provide incremental recovery, as reflected in the modeled scenarios, from remaining mixed waste and residuals while minimizing additional disposal.

Despite recovery efforts across prevention, reuse, source-separated systems, and mixed waste processing, a portion of material remains unrecoverable and must be managed through Minnesota’s disposal system.

The amount of material sorted and sent to end markets by each facility in 2021 is shown in Table 13.

Figure 17. Recycling processing infrastructure in Minnesota

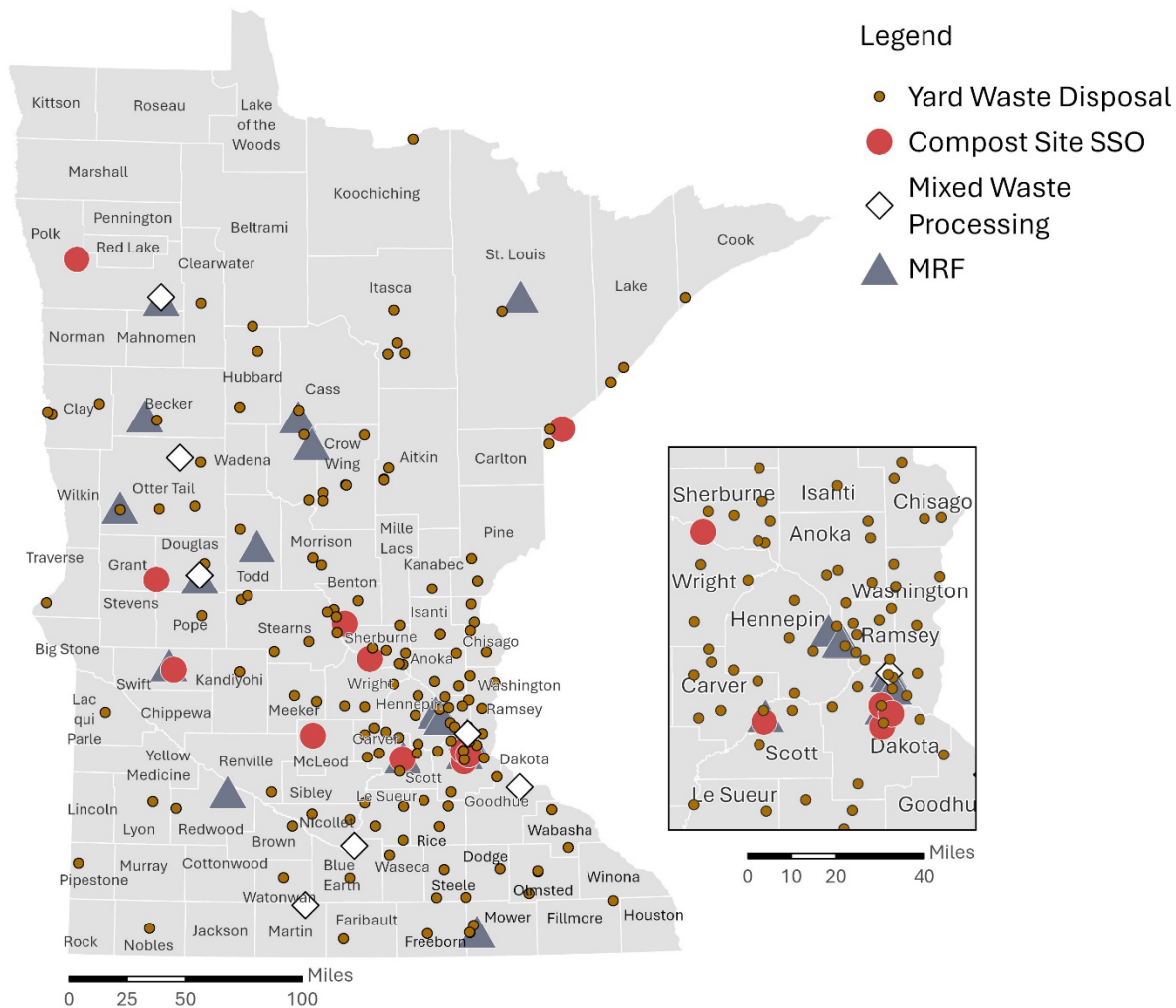


Table 13. Materials recovery facilities in Minnesota

Material recovery facility name	County	Tons sent to end market/sorted in 2021
Republic Services (Inver Grove Heights Recycling Center)	Dakota	1,070
AMG - Alliance LLC	Ramsey	72,612
Becker County Solid Waste Management Facility	Becker	3,126
Cass County Transfer/Recycling Station	Cass	5,265
Dem-Con Materials Recovery Facility	Scott	112,739
Eureka Recycling	Hennepin	110,236
Mower County Recycling Center	Mower	1,387
Otter Tail County	Otter Tail	5,411
Polk County Solid Waste Facility	Polk	6,498
Pope/Douglas Solid Waste Management	Douglas	1,292
Recycling and Energy Center	Washington	12,266
Republic Services Inc (Minneapolis Recycling Center)	Hennepin	79,898
Redwood-Renville Regional Materials Recovery Facility (RRRMRF)	Redwood	5,202
St Louis County Recycling Processing Facility	St. Louis	4,792
Swift County Compost/Recycling Facility	Swift	2,466
Tennis Sanitation LLC	Washington	28,590
Todd County Transfer Station	Todd	1,752
Waste Management Recycle America LLC	Hennepin	179,923
Waste Partners Inc	Cass	1,770

Disposal

Minnesota's disposal system includes a network of 208 facilities that handle MSW and combustion ash. These facilities fall into three main categories:

- **transfer stations (176 facilities):** consolidation points where waste is aggregated before being sent to landfills, WTE facilities, or, in some cases, MRFs or organics processors; especially critical in Greater Minnesota, where direct haul would otherwise require long travel distances
- **MSW landfills (20 facilities):** provide final disposal for MSW statewide; remain the largest disposal pathway, with volumes varying significantly by region
- **waste-to-energy (WTE) Facilities (7 facilities):** combust MSW to generate electricity and/or heat, reducing volume by approximately 70% while producing ash that requires landfilling
- **ash landfills (5 facilities):** manage residual ash from WTE facilities; operated separately from MSW landfills due to the distinct characteristics of combustion residuals

Within this system, waste-to-energy facilities play a distinct role in processing MSW prior to final disposal, particularly in regions where statutory requirements apply.

Role of WTE in the System

WTE facilities reduce the physical volume of waste through combustion and may recover metals from ash. On average, processing (including material recovery and, in some cases, energy recovery) significantly reduces the volume of MSW requiring final disposal.

In the TCMA, Minn. Stat. § 473.848 requires that mixed municipal solid waste generated within the metropolitan area be processed before land disposal. This statutory processing applies specifically to the metropolitan counties governed under Minn. Stat. ch. 473 and does not apply statewide. In Greater Minnesota, processing occurs in many areas as part of local system design and infrastructure, but it is not subject to the same statutory mandate.

These contributions are significant, but they do not replace the need for prevention, reuse, and recycling strategies higher in the waste management hierarchy. Over the long term, sustained investment in upstream strategies like prevention, reuse, and high-quality recycling can reduce the overall amount of waste entering the system while still ensuring that, where required by law, waste is processed prior to disposal.

Additionally, stakeholders noted that the cumulative environmental and community impacts of solid waste disposal and processing infrastructure (e.g., WTE, MWP, transfer stations, and landfills) have in some cases been concentrated in communities already experiencing environmental and socioeconomic stressors.

Advancing upstream reduction, reuse, and high-quality recycling strategies can reduce the overall volume of material requiring disposal or combustion over time. While the extent of impact reduction depends on several factors, including facility operations, permit conditions, regulatory enforcement, and regional waste flows, sustained reduction in disposed tonnage has the potential to lessen cumulative burdens associated with solid waste infrastructure. Where legal processing requirements apply, these reductions can occur while maintaining compliance with applicable statutes and permit conditions.

Ash Landfills and Metal Recovery

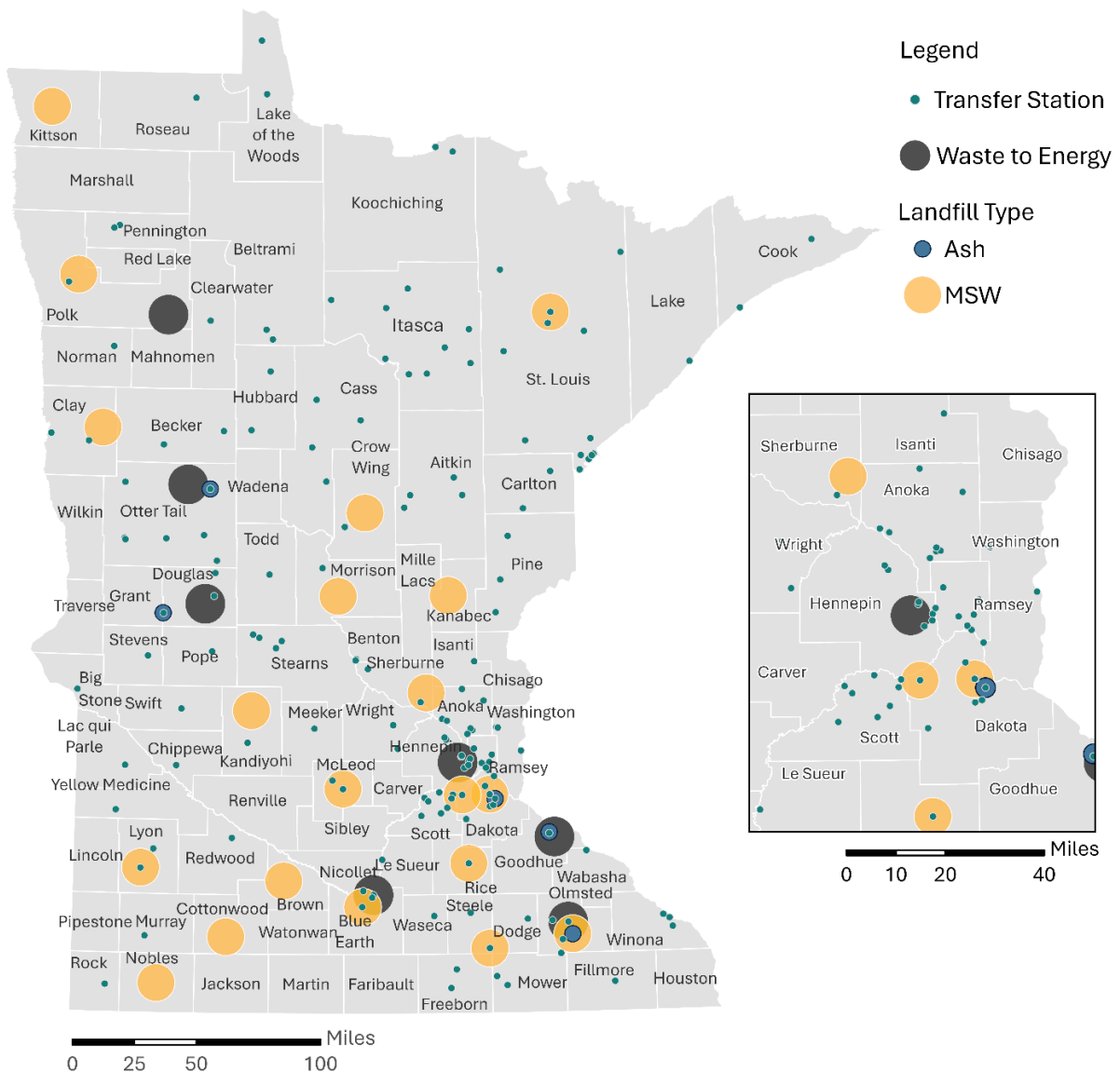
Ash landfills differ from MSW landfills in both scale and material characteristics. Combustion ash is more homogeneous than unprocessed MSW, enabling additional material recovery opportunities and more controlled residual management.

- **metal recovery:** some Minnesota facilities recover metals from ash after combustion; examples include Pope/Douglas Solid Waste Management (ferrous and non-ferrous recovery), Polk County (ash screening for road construction with ferrous removal; most metal recovery occurs pre-combustion at the MRF), PLMSWA (pilot-stage ferrous recovery of approximately 2%, or ~200 tons annually from ~10,000 tons of ash), and SKB Environmental (GEM-Ash), which has processed more than 1 million tons since 2015 and recovers ferrous and non-ferrous metals across multiple fractions; overall, post-combustion recovery can return approximately 2% of original MSW tonnage to the recycling stream, with variation by facility design, ash characteristics, and pre- vs. post-combustion recovery
- **residual management:** remaining ash managed in engineered facilities after metal recovery and any beneficial use; ash landfills regulated under Minnesota solid waste rules and designed to manage ash-specific characteristics such as fine particles and leachate; some ash beneficially used in road construction under state-approved determinations, reducing volumes requiring landfill disposal

Table 14. Active MSW disposal facilities statewide⁶

Type	Subcategory	Quantity
Transfer	-	176
WTE	-	7
Landfill	MSW	20
Landfill	Ash	5

Figure 18. MSW-related disposal infrastructure in Minnesota

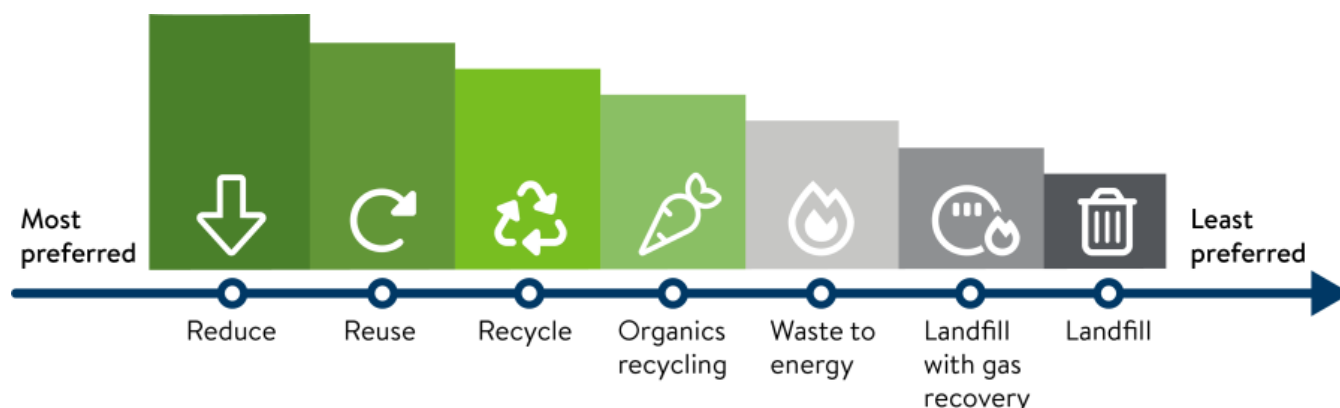


⁶ Minnesota Demolition Debris Land Disposal and Industrial Waste Land Disposal facilities are not shown in Table 14 as they are not a focus of this report.

Pathway to the 90% Diversion Target

Reducing Minnesota’s reliance on disposal facilities will require significant expansion of waste prevention, reuse, and recycling. Minnesota’s statutory waste management hierarchy provides the guiding framework: prevention first, followed by reuse, then recycling and organics recovery, with disposal (WTE and landfilling) as last-resort options. This hierarchy is intentional, as higher-priority strategies deliver the greatest environmental benefits, while overreliance on end-of-pipe systems risks undermining decades of progress.

Figure 19. Minnesota's waste management hierarchy



90% Diversion Scenarios

The 90% diversion model is achieved upward through the hierarchy:

- prevention
- reuse
- source-separated recycling: MRF-compatible collection and drop-off and special recycling collection programs
- source-separated organics (SSO)
- mixed waste processing (MWP): modeled as a supplemental “safety net”
- remaining material managed through disposal: WTE and landfill

Achieving 90% diversion would require Minnesota to become a national leader in prevention, reuse, and source-separated recycling. These scenarios are intentionally ambitious and are designed to test what is possible if Minnesota makes coordinated investments in equitable access, robust education, and modernized infrastructure.

Opportunities for Policy and System Improvements

Achieving the modeled diversion outcomes would require coordinated action across public agencies, private waste and recycling operators, product manufacturers, retailers, and residents. The materials management system in Minnesota is a public-private partnership, and system transformation will require shared responsibility.

- **oversight of hauler communications:** prevent misleading or inconsistent messaging that undermines source separation and public trust
- **equitable access to services:** expand curbside, drop-off, and special collection programs, especially in Greater Minnesota and multi-family housing
- **investment in prevention and reuse:** support repair, resale, food donation infrastructure
- **policy expansion and implementation:** build on tools such as extended producer responsibility (EPR), pay-as-you-throw (PAYT), and targeted disposal bans through expanded coverage, stronger performance standards, and consistent statewide implementation
- **education and outreach:** sustain public trust, participation and reduce contamination across the system
- **pre-processing of MSW:** require or incentivize recovery of recyclables and organics prior to disposal, including waste exported out of state; consistent with Minnesota's waste management hierarchy and metropolitan disposal restrictions, with the MPCA Metropolitan Solid Waste Management Policy Plan (2024) calling for pre-processing at TCMA facilities by 2030
- **CII-focused strategies:** expand large-generator organics requirements, C&D recovery standards, sector-specific technical assistance, and performance-based reporting for high-volume commercial waste generators

Minnesota's pathway to 90% diversion depends on scaling prevention, reuse, and source-separated collection, with MWP serving a supplemental role and WTE and landfiling reserved as last-resort disposal options. With strong policy alignment, infrastructure investment, and attention to system integrity, Minnesota can achieve diversion levels among the highest in the nation while reducing reliance on disposal and maximizing environmental and community benefits.

PROTECTING SYSTEM

Public trust is critical to achieving high diversion.

- "It all gets sorted anyway" messaging undermines source separation.
- Inconsistent or misleading communication reduces participation and increases contamination.

Enhance oversight of hauler communications, expand statewide education, and consider policy tools to ensure accurate information and support source-separated systems.

Diversion Modeling Components and Inputs

Selection of Diversion Targets

The diversion targets modeled in this report were selected to reflect the Legislature’s direction to evaluate pathways to reduce disposal of municipal solid waste by more than 90 percent by 2045 or sooner. The modeled scenarios are designed to test system capacity under high-performance conditions, incorporating aggressive but technically feasible expansion of prevention, reuse, recycling, and organics management.

The percentage reductions are informed by:

- performance levels achieved in leading U.S. and international jurisdictions
- Minnesota-specific waste characterization data
- infrastructure scaling assumptions
- policy tools already in use or under consideration

These targets represent modeled system potential under coordinated policy implementation and infrastructure investment. They are not forecasts of near-term performance under current conditions.

Interpreting the 90% Diversion Scenarios

The 90% diversion scenario represents a modeled system potential under coordinated, statewide implementation of prevention, reuse, recycling, organics recovery, and complementary policy tools. It reflects the upper-bound performance achievable when infrastructure capacity, market development, regulatory alignment, and public participation operate cooperatively. The 90% figure should not be interpreted as a guaranteed outcome under current conditions, nor as a short-term forecast.

Rather, it functions as a systems planning benchmark to evaluate the scale of infrastructure, policy alignment, and behavioral change required to significantly reduce reliance on disposal (e.g., landfilling and waste-to-energy). Achieving diversion at this level would require sustained investment, cross-sector collaboration, and phased implementation over time. Lower diversion levels may occur under partial implementation scenarios or if market, policy, or participation constraints limit system performance.

The Legislature directed the MPCA to evaluate pathways capable of reducing disposal by more than 90 percent; this modeling exercise assesses what would be required to approach that threshold under robust implementation conditions.

Prevention & Reuse

Modeling Inputs

Hierarchy framing

Reuse, repair, and refurbishment sit at the top of Minnesota’s waste hierarchy. These activities conserve resources, reduce GHGs associated with manufacturing and disposal and create local economic benefits. By preventing materials from entering the disposal system, they can reduce the volume of material transported to centralized landfills and waste-to-energy facilities, thereby limiting associated truck traffic and combustion-related emissions relative to disposal-based management. While reuse and repair activities also require transportation and facilities, they typically operate at smaller, distributed scales and do not generate the combustion emissions or landfill gas associated with disposal infrastructure.

Current status in Minnesota

In 2021, MPCA tracked reuse in categories like donated food, wood, textiles, electronics, scrap metal, and durable plastic goods. Reported reuse ranges from 0.01% to 3.5% of total generation, but this understates reality, as significant reuse occurs outside formal reporting systems. Specifically, reuse often flows through nonprofits, mutual-aid networks, resale platforms, and informal exchanges that are not captured in SCORE data.

While Minnesota is expanding reuse through grants and outreach, increasing the recovery of reusable materials remains a significant opportunity, particularly given the volume of reusable materials that continue to be discarded.

Data sources and category nuance to carry into modeling

- **food scraps (edible versus inedible):** 2019 MPCA composition analysis distinguishes edible from inedible scraps within the MSW stream, supporting more realistic modeling of prevention and diversion potential
- **WTE waste sorts:** required waste characterization studies conducted every five years under facility air permits

Policy context (what is already moving the needle)

- **Right to Repair Act (effective 2024):** requires Original Equipment Manufacturers (OEMs) to provide parts, tools, and manuals for covered products; implementation considerations include pathways, usability of OEM portals, and turnaround times; a centralized state resource could improve accessibility and support repair uptake
- **Packaging Waste and Cost Reduction Act (EPR for Packaging, 2023 law):** requires packaging and paper products to be refillable, reusable, recyclable, or compostable by 2032; prevention and reuse are expected outcomes; modeling estimates (Table 15) provide directional insight and can be refined as EPR data becomes available
- **MPCA grants and local initiatives:** FY24 grants include \$4.8M for wasted food prevention and \$4.5M for organics management; funded projects demonstrate measurable diversion potential; tracking outcomes (e.g., tons diverted, contamination reduction, participation, capacity) will support future model refinement

Prevention levers used in the model (examples and cautions)

While prevention strategies can theoretically be applied to any material category, the diversion model estimates the potential growth of prevention and reuse across targeted material types where evidence suggests meaningful opportunity and scalable policy support.

- **plastic film:** prevention (e.g., carryout bags) modeled with sensitivity bounds; evidence from jurisdictions with bag bans shows substantial reductions, with rebound effects (e.g., increased paper bag use or reusable accumulation) incorporated into assumptions; Minnesota law currently preempts local bag bans, so this lever reflects potential outcomes under expanded policy options rather than current conditions
- **single-use food service packaging:** prevention demonstrated in closed systems such as stadiums and universities through reuse programs, hydration stations, and education; examples include a 39% reduction in bottled beverage sales at Washington University in St. Louis and a 50% waste reduction at Merriweather Post Pavilion; broader application may include reusable container systems, beverage dispensing, and behavior shifts (e.g., increased tap water use, reduced reliance on packaged beverages)
- **wasted food:** prevention assumptions include public education, improved food management practices, and expanded food rescue and redistribution systems; modeling distinguishes between edible surplus food and inedible scraps when estimating preventable tonnage;

additional climate benefits include avoided methane emissions from landfills and reduced upstream emissions from production, processing, and transportation

- **textiles:** prevention strategies include rental, repair, resale, and extended product use; emerging policy momentum through EPR (e.g., California SB 707); research indicates high reuse potential, though real-world capture rates remain low; modeling differentiates between donation and actual reuse, with only continued use credited to avoid overstating diversion impacts
- **deconstruction and building materials:** construction and demolition materials represent a major reuse opportunity; deconstruction policies can increase recovery of reusable materials such as lumber and fixtures; examples from Portland and Seattle demonstrate strong outcomes, with Hennepin County providing a Minnesota-based example of reuse and workforce development benefits

Reuse levers used in the model (examples and cautions)

Reuse efforts focus on durable goods that, when properly recovered, can often be given another life. These include items such as glass bottles and jars, durable plastics, metal scrap, and C&D materials. In the case of wasted food, reuse refers to donation pathways that recover edible food for human consumption.

Local ordinances can establish requirements for C&D diversion, including mandates that materials from construction, renovation, or demolition projects be reused or recycled. For example, Cooke County, Illinois, requires demolition and major renovation projects to recycle at least 70% of debris and divert 5% for reuse, policies that have resulted in 130,000 tons of material salvaged or reused since the ordinance took effect in 2012 (Cook County Government 2015).

Similarly, San Jose, California uses a refundable deposit system on demolition and renovation projects in both residential and commercial buildings, including projects valued as low as \$2,000, with deposit recovery contingent on achieving at least 50% diversion by weight (City of San Jose d.).

The prevention and reuse values presented below are scenario-based modeling inputs used to test pathways to achieving 90% diversion. The percentage assumptions reflect performance levels that have been achieved in other jurisdictions through combinations of actions that are currently implementable under existing authority, voluntary market and behavioral shifts, infrastructure expansion, and potential policy expansions that the Legislature may choose to consider.

The modeled values represent technically and programmatically achievable outcomes under coordinated implementation. They are not projections of near-term performance under current conditions, nor do they assume that any single policy change will produce these results. Rather, they illustrate potential benefit levels that could be realized through sustained alignment of policy, market behavior, infrastructure investment, and enforcement.

Table 15 provides the modeled prevention and reuse by material type for the 90% diversion model. In general, prevention efforts are focused on single-use items such as aluminum cans, plastic bottles, and film.

Table 15. Waste prevention and reuse under the 90% diversion model (2021 baseline)

Waste category RRS general	Waste category RRS specific	Prevention	Reuse
Glass	Glass Bottles and Jars	20%	20%
Metal	Aluminum Cans	30%	0%
Metal	Ferrous Scrap	0%	20%

Waste category RRS general	Waste category RRS specific	Prevention	Reuse
Metal	Non-ferrous Scrap	0%	20%
Organics	Wasted Food	40%	20%
Organics	Recyclable Wood	40%	20%
Plastic	Plastic PET #1 Bottles	30%	0%
Plastic	Plastic PET #1 Non-Bottle	30%	0%
Plastic	Plastic HDPE #2 Bottle & Non-Bottle colored and natural combined	30%	0%
Plastic	Plastic PS #6 Expanded Polystyrene	90%	0%
Plastic	Plastic Mixed Plastics Rigid #3-#7	20%	20%
Plastic	Plastic Film	60%	0%
Textiles	Textiles	10%	20%
Other	Electronics	0%	20%
Other	Construction and Demolition	0%	20%
Other	Bulky Waste Mattresses	0%	20%
Other	Bulky Waste Carpet	0%	20%
Other	Other Bulky Waste	0%	20%
Paper	Other Paper	10%	0%

Source-Separated Recycling

Source-separated recycling programs, including curbside collection of recyclables and SSO, drop-off collection of recyclables and SSO, and special pick-up programs, are essential to achieve the levels reflected in the modeled diversion scenario. While many residents currently have access to some form of these programs, statewide expansion and increased participation will be necessary to meet the targets in the 90% diversion models. Avoiding mixing materials that can be recycled or composted with other MSW is critical to reducing contamination, preserving material quality, and maximizing the value of recovered commodities.

Table 16 provides the diversion model inputs for the source-separated recycling programs. These numbers are meant as minimum recycling targets. For example, drop-off recycling rates were set at 45%; however, some drop-off items have higher reported recovery rates, like non-ferrous scrap metal with a 2021 recovery rate of 85%. If the reported recycling rate for any material were greater than the minimum targets, the higher recycling rate was used in the model. Achieving the diversion rates modeled will require policy and programmatic action, coupling policies such as extended producer responsibility and disposal bans with investments in infrastructure (e.g., convenient drop-off sites), education, and community engagement, leveraging the trusted leadership network within communities.

Table 16. Source-separated program capture rate for 90% diversion model

Management of material	Diversion model (minimum targets)
Curbside SSR	75%
Drop-off recycling	45%
SSO - wasted food	55%
SSO - yard waste	90%
SSO - other organics	25%

MRF-Compatible Recycling Programs

MRF-compatible recycling programs serve single-family and multi-family households, as well as commercial and institutional properties, by providing convenient access to recycling services. These programs are designed to capture commonly recycled materials, including:

- corrugated cardboard
- newspapers, magazines, office and mixed paper
- cartons
- aluminum cans
- steel cans
- glass bottles and jars
- plastic bottles, jugs, and tubs

Achieving a 75% recovery rate for MRF-compatible recyclables will require significant expansion of both access to and participation in recycling programs across Minnesota. Currently, access remains uneven: only 61% of single-family households have curbside recycling, and just 33% of multi-family residents have access to any recycling program, whether onsite or through drop-off options (The Recycling Partnership, 2024).

Even where programs are available, participation is not universal. Nationally, only 59% of households with access actively participate in recycling (The Recycling Partnership, 2024). While comparable data are not available for the commercial sector, similar access and participation gaps likely exist for businesses and institutions, indicating a need to expand convenient and cost-effective recycling options across all sectors.

MPCA will also need to invest in education and outreach that not only informs residents and businesses about how and when to participate but also builds long-term trust and engagement within communities. Effective strategies must leverage local leaders, respond to specific community needs, and be delivered in multiple formats to reach diverse audiences. Education efforts should be ongoing, culturally responsive, and equity-centered so that all Minnesotans are supported in fully participating in recycling programs.

Despite these challenges, the target recovery rates are attainable. In 2021, several materials in Minnesota already met or approached the minimum targets set in the diversion models, including cardboard (56%), white office paper (57%), and mixed paper (65%).

Alternative Collection Systems

Recyclable items that are not effectively captured or sorted at MRFs must be collected for recycling in separate programs, either through drop-off recycling facilities or special pick-up collection routes for residents that cannot easily bring items to drop-off facilities. These items include non-container glass, ferrous and non-ferrous scrap metal, wood waste, electronics, C&D materials, bulky items such as large toys, furniture, mattresses, and carpet, as well as tires, textiles, expanded polystyrene, and plastic film.

As it is with MRF-compatible recyclables, keeping these materials separate from the MSW stream reduces contamination and enhances the quality and market value of recovered materials. Importantly, many of these items, particularly bulky waste, textiles, C&D materials, and electronics, are not efficiently recovered any other way. Ensuring they are managed through dedicated drop-off and special pick-up programs is therefore essential to achieving the modeled outcomes.

For some Minnesotans, coordinating transportation to a drop-off location or prioritizing the time it takes to haul materials to a specific location can be a barrier to participation. Robust drop-off infrastructure

should be complemented by special pick-up programs that allow equitable and convenient access for recycling these materials without putting the burden entirely on the residents. Periodic curbside pickup for items typically collected through drop-offs, like bulky items, household hazardous waste, and textiles, can provide an important service, especially for elderly, rural, or low-income residents. Another option to provide convenient access to these services, particularly in rural areas, is to provide mobile collection events in different parts of a city or region.

While costs of programs like these vary widely dependent on factors such as the types of materials collected, participation levels, transportation needs and geography covered, and processing requirements, some examples of programs like this in Minnesota and in other states across the country are included below:

- [St. Paul, Minnesota](#): one bulky item pickup per unit per calendar month included with regular garbage service; unlimited mattress recycling provided at no additional cost
- [Minneapolis, Minnesota](#): weekly curbside collection of up to two large items (e.g., furniture, carpets, appliances, electronics, mattresses, metals); appliances, e-waste, and metals recycled, with other materials landfilled; approximately 26,586 items collected annually, including ~1,734 tons recycled in 2024; program cost approximately \$3.0M annually; exploring furniture recycling partnerships
- [Hopkins, Minnesota](#): on-demand bulky item pickup through Public Works; fee-based service (\$25 per item plus state and county fees), with higher costs for appliances (~\$40) and mattresses (~\$100)
- [Bloomington, Minnesota](#): monthly scheduled bulky item pickup in partnership with Better Futures Minnesota; no direct fee to residents, with costs covered through utility billing; focus on reuse and recycling of collected materials
- [Pennsylvania Resources Council \(southwestern Pennsylvania\)](#): mobile collection events for e-waste, polystyrene, and other materials; model demonstrates potential for nonprofit-led programs supported through grants
- [Phoenix, Arizona](#): citywide HHW curbside collection program serving ~420,000 households; one annual pickup included in monthly service fee (\$36.59); program cost approximately \$565,000 annually; participation approximately 1% of households (4,797 collections in FY 2024/25)
- [Seattle, Washington](#): curbside special item collection program offering a mix of fee-based and free services (e.g., foam blocks, cooking oil); approximately 31,500 service requests in 2024 (~9% participation); low-income households eligible for free pickups
- [Resource Renew \(Duluth area\)](#): community clean-out events targeting environmentally disadvantaged areas; accepts bulky waste, HHW, e-waste, scrap metal, and appliances; recent event collected ~6.0 tons across 19 pickups, with hauling costs of \$760–\$1,000 per event

Several materials that rely on drop-off recycling already exceed Minnesota's 45% recovery target, including ferrous and non-ferrous scrap metal and tires. These high recovery rates are driven by strong end-market demand (e.g., for scrap metal) and regulatory tools such as disposal bans (e.g., for tires).

However, other materials primarily collected through drop-off or special pick-up programs showed much lower recovery rates in 2021 SCORE data (e.g., painted and treated wood (1%), electronics (26%), other plastics (28%), and dimensional lumber (38%)). On average, drop-off and special pick-up materials had a recovery rate of just 35% in 2021.

The modeled 90% diversion scenario projects increasing drop-off recovery rates to up to 45%. Achieving this level of performance will require targeted investments in:

- **expanded drop-off access:** increased availability of recycling program for residents and businesses
- **equitable service delivery:** improved access through special curbside pickup programs or mobile collection events
- **education and outreach:** increased awareness of recovery options and the value of keeping materials out of the landfill
- **policy mechanisms:** the use of tools such as EPR, PAYT, and disposal bans
- **end market development:** growth in local capacity to process and utilize recovered materials

Minnesota has taken proactive steps to expand access and convenience for recycling hard-to-recycle materials. The state passed the Electronics Recycling Act in 2007, and in 2016 updated the program to implement a market share-based recovery system for covered electronic devices. These include televisions, computer monitors, laptops, tablets, and peripheral items such as keyboards, mice, and external hard drives, as well as commonly accepted additional devices like printers, scanners, fax machines, and DVD players. Under the law, manufacturers must register with the MPCA, pay a registration fee, and support the collection and recycling of covered electronics in proportion to their market share. Between 2017 and 2025, the program achieved an average recovery rate of 3.9 pounds of recycled electronics per capita annually (MPCA, 2025a).

While the program has expanded access to electronics recycling statewide, stakeholders have raised concerns that manufacturer payments do not fully cover the cost of collection and recycling under current market conditions. As a result, revisions to the program are under consideration, including potential updates to the funding structure and expansion of the list of covered products to better align with evolving waste streams and program costs.

Another example of Minnesota expanding access to hard-to-recycle materials is the state's Architectural Paint Stewardship program. Under the law, no architectural paint may be offered for sale in the state unless the paint producer participates in the approved stewardship plan operated by PaintCare. To support convenient collection, PaintCare supports a network of county HHW programs established by the state that collect residential paint. As of 2025, PaintCare reported 269 year-round drop-off sites across Minnesota, with 98% of residents living within 15 miles of a location. Most sites are located at hardware stores, paint retailers, and HHW facilities. In 2024 alone, the program successfully collected more than 900,000 gallons of postconsumer paint (PaintCare, 2025).

Even with strong program investments, achieving a 40 - 65% recovery rate of hard-to-recycle materials through drop-off and special pick-up programs would require a significant and sustained shift in Minnesota's waste management strategy. This shift is essential if the state is to reach their diversion targets. Once hard-to-recycle materials are mixed into the MSW stream, they are difficult, if not impossible, to recover through MRFs or mixed waste processing. Diverting these items at the source through dedicated drop-off and special collection programs is therefore critical and Minnesota cannot reduce reliance on disposal without a dedicated focus on increasing recovery of hard-to-recycle materials.

Source-Separated Organic (SSO) Recovery Program

Collection of source-separated yard waste and wasted food is essential for meeting the modeled diversion goals. Effective SSO programs focus on minimizing contamination from non-compostable materials, which reduces the need for costly removal processes and helps address environmental concerns, including PFAS.

Consistent with the waste management hierarchy, the most cost-effective approach is to prevent wasted food and rescue edible food before it enters the waste stream. Minnesota has made targeted investments in wasted food prevention and food rescue, including grant funding administered through the MPCA and other partners, although funding levels and availability may vary over time. The state has established a goal to reduce wasted food by 50% by 2030, relative to a 2013 baseline.

In addition to ongoing base funding, the Legislature appropriated significant one-time funding in 2023 to accelerate prevention and food rescue infrastructure statewide. This expanded grantmaking and supported multiple projects focused on scaling infrastructure, partnerships, and regional capacity.

When prevention or rescue are not possible, composting remains the most cost-effective and environmentally beneficial recycling pathway. Windrow and aerated static pile (ASP) systems are widely used in Minnesota, producing compost that supports landscaping, agriculture, and other beneficial uses.

Modeled SSO recovery rates

The SSO recycling rates used in the model are divided into three categories:

- **yard waste:** longstanding landfill ban supports high recovery (87% in 2021); model assumes continued strong performance with a 90% capture rate
- **wasted food:** lower recovery rates (17% in 2021) due to limited collection access outside metro areas, infrastructure gaps, and household concerns such as odor or pests; model projects an increase to 55%
- **other organics:** includes materials such as cork, rope, sawdust, and animal carcasses; represents a small portion of the waste stream with limited recovery options

Additional organics materials and policy context

- **compostable paper and packaging:** includes soiled paper (e.g., napkins, pizza boxes) and BPI-certified compostable products; accepted at many Minnesota facilities and regulated under Minn. Stat. § 325E.046, which restricts “compostable” labeling to certified products beginning January 1, 2026
- **wasted food composition:** MPCA’s 2019–2022 study found approximately 62% of wasted food was edible or recoverable, reinforcing the importance of prevention and rescue strategies
- **program access and statutory framework:** under Minn. Stat. § 115A.552, residents must be provided the opportunity to recycle at no extra charge; because organics are considered recyclable, this framework supports expansion of SSO programs; communities across Minnesota have developed a range of programs to increase access

TCMA programs

- **Hennepin County:** countywide ordinance (2022) requiring curbside organics for single-family households; prohibits higher fees for organics service than trash; supported by drop-off mapping, technical guidance, and standardized program design; model for statewide expansion
- **St. Louis Park and Minneapolis:** robust residential programs combining curbside and drop-off access; St. Louis Park provides weekly no-cost curbside collection and 10 drop-off sites; Minneapolis offers citywide curbside service and additional drop-off access; programs emphasize convenience and education, with low contamination (~1% in Minneapolis)
- **Ramsey and Washington counties:** food scraps collection integrated into regular trash using compostable bags and backend sorting with AI-enabled robotics; reduces need for separate carts but requires more complex processing infrastructure
- **Shakopee Mdewakanton Sioux Community (SMSC):** Dakota Prairie Composting Facility, largest SSO site in the Great Lakes region; serves Tribal, municipal, and commercial customers; demonstrates regional infrastructure leadership

- **Dakota and Scott counties:** network of drop-off sites supported through partnerships with SMSC and New Prague Organics; expands access in suburban and rural areas and complements curbside programs

Greater Minnesota programs

- **Resource Renew (Duluth area):** commercial SSO separation requirement for large generators paired with technical assistance, food donation support, and regional processing infrastructure
- **Pope/Douglas Solid Waste Management:** Glacial Ridge Compost Facility serving as a regional processing hub; reduces hauling distances and supports multi-county diversion
- **Polk County:** SSO composting site with residential drop-off; facility upgrades support processing of bagged organics and separation from MSW
- **Otter Tail County:** pilot program linking local collection to regional composting facility; includes curbside and drop-off access; demonstrates inter-county collaboration
- **Beltrami County:** organics program for residents and businesses accepting food scraps, soiled paper, and certified compostables; demonstrates rural program viability

Tribal programs in Greater Minnesota

- **Fond du Lac Band of Lake Superior Chippewa:** \$1.5M EPA SWIFR-funded composting hub-and-spoke system serving northeastern Minnesota
- **Grand Portage Band of Lake Superior Chippewa:** in-vessel composting system funded by MPCA; supports local diversion and food sovereignty
- **Prairie Island Indian Community:** residential organics program using neighborhood compost systems managed by community stewards
- **Leech Lake Band of Ojibwe:** composting initiative linked to community gardens, supporting local food systems and food sovereignty

CII program models (Examples from Other States)

- **Massachusetts:** commercial food material disposal ban for generators above threshold; requires donation and organics recycling
- **New York:** food donation and scraps recycling law requiring large generators to donate edible food and recycle remaining organics within defined distance thresholds
- **Seattle, Washington:** mandatory commercial recycling and organics requirements with enforcement through contamination thresholds and account charges
- **San Francisco, California:** mandatory separation of recyclables, compostables, and trash for residents and businesses
- **California (CALGreen):** statewide requirement for at least 65% diversion of construction and demolition materials
- **Portland, Oregon and Boulder, Colorado:** deconstruction requirements supporting reuse and higher-value material recovery

The metro, Greater Minnesota, and Tribal examples mentioned above demonstrate the diverse pathways Minnesota communities are using to expand access to SSO recycling. In the TCMA, ordinances and curbside programs are driving broad access. In Greater Minnesota, counties and regional facilities are developing infrastructure that makes SSO diversion viable outside the metro. Tribal Nations are simultaneously advancing both infrastructure and community-scale programs that integrate organics diversion with broader sustainability and food sovereignty goals. Collectively, these efforts highlight Minnesota's statewide progress and the importance of continued investment to ensure all residents have equitable, convenient access to organics recycling.

Despite significant progress expanding wasted food diversion programs across Minnesota, notable gaps remain in both access and participation. Even in communities with established curbside or drop-off programs, participation rates are often lower than needed to achieve modeled diversion outcomes. Expanding infrastructure alone is insufficient without sustained engagement, education, and behavior change.

Multi-family households face additional barriers. The most common form of access for multi-family residents is drop-off programs, which, while critical for those without onsite service, place additional burden on participants and can reduce overall engagement. Program design challenges including shared waste spaces, property management coordination, and contamination concerns further complicate implementation.

Additionally, while wasted food recycling programs are concentrated in the TCMA, many rural residents lack consistent access to SSO recycling options. Outreach materials are typically provided in English, limiting participation from non-English-speaking residents. Some metro counties have begun addressing this gap through culturally accessible messaging, multilingual education and outreach campaigns to improve awareness and participation across diverse communities.

Achieving higher recovery rates will require not only continued infrastructure expansion, but also sustained investment in culturally responsive education, community partnerships, and program design strategies that reduce participation barriers.

Statewide policy mechanisms can influence the pace and scale of wasted food diversion. Vermont implemented a phased residential and commercial food scrap disposal ban, culminating in a statewide requirement in 2020. By 2023, Vermont reported an estimated 52% residential diversion rate for food scraps (Vermont Department of Environmental Conservation, 2023). While diversion outcomes depend on infrastructure capacity, education, enforcement, and market conditions, this example demonstrates that coordinated statewide policy combined with infrastructure investment can substantially increase participation and recovery rates.

Mixed Waste Processing (MWP)

MWP facilities accept MSW without prior sorting and attempt to recover recyclables and organics before the remainder goes to disposal. Because recovered materials from MWP are typically lower quality and more contaminated in addition to facilities' higher capital and operating costs, MWP is modeled as a secondary measure rather than a primary pathway to diversion. MWP can complement but not replace waste reduction, reuse, recycling, and SSO programs, which remain the most effective and efficient ways to achieve diversion.

Advances in automation, including optical sorters, artificial intelligence, and advanced magnets, have improved capture rates while reducing staffing needs, making MWP systems more efficient than earlier designs. These facilities can recover a mix of materials such as cans, cardboard, some plastics, and food waste. Organics captured in this process are typically unsuitable for composting but can be sent to anaerobic digestion (AD), with the resulting digestate sometimes modeled as being further processed into biochar. This approach may help stabilize nutrients, reduce odors, and even support long-term carbon storage, though commercial applications, permitting, and end markets for MSW-derived biochar remain limited.

Despite these advances, MWP faces significant limitations. Fiber recovery remains poor because paper is often saturated with liquids and contaminated by organics. Emerging systems such as the "Juno" process show promise for cleaning and recovering this material but are not yet proven at commercial scale. Digestate from MSW also poses challenges, as it often contains PFAS, microplastics, and heavy

metals. Converting digestate to biochar has been proposed as a risk mitigation strategy; however, long-term contaminant behavior, regulatory standards, product safety, and end-market acceptance are still evolving areas of research and policy development.

At the same time, costs for construction, operation, and maintenance of MWP facilities are high, and some facilities across North America have reported overruns and under-performance relative to expectations. End markets for some recovered streams, such as fiber, biochar, or bulky plastics, remain limited or variable depending on quality and contamination levels. Recovery is not practical for certain materials, including mattresses, electronics, gypsum board, and bulky waste; these items are typically removed manually and sent to disposal.

In Minnesota, MWP approaches have been tested in several contexts. Atomic Recycling (now part of LRS) operates a construction and demolition materials recovery facility in Minneapolis and reports recovery rates of around 45% for wood, concrete, shingles, cardboard, and metals. Red Wing and Dem-Con have piloted pre-processing of organics-rich waste streams, including trials linked to anaerobic digestion (AD) and biochar production. These examples highlight both the potential and the current limits of MWP within the state.

The effectiveness of MWP in contributing to statewide diversion depends on performance assumptions. In the 90% diversion scenario, MWP is modeled at the upper bounds of current technology, including recovery of some materials that are more efficiently captured through source-separated programs. Achieving this level of performance would require significant investment in equipment and labor, strong end-markets for recovered outputs, and major advances in contamination management. These are conditions that may not be achievable at scale in the near term.

For this reason, MWP is treated as a supplemental recovery step, rather than a substitute for prevention, reuse, and source-separated collection. In the modeled system sequence, MWP captures residual recoverable materials but does not drive the primary diversion gains.

Tables 9 and 10 summarize the maximum set of material categories assumed recoverable through MWP in the 90% diversion scenarios; these assumptions represent upper-bound performance and are not intended to imply that MWP becomes the foundation of the diversion system.

Table 17. Material capture assumptions for MWP under the 90% diversion scenario⁷

Materials assumed to be captured through MWP	Materials not assumed to be captured through MWP
• Glass bottles and jars • Glass non-container • Aluminum cans • Steel cans • Ferrous scrap • Non-ferrous scrap • Wasted food • Recyclable wood • Yard waste • Other organics • Corrugated cardboard • Paperboard and boxboard • Newspaper • Magazines • White office paper • Mixed paper • Other paper • Gable-top and aseptic cartons • Compostable paper • Plastic PET #1 bottles and non-bottles • Plastic HDPE #2 bottles and non-bottles • Plastic PP #5 • Plastic mixed plastic rigid #3-#7 • Other plastics	• Plastic PS #6 expanded polystyrene • Plastic film • Textiles • Electronics • Construction and demolition • Household hazardous waste • Bulky waste mattresses • Bulky waste carpet • Other bulky waste • Tires • Residue • Inert rocks, soil, and fines

Table 18. Materials diversion rates for the 90% diversion model

Materials captured in 90% diversion model	Recycling diversion	Organics diversion	Total diversion
Corrugated Cardboard	70%	25%	95%
Paperboard Boxboard, Newspaper (ONP), Magazines, White Office, Mixed Paper, Gable-top and Aseptic Cartons Combined	15%	80%	95%
Steel Cans, Steel Aerosol Cans, Ferrous Scrap	85%	-	85%
Plastic PET #1 Bottles, Plastic PET #1 Non-Bottle	80%	-	80%
Plastic HDPE #2 Bottles Natural	80%	-	80%
Plastic HDPE #2 Bottles colored, Plastic HDPE #2 Non-Bottle colored and natural combined	85%	-	80%
Plastic PP#5, Plastic Mixed Plastics Rigid #3-#7, Plastic Durable and Bulky Plastic Items, Plastic Other Plastic	85%	-	85%
Aluminum Cans	85%	-	85%

⁷ Note: "Captured" reflects modeled assumptions of material recovery through mixed waste processing and may include materials recovered for lower-value uses or requiring additional processing. Actual recovery rates and end uses may vary.

Materials captured in 90% diversion model	Recycling diversion	Organics diversion	Total diversion
Aluminum Foil, Non-ferrous Scrap, Mixed Ferrous and Non-Ferrous	85%	-	100%
Compostable Paper Non-Recoverable	-	100%	80%
Wasted Food	-	80%	90%
Yard waste	-	90%	90%

Diversion Modeling Results

Statewide Diversion Scenario Modeling Results

Prevention and reuse are the foundation of Minnesota’s waste management hierarchy. Although prevention is not considered diversion under Minnesota statute, it is included in this modeling to show its critical role in reducing overall MSW generation. By avoiding waste at the source, prevention delivers the greatest environmental and equity benefits as it reduces the need for new extraction and manufacturing, minimizes the energy and emissions from downstream processing, and lessens the siting burdens that disproportionately impact historically overburdened communities. For these reasons, prevention is modeled as a reduction to the total waste stream, separate from diversion, but emphasized as a top programmatic and policy priority.

Reuse, by contrast, is counted as diversion. It captures materials before they enter recycling or disposal systems, preserving their value, reducing demand for new production, and supporting local repair and resale markets. In Minnesota’s diversion pathway, reuse plays an expanded role compared to 2021, with modeled increases from about 1.5 percent of the MSW stream to 5 percent under the 90% scenario.

Source-separated recycling and organics collection (SSR/SSO) form the backbone of Minnesota’s diversion strategy. These programs are cost effective, environmentally preferable, and broadly proven at scale. They are modeled to capture two-thirds of diverted material.

MWP plays a supporting role and accounts for less than one-quarter of diversion; accordingly, it is treated as a supplemental recovery option for capturing recyclables and organics disposed of in the waste stream. While MWP can contribute additional tonnage, it requires significant capital and operating investment, yields material streams with higher contamination, and faces limited end-market demand.

Table 19 and Figure 20 show the distribution of tons by strategy under the 90% diversion model compared to 2021 baseline disposal of 3.4 million tons. To reach 90% diversion, 2.8 million tons of MSW must be shifted from disposal to prevention, reuse, and recycling programs.

Figure 20. Distribution of MSW by management method under baseline (2021) and 90% diversion scenario (tons)⁸

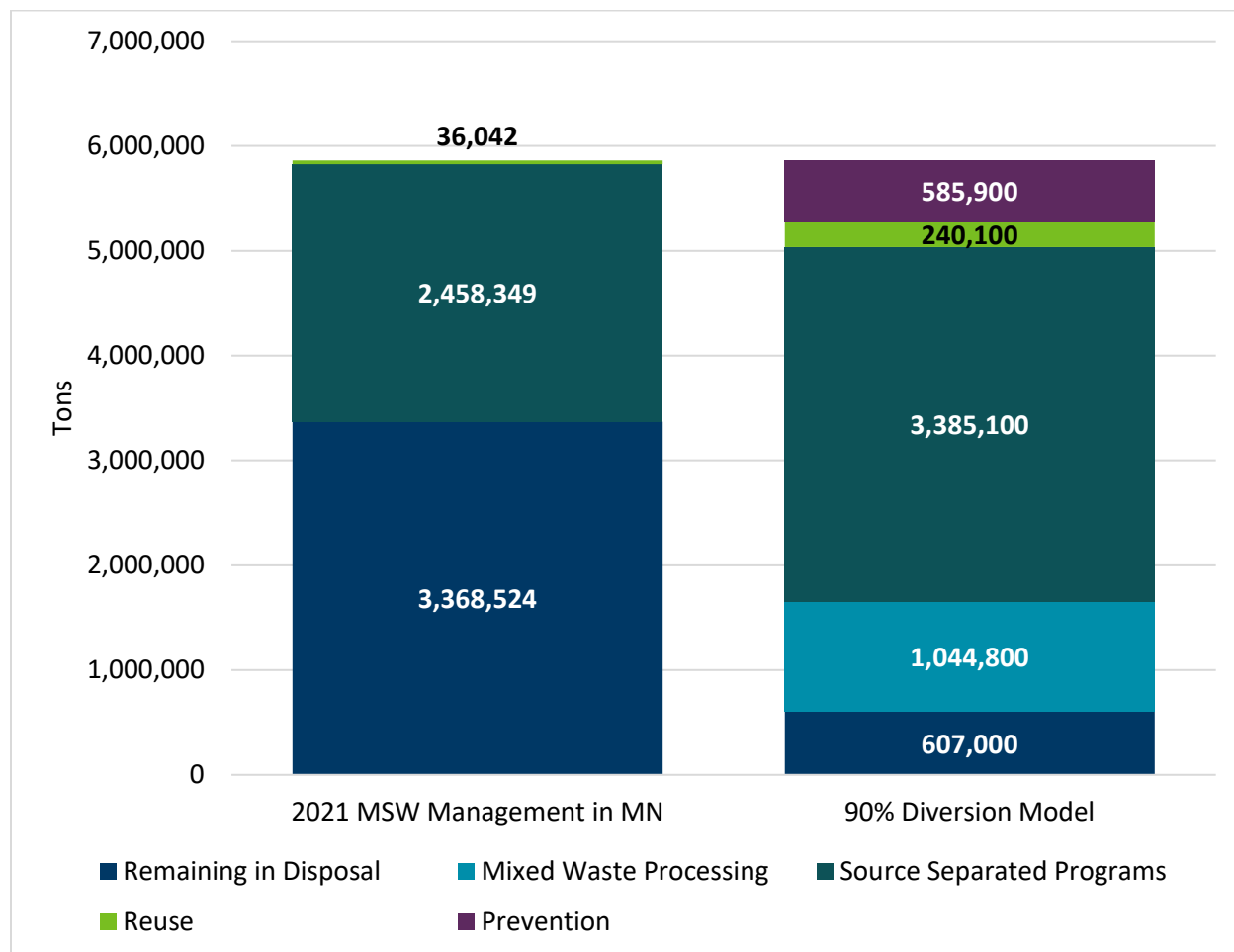


Table 19. Tons to each material management strategy for the 90% diversion model

Material management strategy	2021 baseline	90% diversion model
Prevention	-	585,874
Reuse	36,042	240,123
Source-separated Programs	2,458,3499	3,385,111
Mixed Waste Processing		1,044,764
Remaining in Disposal	3,368,524	607,043
Total	5,862,915	5,862,915
Diversion Rate (excl. prevention)	43%	90%

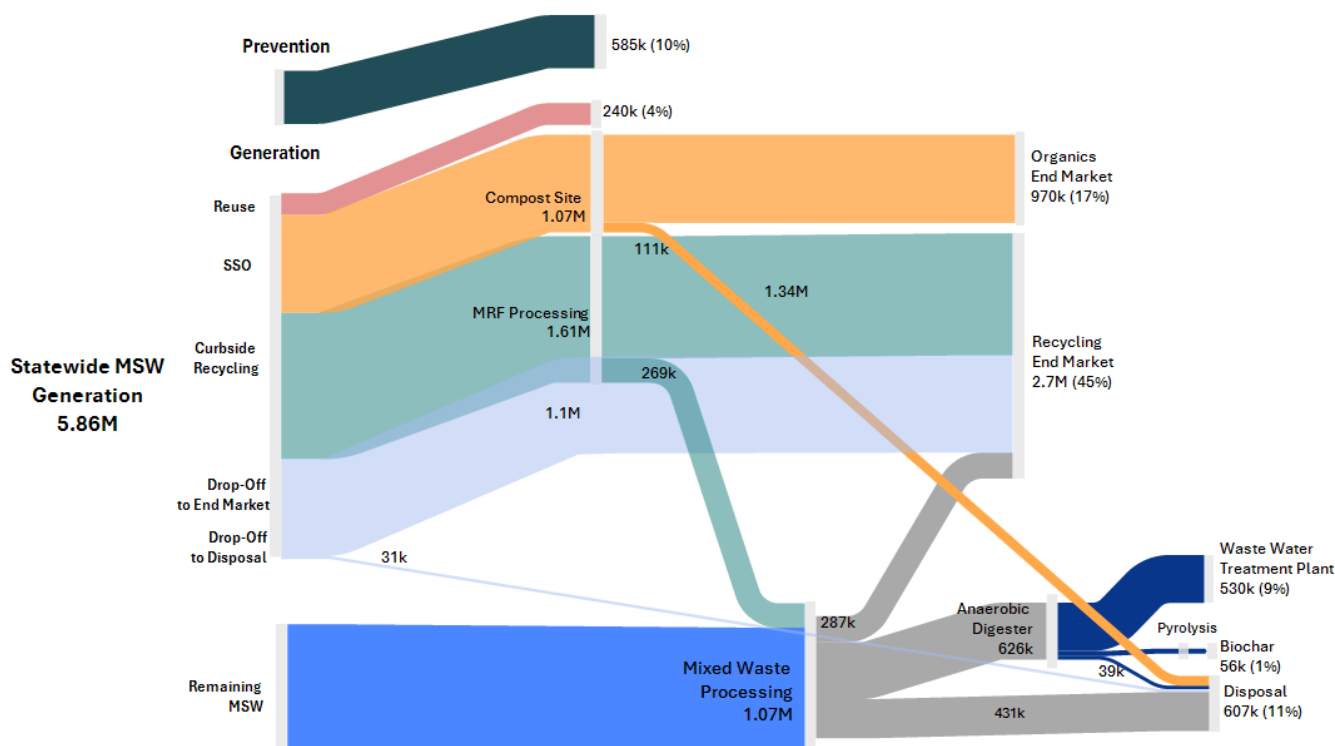
Figure 21 and Figure 22 illustrate how MSW flows through reuse and diversion systems under the 90% diversion scenario. The model assumes that materials are progressively captured for reuse, recycling, and organics management before MWP serves as a final backstop.

⁸ Minnesota has some recycling efforts through mixed-waste processing and WTE metal capture; however, the volume of material capture from those activities cannot be separated from the source separated collection programs.

⁹ Baseline 2021 recycling in Minnesota includes source-separated collection programs, recycling from MWP, and recovery of metals from WTE. It is not possible with current data to differentiate the source of recycled material.

Residual management is an important factor in this modeling. Materials processing facilities like MRFs and compost sites always generate residuals. Under Minn. Stat. § 473.844, subd. 1(c), MRFs must meet an 85/15 recovery-to-residue standard, and most currently achieve 88–91% recovery, with residuals in the 9–12% range. For modeling purposes, residuals from MRFs, compost facilities, and drop-off programs are assumed to be routed to MWP facilities where additional recyclables and organics can be recovered. Unrecoverable residues from these processes are ultimately sent to disposal. Achieving the 90% diversion scenario assumes near-optimal participation and capture rates across all programs, increased reliance on MWP, and successful deployment of emerging or unproven technologies. Achieving this level would require significant new investments, regulatory development, and market creation, and may not be realistic without major breakthroughs. For policymakers, the results highlight the hierarchy of strategies. Prevention and reuse are essential to reducing overall waste generation, though only reuse is counted as diversion. Source-separated recycling and organics programs must remain the backbone of Minnesota’s system. Mixed waste processing can provide additional diversion but should be seen as a last resort, not a substitute, for upstream action.

Figure 21. Flow of MSW through management pathways under the 90% diversion scenario (tons)



Generator Scenario Modeling Results

Achieving statewide diversion targets requires coordinated efforts across all major sectors of Minnesota’s MSW stream: single-family households, multi-family households, and the CII sector. The model shows that while households play an important role, most additional diversion must come from CII sources. Of the total new tons that must be diverted, approximately 37 percent will need to come from single-family households, 10 percent from multi-family households, and 54 percent from the CII sector (Figure 22). Given that slightly more than half of new diversion must come from the CII sector, policy design, enforcement mechanisms, and technical assistance efforts should prioritize large generators and high-volume material streams.

Many municipal diversion programs remain focused on single-family households, where curbside recycling and organics service are most established. Multi-family and CII properties, however, have

historically shown lower participation rates and more variability in program access and implementation compared to single-family households. Under state statute (Minn. Stat. § 115A.151), commercial buildings, including multi-family residential buildings with four or more units, that generate more than four cubic yards of trash per week must provide recycling for at least three materials such as paper, glass, metal, or plastic containers. While this requirement covers both sectors, it applies only in Minnesota's metropolitan region, and enforcement resources are limited while resources for technical assistance are insufficient. As a result, access and compliance remain uneven across the state.

Table 20 provides a breakdown of the additional diversion tonnage required by generator type and diversion pathway in the 90% models. Under the 90% model, an additional 1.72 million tons must be captured statewide, with approximately 919,000 tons, accounting for over half of the required new diversion expected from the CII sector. Of this amount, nearly half is modeled to come from prevention and reuse activities alone, underscoring the importance of upstream strategies within commercial and institutional settings. Because commercial and institutional generators produce large volumes of relatively homogenous material streams, even moderate improvements in prevention, reuse, and source-separated recovery can yield substantial tonnage gains relative to residential programs.

What CII Diversion Looks like in Practice

Commercial, institutional, and industrial generators produce large volumes of relatively homogenous material streams, creating opportunities for high-impact diversion when programs are properly designed and supported. Examples of scalable CII diversion strategies include:

- **commercial organics recovery:** source-separated collection and food rescue partnerships for large food-generating entities (e.g., grocery retailers, distributors, universities, hospitals, correctional facilities); consistent and concentrated waste streams support higher recovery rates than residential systems
- **construction and demolition (C&D) material recovery:** job-site separation, deconstruction practices, and salvage markets for wood, metal, concrete, and gypsum; reduces disposal and contributes significant tonnage toward diversion goals
- **sector-specific reuse and surplus management:** reuse networks and secondary markets for durable goods, equipment, furniture, and surplus materials across businesses and institutions; extends product life and prevents entry into the waste stream
- **packaging and commercial recycling improvements:** enhanced collection infrastructure, standardized materials, and producer responsibility policies to increase recovery of high-volume packaging and paper streams

Because of the scale and concentration of materials in the CII sector, even modest percentage increases in diversion can yield substantial tonnage gains relative to residential programs.

The results make clear that reaching Minnesota's diversion targets will require:

- **universal access to services:** recycling and organics collection across all housing types, including multi-family, paired with sustained efforts to increase participation and reduce contamination.
- **CII requirements and accountability:** expanded requirements, enforcement, technical assistance, and performance tracking across the state, not limited to the metro; requirements alone insufficient without engagement and compliance support
- **investment in prevention and reuse:** expanded infrastructure for businesses, schools, and institutions, which account for a significant share of the additional CII diversion required under the 90% model

In short, while households remain a critical part of the solution, Minnesota cannot achieve 90% diversion without systemic improvements in the CII sector, stronger and more consistent policies, and sustained participation across all generator types.

Figure 22. Additional tons to be captured by generating sector (proportion)

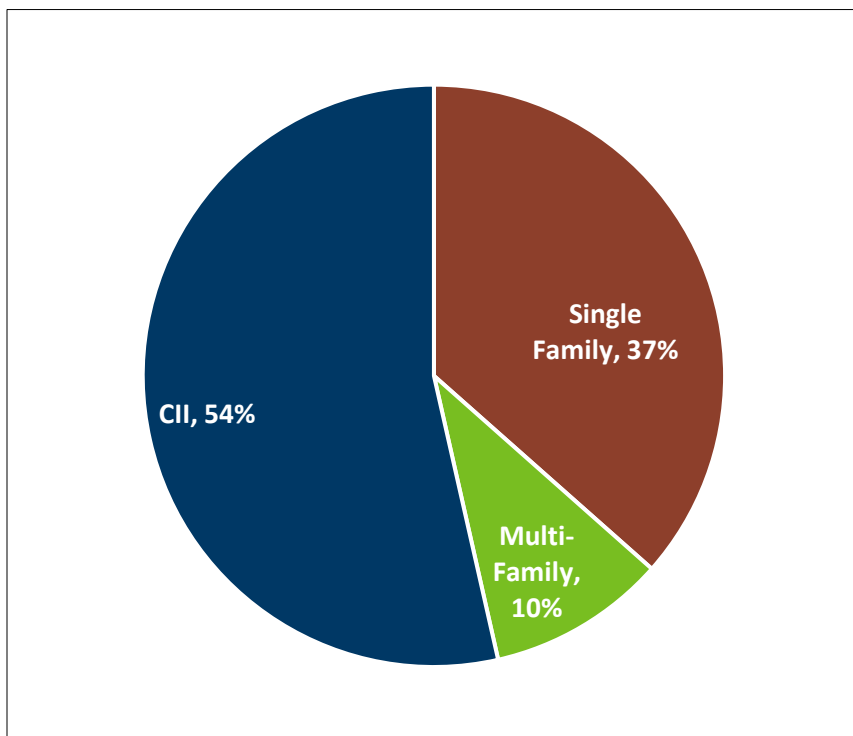


Table 20. Additional tons to capture by generator type to reach the modeled diversion rate¹⁰

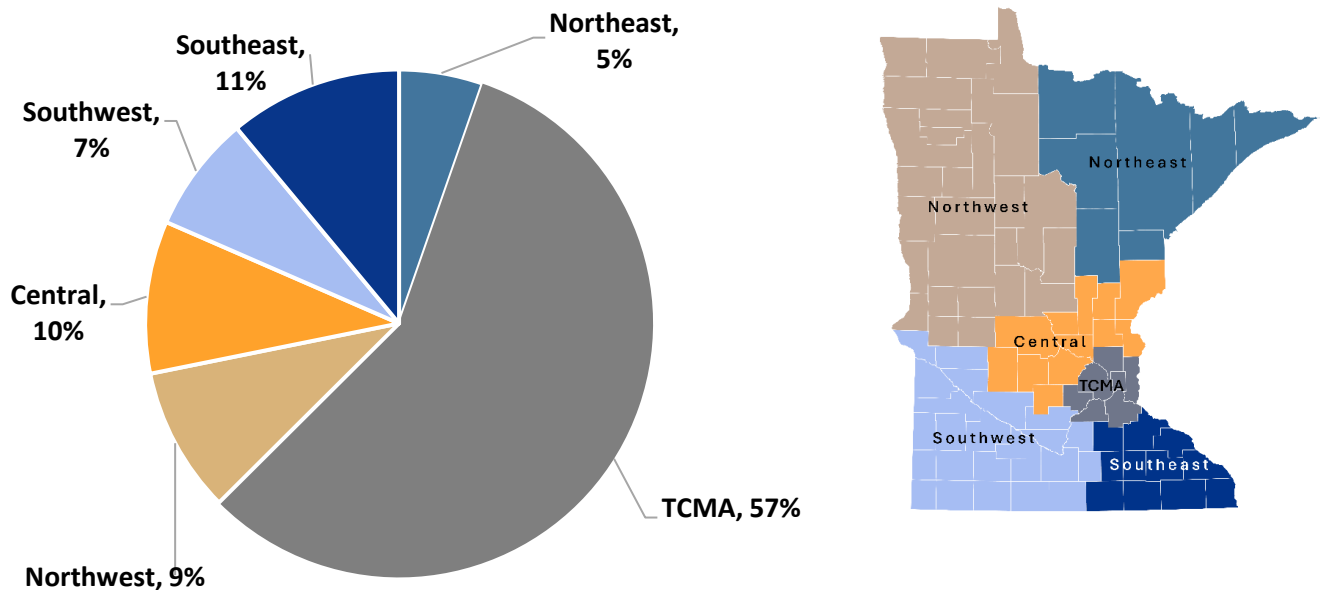
Diversion pathway	Single-family	Multi-family	CII	Total
Prevention	210,500	57,100	318,300	585,900
Reuse	71,300	19,900	112,900	204,100
MRF-compatible	116,700	31,700	173,500	321,800
Drop-off Recycling	111,600	30,200	170,400	312,200
SSO Collection	117,100	31,500	144,100	292,800
Total	627,200	170,300	919,200	1,716,700

¹⁰ Totals may not match due to rounding of individual values.

Regional Scenario Modeling Results

More than half of Minnesota's population resides in the TCMA. As a result, the Metro region contributes the majority of total diversion in the model, with approximately 57 percent of diverted tons projected to come from the TCMA's MSW (Figure 23).

Figure 23. Regional proportion of total diversion needed to reach modeled scenario goals



Even so, nearly half of Minnesota's waste is generated outside the TCMA, and achieving statewide diversion targets will require meaningful contributions from every region. Figure 24 and Table 21 provide a breakdown of the additional tons captured by prevention, reuse, source-separated programs, and mixed waste processing across the state.

The TCMA is projected to deliver the largest diversion tonnages due to its population density and established infrastructure, including widespread curbside recycling and organics programs. Yet even here, significant new gains are needed to move from current diversion levels to 90%. For example, TCMA diversion would need to nearly double to achieve 90% diversion, requiring stronger participation, expanded reuse networks, and greater reliance on processing facilities.

In Greater Minnesota, the modeling underscores the importance of equitable access. Many rural and regional communities face gaps in service, such as limited curbside recycling or the absence of SSO collection. These gaps can limit system performance even if individual participation is high. Increasing diversion statewide will require that prevention, reuse, and recovery programs are accessible across the state, regardless of geography or population density.

The results also highlight that strategies must be tailored to regional conditions. In regions with strong agricultural bases, such as the Central and Southeast, SSO collection may offer synergies with composting and anaerobic digestion infrastructure. In the Northwest and Northeast, longer hauling distances and smaller service populations mean regional collaboration and shared facilities will be critical to cost-effectively manage material.

Overall, while the TCMA anchors statewide diversion progress, the modeled outcomes cannot be achieved without robust participation and infrastructure investment in every region. Ensuring equitable

statewide access to prevention, reuse, and source-separated collection is therefore essential not only to fairness but also to system feasibility.

Figure 24. MSW management by method under the 90% diversion scenario, by region (tons)

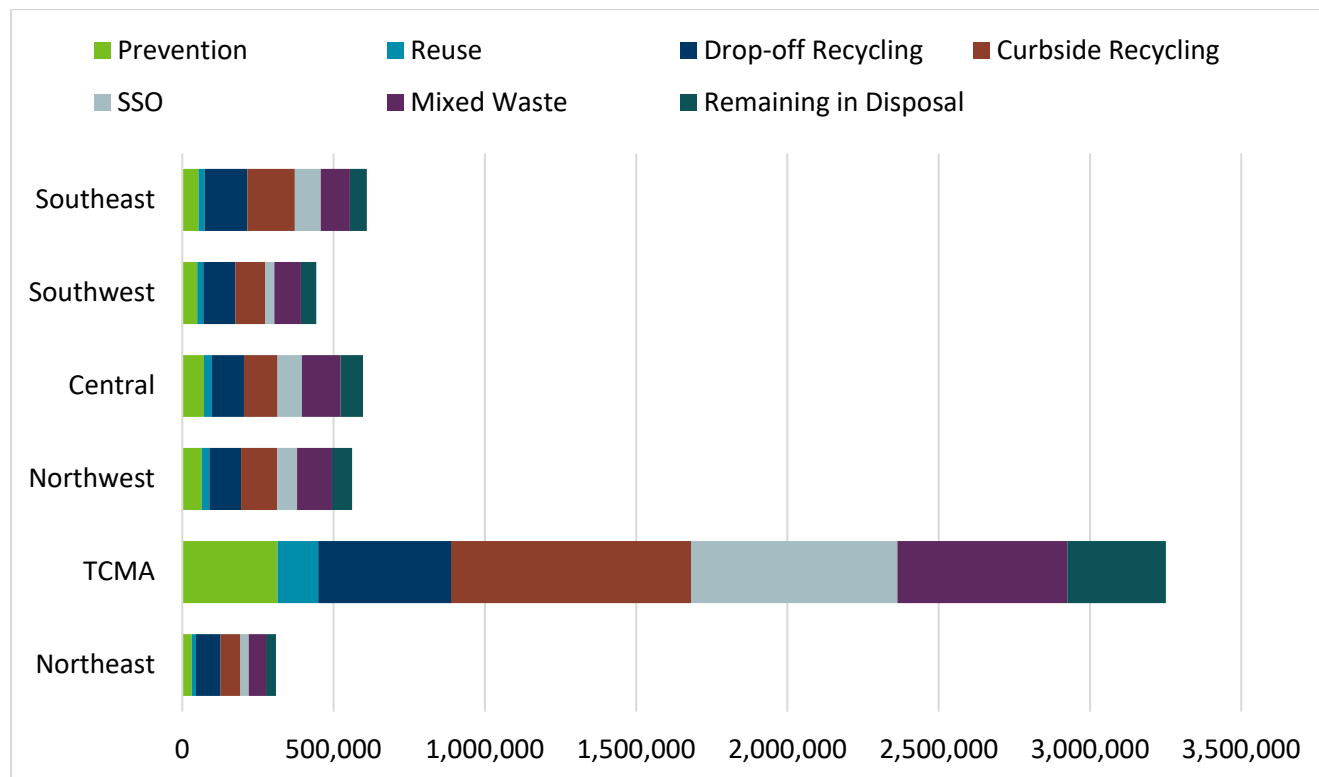


Table 21. MSW management by method under the 90% diversion scenario, by region (tons)¹⁰

Minnesota region	Prevention	Reuse	Drop-off recycling	MRF-compatible recycling	SSO	Mixed waste	Remaining in disposal
Northeast	31,700	14,000	87,100	65,000	28,000	56,400	32,800
TCMA	314,700	134,700	492,700	792,900	681,900	561,400	326,200
Northwest	64,600	25,500	116,100	119,600	65,700	115,200	66,900
Central	71,800	26,800	112,900	110,900	80,200	128,000	74,300
Southwest	49,400	19,600	112,500	99,600	28,900	88,000	51,100
Southeast	53,700	19,600	148,200	157,200	85,700	95,800	55,600

Investments Required for Diversion Goals

Increasing diversion and reducing reliance on disposal will require sustained investment in prevention, reuse, and source-separated collection programs. These investments should focus not only on tonnage, but also on equity and access, ensuring that residents, businesses, and institutions across the state have convenient opportunities to participate. Furthermore, investments must work together, as no single strategy is sufficient to meaningfully reduce reliance on disposal on its own.

Programmatic Investments

Reaching the high-diversion outcomes modeled in this report will require sustained investment in prevention, reuse, and source-separated collection programs. These investments should focus not only on tonnage but also on equity and access, ensuring that residents, businesses, and institutions across the state have convenient opportunities to participate in waste prevention and diversion.

Prevention and Reuse Programs

Prevention and reuse are the most cost-effective strategies for meeting diversion goals. By avoiding waste at the source, they reduce collection and disposal costs, extend the life of existing infrastructure, and deliver upstream environmental and economic benefits. Minnesota already has pockets of repair and reuse activity in every county, but these networks require additional support to expand, modernize, and scale their impact.

Targeted investments can increase access for households, schools, and businesses to repair, sharing, and reuse services. Greater access not only diverts materials from disposal but also lowers costs for residents, supports local jobs, and strengthens community resilience. Prevention and reuse programs are also adaptable to community context, from small nonprofit lending libraries and fix-it clinics to large-scale institutional initiatives.

Prevention and reuse investments are highly economical. Because prevention and reuse reduce waste before it enters the system, they also help extend the life of existing infrastructure and reduce long-term system costs while supporting local reuse and repair economies. Scaling these approaches will require policy alignment, including procurement standards, funding mechanisms, and incentives that prioritize waste prevention over disposal.

Prevention and reuse strategies operate across multiple scales, from community-based programs to large-scale infrastructure, commercial operations, and policy interventions. The following examples¹¹ illustrate how these approaches can be implemented across sectors to reduce waste, lower costs, and strengthen system performance.

Local reuse and repair programs

- **Grandma's Marathon (Duluth, MN):** replaced single-use cups and bottles with reusable silicone cups along the racecourse; partnership with Hiccup (since 2022) enables reuse and washing, preventing approximately 148,000 plastic bottles and 50,000 paper cups annually
- **Minnesota Toy Library:** lending program for families with young children; allows checkout of up to five toys for two to four weeks across three locations, with options to donate gently used toys

¹¹ Additional detail is provided in Appendix A.4: Prevention and Reuse Case Studies.

- **Minnesota Fix-it Clinics:** volunteer-led repair programs providing free assistance for electronics, appliances, clothing, and small devices; extend product lifespans, build community skills, and reduce disposal of repairable goods; originated in Hennepin County and expanded statewide
- **Resource Renew Material Recovery Center (MRC) reuse area:** provides free access to gently used furniture, housewares, bikes, and household items collected at drop-off facilities; redistributes materials that would otherwise be discarded and expands reuse access
- **Bridging (Minnesota):** nonprofit organization redistributing furniture and household goods to individuals and families transitioning out of homelessness; diverts substantial volumes of reusable materials while supporting housing stability and community well-being

These examples demonstrate that reuse and repair systems can be implemented across a range of community types and scales, delivering measurable environmental, economic, and social benefits. Significant opportunities exist in the built environment, where construction and demolition activities generate large volumes of recoverable material.

Built environment and C&D reuse

- **sustainable built environment reuse and deconstruction:** at least 20 local governments in Minnesota have emerging or established initiatives, many outside the TCMA; programs recover materials from demolition, support reuse markets, reduce disposal, and lower construction costs
- **Better Futures Minnesota (BFM):** deconstruction and material reuse services recovering lumber, fixtures, and architectural components; materials resold through reuse outlets, supporting workforce development and reducing C&D disposal
- **architectural salvage and reuse retailers:** businesses recovering and reselling doors, cabinets, lighting, hardware, and dimensional lumber; extend material life, reduce disposal, and support secondary markets; expansion of salvage infrastructure and deconstruction requirements could significantly increase recovery

Commercial and institutional prevention

- **Peerless Coffee & Tea (Alameda County, California):** equipment upgrades reduced non-recyclable Mylar waste by 95% and total waste by 85%, generating approximately \$100,000 in annual savings; demonstrates impact of targeted capital investment
- **Pacific Coast Food Waste Commitment (PCFWC):** public-private partnership supporting operational improvements in food manufacturing; participating companies achieved significant reductions (e.g., 47–64% recovery of edible produce, >70% reduction in wasted food across production lines); demonstrates rapid, scalable reduction through process changes

Policy and systems-level interventions

- **single-use bag regulations (12 states):** bans and fees reduce plastic bag use by up to 300 bags per person annually and reduce litter by at least one-third; large-scale impacts include billions of bags eliminated annually; effectiveness influenced by policy design and fee structures
- **Boulder Valley School District (Colorado):** reusable food service containers reduced approximately 4,500 pounds of cardboard waste annually and saved ~\$4,500 in costs; demonstrates effectiveness of institutional procurement changes
- **Rip City Reuse Program (Moda Center, Portland, Oregon):** reusable cup system with 82% return rate replaced nearly 1 million single-use cups and prevented over 30,000 pounds of plastic waste; lifecycle analysis shows improved environmental performance compared to single-use alternatives

Together, these examples demonstrate that prevention and reuse strategies are most effective when supported by coordinated policy, infrastructure, and market conditions that enable adoption at scale

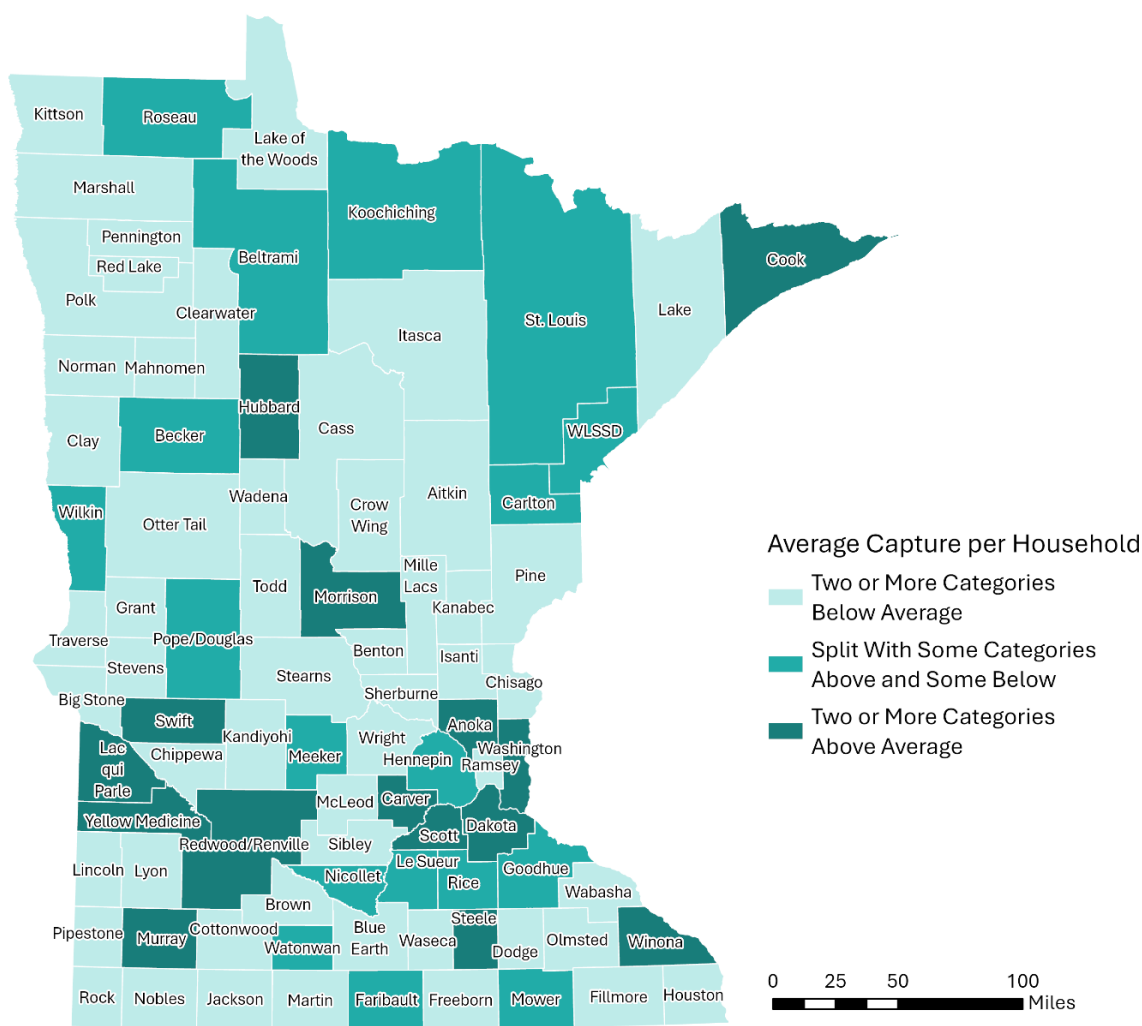
across sectors. While these strategies reduce the amount of material entering the waste stream, source-separated recycling and organics programs remain essential for capturing materials that do enter the system.

Source-Separated Collection Program Investments

Source-separated recycling and organics programs remain the backbone of Minnesota’s diversion system. Achieving the capture rates required by the 90% diversion scenario will demand significant investment in education, outreach, and program expansion. These investments must work together, as no single strategy is sufficient to achieve meaningful reductions in disposal on its own.

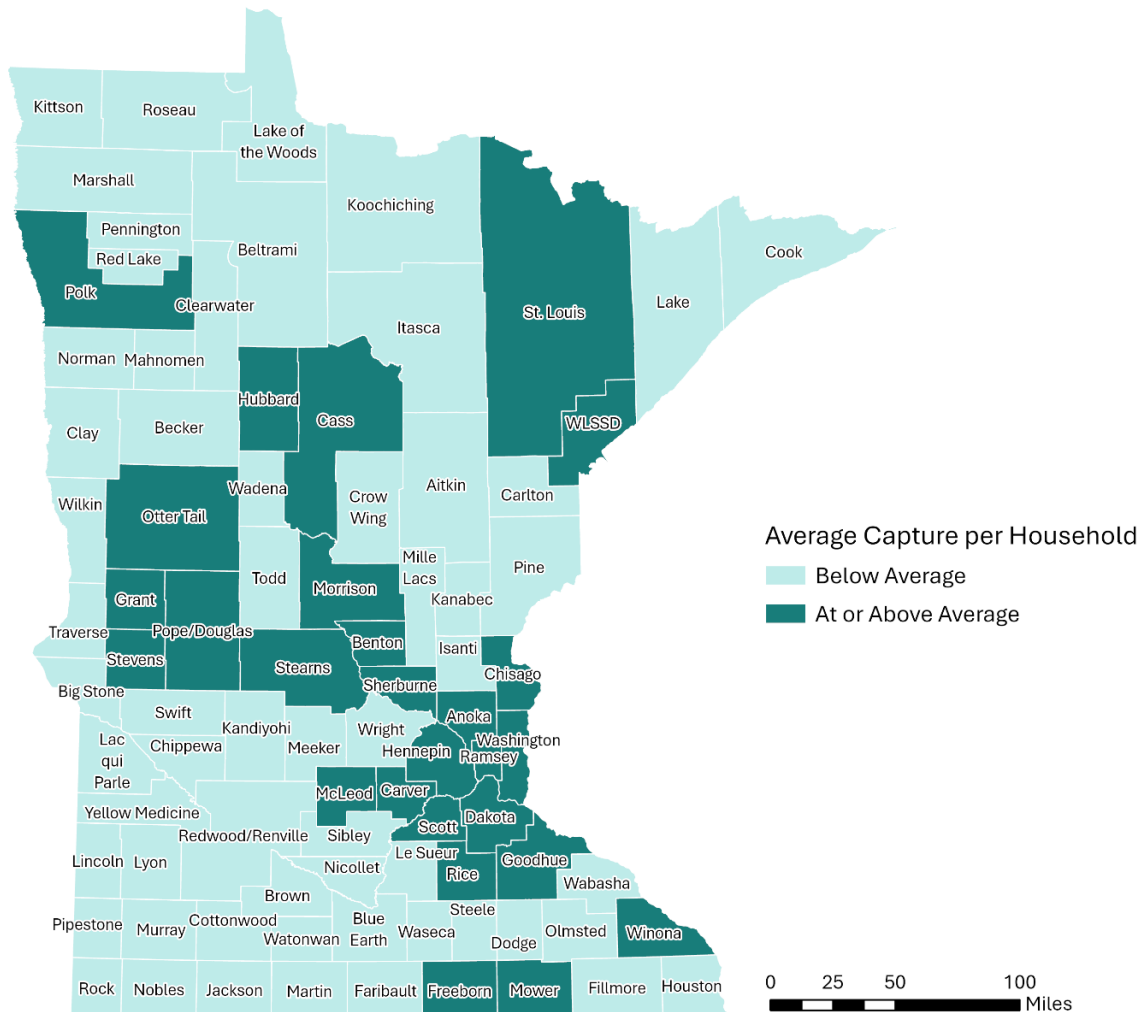
A county-level analysis of per-household recycling rates for core materials (e.g., aluminum cans, corrugated cardboard, glass, and mixed paper) shows wide variation across the state (Figure 25). Counties performing below the statewide average in two or more categories are most in need of targeted investment, though even high-performing counties must expand and optimize programs to improve overall system performance

Figure 25. Per-household capture rates for selected recyclables by county



A second analysis compared per-household organics diversion, including yard waste, SSO, food recovery people and livestock) across counties (Figure 26). Again, gaps in access and participation are evident, particularly in rural areas. Scaling organics collection and recovery systems will be critical to increasing diversion and reducing overall reliance on disposal.

Figure 26. Per-household capture rates for organics by county



Without major expansion of organics programs, Minnesota will face significant constraints in reducing disposal and increasing overall diversion. Across regions and program types, these findings highlight the need for targeted, system-level investments to improve access, increase participation, and strengthen program performance statewide.

To address these gaps, targeted programmatic investments should focus on three priority areas:

- **close access gaps:** map program availability statewide, including curbside and drop-off recycling and organics programs; differentiate program structures (e.g., universal curbside vs. subscription, permanent vs. temporary drop-off) and identify municipalities lacking consistent or convenient access
- **increase participation:** assess accessibility barriers such as distance to sites, rural versus urban availability, and participation levels; evaluate outreach and education approaches, including multilingual resources, school programs, and resident feedback systems

- **improve system consistency and performance:** identify material gaps to ensure common recyclables (e.g., aluminum, cardboard, glass, mixed paper, plastics) are accepted consistently statewide; evaluate funding mechanisms for stability and sufficiency and identify best practices for scaling

Strategic investment in prevention, reuse, collection systems, and supporting policies will allow Minnesota to reduce reliance on disposal in ways that are cost-effective, equitable, and sustainable. Together, these programmatic investments demonstrate that improving system performance will require coordinated action across prevention, reuse, collection, and policy, supported by sustained funding, clear accountability, and equitable access statewide.

Diversion Infrastructure Investments

Minnesota's waste management system was built to ensure reliable collection and disposal capacity statewide. While diversion programs have expanded in recent decades, prevention, reuse, and organics recovery infrastructure remain less consistently available across regions and generator types. While recent years have seen new investment in recycling and composting facilities, access to diversion opportunities is not universal across the state. Where gaps exist, the default option remains WTE or landfilling. To reduce reliance on disposal, Minnesota must continue expanding diversion infrastructure to be able to move away from disposal and toward recovery, ensuring that all recoverable materials are captured first, with disposal reserved only for what cannot be recovered.

This transition will require building out new capacity for reuse, recycling, and organics management, supported by strong policies and stable funding. The infrastructure estimates presented below are directional and intended to illustrate the scale and types of investments that may be required. Actual system design will depend on regional conditions, existing facility upgrades, and policy decisions.

The following sections provide directional insight into the additional processing capacity needed to reduce reliance on disposal. Achieving higher diversion depends not only on expanding infrastructure, but also on sustained participation and effective program design. Costs and implementation approaches will vary across regions based on population density, infrastructure, and access.

Reuse Infrastructure

Reuse is central to Minnesota's diversion strategy, yet infrastructure needed to support reuse remains less formalized and less consistently supported than recycling and disposal systems. Modeling specific capacity needs is difficult due to limited data, but the direction is clear: Minnesota will need to expand the physical spaces, programs, and networks that enable repair, lending, and redistribution of goods.

Prevention and reuse programs succeed when supported by enabling infrastructure that makes participation convenient and reliable. The prevention and reuse case studies described earlier illustrate program models such as repair services, lending systems, reusable foodware, and returnable transport packaging. The reuse infrastructure categories below translate those models into the types of infrastructure required to scale reuse statewide.

Minnesota's prevention and reuse initiatives demonstrate that diversion outcomes are shaped as much by governance and system design as by individual programs. While many reuse activities are delivered by nonprofits, volunteers, or private providers, their ability to scale depends on coordinated action across public agencies, private businesses, institutions, and manufacturers. Decisions related to procurement, product design, service models, facilities planning, and supply chain management can significantly influence the volume of materials entering or avoided within the waste stream.

For example, corporate shifts away from single-use packaging, adoption of reusable food ware systems, or elimination of unnecessary disposable items can produce diversion impacts at a scale far beyond individual household behavior. Because the CII sector represents the largest share of additional diversion required under the 90% model, private-sector leadership in prevention and reuse will be essential.

In this way, advancing reuse and prevention is less about inventing new programs and more about intentionally designing both public and private systems that enable proven models to operate at scale.

Together, these infrastructure categories represent the physical, operational, and service systems that must be expanded or newly developed for reuse to contribute meaningfully to achieving the modeled outcomes.

Physical reuse & redistribution facilities

Facilities that enable collection, storage, refurbishment, and redistribution of durable goods and materials. Common facility types include:

- furniture and household goods warehouses (e.g., Bridging-type models)
- architectural salvage and deconstruction material outlets
- tool libraries and lending hubs
- surplus redistribution centers serving institutions and businesses

Scaling reuse requires expanded warehouse space, logistics capacity, inventory systems, and regional coordination.

Repair & refurbishment capacity

Programs and enterprises that extend product life through repair and refurbishment. Common program types include:

- fix-it clinics and community repair events
- commercial repair businesses
- electronics refurbishment programs
- appliance and equipment reconditioning services

Infrastructure needs include skilled labor training, parts supply chains, repair-friendly product design, and accessible service locations.

Institutional & commercial reuse systems (CII)

Operational systems within businesses, schools, healthcare facilities, and government entities that prevent waste generation or enable reuse at scale. Examples include:

- reusable foodware and transport packaging systems
- internal surplus asset redistribution programs
- procurement standards prioritizing durable and repairable goods
- construction deconstruction requirements and salvage coordination

Because the CII sector represents the majority of additional diversion required under the 90% model, expanding reuse within institutional and commercial settings is critical.

Market development & secondary material networks

Markets that create stable demand for reused goods and recovered materials. Examples include:

- online resale platforms
- commercial resale businesses
- material exchange networks

- partnerships between generators and reuse outlets

Strong secondary markets increase material value, reduce disposal incentives, and attract private investment.

Policy, incentives, and performance signals

Regulatory and economic mechanisms that enable reuse to compete with disposal. Examples include:

- procurement requirements for reusable systems
- differential disposal pricing
- deconstruction standards
- reporting requirements for large generators
- tax or grant incentives for reuse infrastructure

These tools influence both public and private sector behavior.

A reuse economy requires sustained cross-sector coordination and investment. Public policy, private-sector procurement, nonprofit service delivery, and institutional leadership must align to integrate reuse into existing waste systems, expand regional access, and ensure reliable long-term operations.

Expanding reuse and recycling infrastructure in Minnesota will require coordinated public investment, private capital, and market innovation. While enhanced SCORE funding and county-level capital investments can support system development, many reuse enterprises can scale through private-sector leadership and evolving business models. Embedding reuse into procurement practices, product design, take-back systems, and broader policy frameworks will be critical to generating sustained demand and long-term viability.

By strengthening both physical infrastructure and enabling market conditions, Minnesota can build a system where diversion is the default, reuse and recycling are accessible statewide, and disposal is reserved only for materials that cannot be recovered.

Equally important is embedding reuse into broader policy and market frameworks. Right-to-repair laws, retail take-back programs, extended producer responsibility systems, procurement policies across both public and private institutions, and vendor take-back requirements can all accelerate this shift. When businesses, institutions, and government entities align purchasing practices with reuse objectives, they create steady demand and send clear market signals that support long-term system transformation.

By investing in both physical infrastructure and enabling policies, Minnesota can build a system where diversion is the default, reuse and recycling are accessible statewide, and disposal is reserved only for what cannot be recovered.

Minnesota will need to expand the physical spaces, programs, and networks that enable repair, lending, and redistribution of goods.

Source-Separated Recycling Infrastructure

The report estimates the additional includes MRFs, SSO composting facilities, MWP facilities, and drop-off infrastructure needed to reach the 90% diversion target, accounting for existing processing capacity across the state.

Material Recovery Facilities

Achieving high diversion levels will require additional recycling infrastructure, particularly material recovery facilities (MRFs). Under the modeled scenario, up to 20 new MRFs may be needed to provide

an additional 708,900 tons of processing capacity. These estimates represent an upper bound, since actual needs may be lower if existing facilities expand or modernize their operations (Table 22). Actual facility needs may be reduced through expansion or modernization of existing facilities.

The projected facilities vary widely in scale, from small rural MRFs processing about 20,000 tons per year to large, state-of-the-art facilities handling more than 150,000 tons per year. Facility size and design will depend on local and regional conditions. For example, smaller MRFs may be best suited for less densely populated regions to minimize transport distances, while larger facilities can achieve economies of scale and provide higher-quality output for established markets.

Table 22. Existing MRF infrastructure and projected capacity needs under the 90% diversion scenario¹²

Region	Existing MRFs (count)	2021 throughput (TPY)*	Additional to process (TPY)	Additional MRFs (count)	Typical facility size (TPY)
Northeast	1	4,800	60,200	3	Small
Northwest	7	25,100	94,500	5	Small
TCMA	8	597,300	195,600	1	Large
Central	0	0	110,900	5	Small
Southwest	2	7,700	91,900	5	Small
Southeast	1	1,400	155,800	1	Large
Total	19	636,300	708,900	20	

*TPY stands for tons-per-year

Tradeoffs Across Facility Sizes

Small MRFs (~20,000 TPY)

Small MRFs often rely on a higher degree of manual sorting, focusing on core recyclable commodities like cardboard, paper, PET, and metals. Mixed plastics and glass are frequently shipped to other facilities for additional processing. These facilities are relatively simple to operate but tend to have higher residue rates and higher per-ton processing costs.

Medium MRFs (~50,000 TPY)

Medium MRFs typically serve regional populations and operate with a mix of automation and manual labor. They can produce higher-quality commodities than smaller facilities and offer greater scalability, making them well suited for county- or district-level systems.

Large MRFs (>150,000 TPY)

Large MRFs generally serve densely populated regions and operate with state-of-the-art technologies such as automation, robotics, and AI-driven controls. These facilities can achieve the lowest residue rates and highest commodity quality but require significant capital investment and more complex operations.

Each facility size presents tradeoffs in terms of efficiency, cost, and service area. Small MRFs can reduce transportation costs in less densely populated regions but generally lack the efficiency and flexibility of larger facilities. For modeling purposes, smaller MRFs were assumed in less densely populated regions (northeast, northwest, central, and southwest Minnesota) to minimize transfer distances for curbside-collected recyclables.

¹² Additional information on MRF assumption can be found in the Appendix Facility Specification Section.

Large MRFs provide higher-quality output and market consistency but require large service areas and substantial upfront investment. Medium-sized facilities balance these tradeoffs by offering improved efficiency and commodity quality without the scale requirements of the largest facilities.

Table 23 summarizes key characteristics of small, medium, and large MRFs. These attributes are generalized and individual facilities may operate differently than described. Ultimately, Minnesota’s recycling infrastructure will need a mix of facility sizes that reflect regional population density, system efficiency, and equity considerations.

Table 23. Representative characteristics of small, medium, and large MRFs

Feature / scale	Small MRF (~20,000 TPY)	Medium MRF (~50,000 TPY)	Large MRF (>150,000 TPY)
Throughput Capacity	~60–80 tons/day	~150–200 tons/day	500+ tons/day (up to 1,000+)
Footprint	20,000–40,000 sq ft	60,000–100,000 sq ft	150,000+ sq ft
Feedstock	Primarily residential materials, with limited small commercial generators, narrower range accepted materials	Mix of residential & some commercial generators; wider range of material types	High-volume residential and commercial generators with a diverse and variable feedstock
Automation Level	Low; heavy reliance on manual sorting with limited mechanization (e.g., basic screens, magnets, conveyors)	Moderate; combination of manual labor and automated systems (e.g., screens, optical sorters for key commodities, eddy currents)	High; fully integrated automation, including multiple optical sorters, robotics, AI-driven QC, advanced separation (fiber/plastics by resin, glass cleanup)
Labor Requirement	High per ton (10–20+ sorters)	Moderate; balanced manual + automated crews	Low per ton; fewer sorters relative to throughput, often focused on QC
Key Equipment	Conveyors, trommel or disc screens, magnets, balers; limited optical sorting	Screens (disc/trommel), air systems, magnets, eddy current, balers, select optical sorters	Full suite: multiple screens, ballistic separators, air classifiers, advanced optical sorters, robotics, AI vision systems, high-capacity balers
Materials Recycling	Core commodities (OCC, mixed paper, PET, HDPE, ferrous, aluminum); mixed plastics often shipped for additional processing	Wider range of commodities; higher grade fiber & plastics sorted (e.g., PET and HDPE by type)	Broad range of high-purity output streams across multiple grades of paper, plastics (by resin/color), metals, glass
Capital Cost	\$5–10 million	\$15–30 million	\$50–100+ million
Operational Complexity	Low complexity; suited for rural/small metro areas	Moderate complexity; regional scale	High complexity; serve large urban areas or multi-county regions
Operating Cost*	\$130 - \$250/ton	\$110 - \$150/ton	\$90 - \$115/ton
Finished Bale Marketability	Commodities often require additional downstream processing	Regional market-ready bales with moderate consistency	High-specification bales that consistently meet mill & end-market quality standards
Flexibility / Future Proofing	Limited; upgrades often require major redesign	Moderate flexibility for upgrades (e.g., adding eddy current, optical sorters or QC)	Designed for modular expansion, integration of new AI/robotics, and evolving market shifts

*Exclusive of commodity revenue, inclusive of annualized CapEx and OpEx

The model underscores that the processing needs vary between regions. Investments must balance efficiency, equity, and cost, ensuring rural communities are not left behind while also supporting modernized, high-capacity facilities in the TCMA. Expanded SCORE funding, regional planning, and strategic siting decisions will be critical to align new facilities with Minnesota’s diversion targets.

Organics Management Facilities

Minnesota currently has 185 permitted sites for managing yard waste, but only 11 facilities are permitted to accept SSO. It is important to note that many of the yard waste sites do not operate as full composting facilities. In some rural areas, yard waste is still managed through burning or minimal processing that does not meet pathogen reduction standards. As a result, the state’s true composting capacity is smaller than it appears, and much of it is not designed to handle food scraps. Without expansion of SSO infrastructure, statutory and policy goals related to organics diversion will not be achievable.

Minnesota has already achieved high diversion rates for yard trimmings, about 87 percent in 2021, but progress toward the modeled outcomes will depend on expanding SSO capacity. Wasted food, compostable paper, and other organics account for more than 90% of additional organics that would need to be diverted. Processing these materials requires careful management of feedstocks: food waste is nitrogen- and moisture-rich, while yard trimmings provide needed carbon and porosity. Balancing the two is essential to avoid odors, compaction, and other operational challenges.

To meet the modeled diversion target, Minnesota may need as many as 16 new SSO facilities, with capacity to process an additional 450,100 tons of organics annually (Table 24). Facility needs vary by region. Small SSO facilities processing 5,000-15,000 tons per year provide critical access for a distributed processing network to receive material from places like farms and community gardens. However, to process organics, and particularly food waste from the CII sector, each region will need at least one medium (15,000 to 30,000 tons per year) or large facility (50,000 – 70,000 tons per year). A distributed network of medium and large industrial facilities, as well as smaller facilities serving community access, is critical for system resilience and ensuring that temporary shutdowns or disruptions do not compromise the state’s ability to manage organic waste.

Table 24. Existing compost infrastructure and projected capacity needs under the 90% diversion scenario

Region	Existing SSO facilities	Permitted capacity (TPY)*	Additional throughput required (TPY)	Additional facilities (count)	Typical facility size
Northeast	1	16,000	8,300	1	Small
Northwest	2	5,460	42,000	2	Medium
TCMA	4	317,000	226,400	5	Large
Central	3	3,900	58,500	5	Small to Medium ¹³
Southwest	1	6,500	17,400	2	Small
Southeast	0	0	52,000	2	Medium
Total	11	348,860	404,600	17	

Different composting technologies offer tradeoffs in cost, complexity, and product quality:

¹³ The range in facility size for the Central region of Minnesota is due to uncertainty in processing capacity of current SSO facilities.

- **windrows and static piles:** low-cost and widely used for yard trimmings; less suitable for food scraps and provide limited odor control
- **aerated static piles (ASP):** increased process control and shorter retention times; better suited for SSO and mixed feedstocks
- **in-vessel systems:** highest level of control and product quality; require major capital investment and typically deployed in urban or sensitive areas
- **anaerobic digestion (AD):** emerging complementary technology for processing food waste at scale while producing biogas and digestate; digestate management remains a challenge and often requires additional treatment or composting

Table 25. Representative characteristics of compost technologies

Method	CapEx \$/ton	OpEx \$/ton	Materials	Bulking req'd	Retention time	Automation level	Equipment needed	Finished quality
Windrow	\$25 - \$45	\$20 - \$40	Yard, ag residues, some food scraps	Yes	3–6 mo	Low	Loader, turner, screen	Moderate
Static Pile	\$15 - \$30	\$20 - \$30	Yard, wood, limited food scraps	Yes	3–9 mo	Very Low	Loader, pipes (optional)	Variable
ASP	\$20 - \$35	\$15 - \$35	Yard, food, biosolids	Yes	30–90 d	Medium– High	Blowers, pipes, probes	High
In-Vessel	\$50 - \$75	\$125 - \$200	Food, biosolids, pet waste, mixed	Sometimes	7–30 d + curing	High	Vessel, aeration, controls	Very High

More detailed information on the different methods of composting can be found in Appendix A.7 Methods of Composting. Together, composting and AD represent complementary strategies for organics management—composting as a pathway to soil enrichment and carbon sequestration, AD as a means of renewable energy recovery. Expanding both will be necessary to manage Minnesota’s food waste and SSO at scale.

Alternative Collection Systems

Comprehensive alternative collection systems provide residents with safe, convenient options for materials that cannot be managed through curbside recycling or mixed waste processing. These include household hazardous waste (HHW), electronics, bulky items, construction and demolition debris, scrap metal, textiles, plastic film, and wood waste. Because these items are difficult to recover once they enter the MSW stream, drop-off infrastructure is critical to prevent landfilling or WTE.

To evaluate geographic access, the modeling assumes each drop-off site could manage up to 50,000 users annually and that 90 percent of Minnesotans should be within a 15-minute drive. Using these assumptions, the analysis identified a need for 342 additional sites statewide (Table 26).

The modeled number of sites represents an accessibility benchmark rather than a recommendation to construct 342 new facilities. In practice, existing facilities serve far larger populations; Hennepin County’s two HHW sites each serve more than 140,000 residents annually, while Stearns and Winona Counties each serve thousands. Because comprehensive drop-off sites require significant staffing and investment, Minnesota’s real-world needs will be met through a combination of strategies:

- **regional facilities:** strategically scaled sites serving larger populations efficiently
- **mobile and seasonal collection:** supplemental events to expand access in rural and low-density areas
- **retailer and recycler partnerships:** collaboration with retailers and specialized recyclers (e.g., e-waste, paint, mattresses)
- **local reuse and exchange programs:** swap sheds, reuse areas, and material exchange programs for lower-risk materials, supported by education and coordinated hauling networks

This blended approach balances cost, feasibility, and equitable access while addressing the critical need for safe and convenient management of materials not suited for curbside programs.

Table 26. Existing drop-off sites and projected additional sites (modeled)

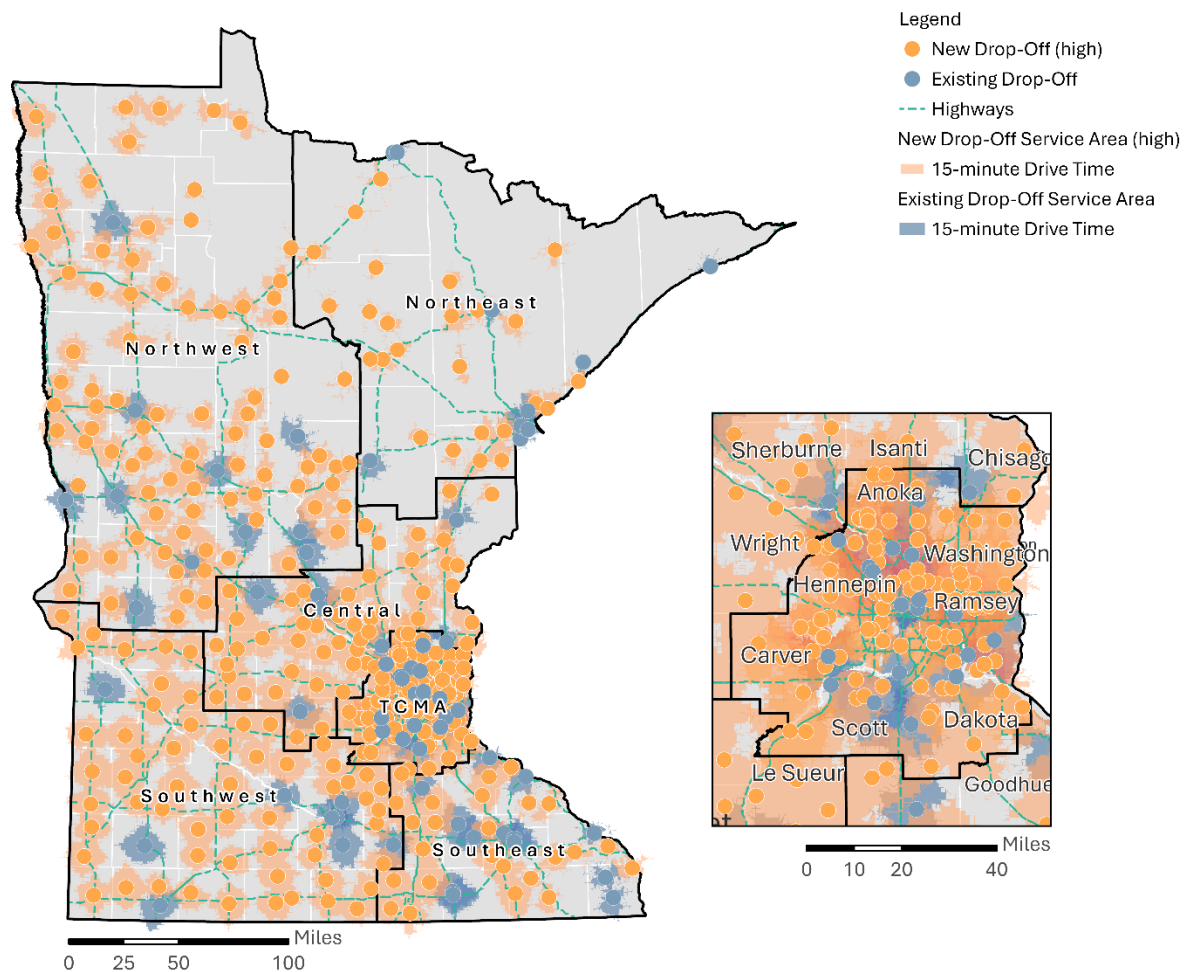
Region	Current drop-off sites	Modeled additional sites
Northeast Minnesota	10	25
Northwest Minnesota	11	87
TCMA	18	97
Central Minnesota	7	49
Southwest Minnesota	9	58
Southeast Minnesota	13	26
Total	68	342

The modeled drop-off locations assume each site can accommodate up to 1,200 tons of material annually and be within a 15-minute drive-time of 90% of the state's population. Results illustrate potential service gaps across Minnesota. In practice, system design considerations differ between Greater Minnesota and the TCMA, including the relative roles of public facilities, private recyclers, and retail or producer-funded collection networks. In Greater Minnesota, the modeled approach would likely rely on fewer large regional facilities supplemented by mobile collection events. This reflects the region's low population density and large geographic area, where smaller local collection points may feed into larger regional hubs for consolidation and preparation for end markets. In contrast, within the TCMA, existing facilities already serve populations of more than 100,000 residents each, making incremental expansion of current sites a more realistic and efficient strategy than developing new regional infrastructure.

Across both contexts, modeled needs could be met through a combination of county-operated facilities, privately operated recycling centers, retail take-back programs, and producer-funded collection systems. Private electronics recyclers, film and flexible packaging collection programs, oil and lubricant container recovery systems, and other sector-specific take-back initiative can complement public infrastructure and help close service gaps. Mobile household hazardous waste and e-waste collection events, whether publicly organized or privately sponsored, can further address areas where permanent infrastructure is less feasible.

Regardless of approach, it is critical that access be as convenient as possible in terms of travel distance, hours of operation, and ease of use, as achieving a 90% diversion rate will require capturing approximately 45% of all drop-off material.

Figure 27. Modeled accessibility gaps for the 90% diversion model



Mixed Waste Processing (MWP) Facilities

Even with ambitious prevention, reuse, and source-separated recycling programs, it is unlikely that Minnesota could reach 90% diversion without some role for MWP. MWP facilities can recover recyclable materials and organics that are missed upstream, but they do so at higher cost and with lower-value outputs.

MWP is not a single technology, but a combination of systems designed to extract recyclables and organics from the MSW stream. For modeling purposes, the scenarios assume MWP facilities co-located with AD and thermal treatment technologies such as pyrolysis. AD can generate biogas as a renewable energy source. Pyrolysis may convert digestate into biochar with potential carbon sequestration benefits and the potential to reduce or transform certain contaminants, including PFAS, under specific operating conditions. While pyrolysis technologies are commercially deployed in certain contexts, application to mixed waste digestate at scale remains an area of ongoing development.

Because operating costs for mixed waste processing are sensitive to economies of scale, the 90% diversion scenario assumes deployment of large-scale facilities with capacities exceeding 400,000 tons per year. The modeling assumption reflects cost-efficiency considerations under the high-diversion

scenario and does not preclude the existence or viability of smaller preprocessing systems, front-end recovery at WTE facilities, or regional hybrid models currently operating in Minnesota.

Under the modeled scenario, approximately three large MWP facilities statewide would be required to manage the remaining MSW after prevention, reuse, and source-separated recycling are applied. MWP is modeled as a supplemental recovery mechanism after prevention, reuse, and source-separated systems are maximized.

Processing Infrastructure Locations

To understand how new diversion infrastructure could be distributed statewide, the modeling included a hypothetical siting analysis. This analysis considered population density, existing facilities, drive times, and distances to transfer stations in order to maximize coverage while minimizing overlap. Environmental justice areas were also mapped, with a 5-mile buffer applied to guide siting decisions and reduce disproportionate impacts.

Figure 28 shows existing and potential new MRFs under the 90% diversion scenario. Larger MRFs (>150,000 TPY) are concentrated in more populated regions where waste volumes are greatest, while smaller facilities (~20,000–50,000 TPY) are modeled in rural areas where proximity to processing is needed to reduce transportation costs.

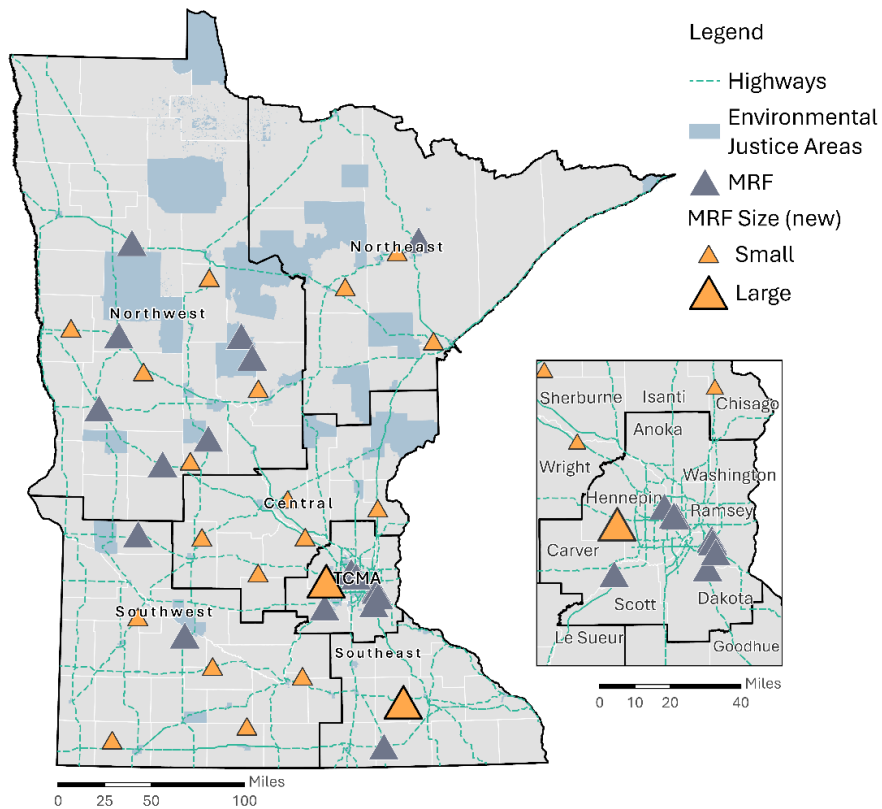
Figure 29 shows modeled siting of new SSO composting facilities. As with MRFs, environmental justice buffers were applied. While the modeling emphasizes centralized industrial-scale sites, smaller community-based, farm-based, and backyard composting options will also be important, particularly in rural areas where large facilities may not be feasible.

Figure 30 illustrates one potential configuration of three large MWP facilities under the 90% diversion scenario. For modeling purposes, these facilities are assumed to operate at a scale that maximizes economies of scale and cost efficiency. While smaller preprocessing systems and hybrid models may also be viable in practice, the modeled configuration reflects consolidated regional facilities designed to manage remaining mixed waste after prevention, reuse, and source-separated recycling are applied.

Because the modeled facilities operate at large scale, they are generally located near major population centers in order to minimize transportation costs and ensure sufficient feedstock supply. However, alternative configurations could also contribute to system performance depending on regional conditions.

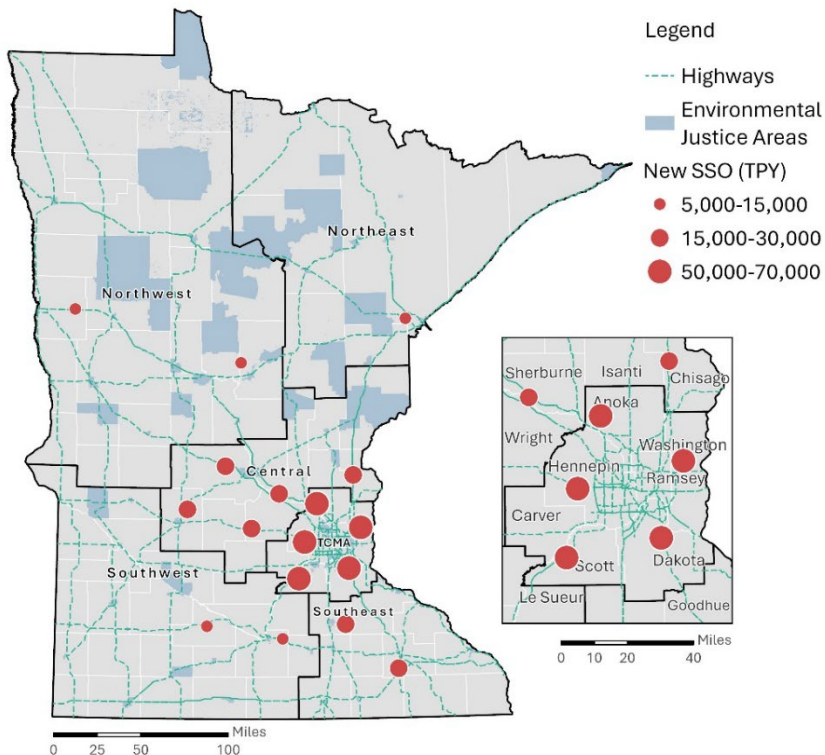
It is important to emphasize that these maps are illustrative, not prescriptive. They show approximate areas where new facilities might logically be sited, but actual locations will depend on land availability, permitting, environmental and community impacts, and local decision-making.

Figure 28. Existing MRFs and illustrative siting of additional facilities under the 90% diversion scenario



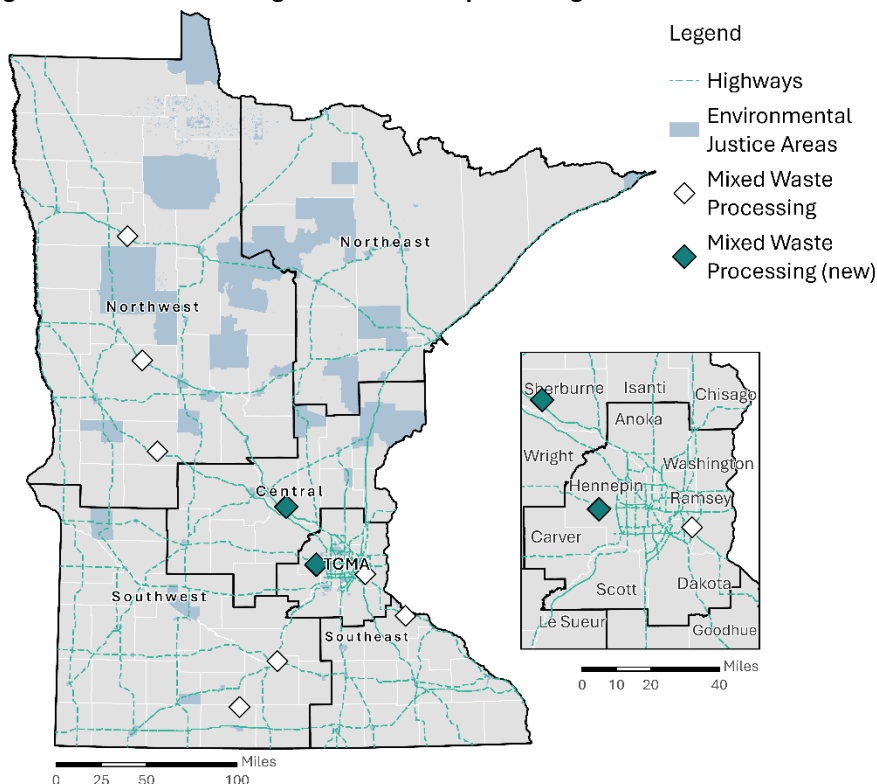
Larger facilities are modeled in higher-population areas, with smaller facilities in more rural regions.

Figure 29. Illustrative siting of SSO facilities



Illustrative siting shows where additional capacity could be needed; actual facility locations would be determined locally.

Figure 30. Illustrative siting of mixed waste processing facilities



Potential siting of three large MWP facilities. Shown locations are near Minnesota's largest population centers and represent hypothetical siting. These are not recommendations.

Processing Infrastructure Financial Investments

Achieving the modeled diversion outcomes would likely require coordinated investments, sustained participation, continued regulatory development, and expanded end markets across the waste management hierarchy. Prevention and reuse reduce overall waste generation, while source-separated recycling and organics programs serve as the primary drivers of material recovery in the modeled scenarios. Mixed waste processing can support additional recovery but functions as a secondary system for managing remaining material, as reflected in the modeled scenarios evaluated in this report.

The directional cost estimates presented in Table 27 include the capital (CAPEX) needed to build new facilities and the annual operating expenditures (OPEX) required to staff, maintain, and operate the different types of facilities needed in Minnesota to achieve the modeled diversion. Costs associated with siting, land acquisition, permitting, and regulatory compliance factors, including environmental review, permitting, zoning, and related state and local approval processes, are not included in this analysis. These estimates assume current facilities remain at existing capacity and all additional needed capacity is provided by new facilities. As such, the number of new facilities needed may be an overestimate if existing facilities have the capacity to expand by adding personnel shifts, updating technology, on-site expansion, or a combination of these three approaches.

It is important to note that these figures are not detailed construction estimates; rather, they are high-level directional costs to illustrate the scale of investment required. Actual costs will vary by site, technology, regional conditions, and other factors. Minnesota-specific costs may be higher than the

national average figures due to labor and permitting requirements, and these costs will vary based on where in the state these facilities are built (e.g. the TCMA will likely have higher costs). The estimates presented in this analysis should therefore be viewed as minimum planning benchmarks, not prescriptive budgets.

An additional assumption used through this analysis is an interest rate of 8% for both building and capital equipment, with an equipment life of 10 years and building life of 20 years.

Table 27. Estimated processing infrastructure costs under the 90% diversion scenario

Facility type	Number of facilities	CAPEX	Annual CAPEX	Annual OPEX	Annual total
Comprehensive Drop-Off	342	\$325,000,000	\$37,000,000	\$34,000,000	\$71,000,000
MRF	20	\$244,000,000	\$32,000,000	\$58,000,000	\$90,000,000
Compost Facility	17	\$159,000,000	\$15,900,000	\$22,000,000	\$37,900,000
Mixed Waste	2	\$252,200,000	\$28,300,000	\$88,200,000	\$116,500,000
Total	381	\$980,200,000	\$113,200,000	\$202,200,000	\$315,400,000

These projections do not currently include the costs of special collection programs for hard-to-recycle and bulky items (e.g., mattresses, carpet, large plastics, scrap wood).

Comprehensive Drop-offs

The modeled drop-off site costs assume a comprehensive drop-off capable of accepting a range of items that could include MRF-compatible recyclables and drop-off recyclables such as scrap metal, plastic film, bulky items, HHW, electronics, and more (Table 28). Each site would therefore require an enclosed or partially enclosed building, containers such as gaylords, dumpsters, and roll-offs, equipment such as at least one baler and forklift, and one staff full-time person per site.

In practice, drop-off infrastructure can be configured in a variety of ways, including mobile collection sites and smaller, localized facilities that accept a limited range of materials and are supported by larger, comprehensive regional hubs. In addition, the private sector can play a significant role in expanding drop-off access through existing scrap yards and retail take-back programs. However, to reach the modeled diversion potential it is critical that convenient access to recycle all identified drop-off materials in this analysis is available to Minnesota residents and businesses.

Table 28. Estimated capital and operating costs for a representative comprehensive drop-off site

Tons/year	Equipment capital cost	Building and site capital cost	Annual CAPEX	Annual OPEX	Annual total	Cost per ton
1,200	\$250,000	\$700,000	\$109,000	\$100,000	\$209,000	\$174

MRFs

Table 29 provides cost estimates for small, medium, and large MRFs. The modeled costs for MRFs assume that both building size and automation increase with increasing MRF size. Smaller MRFs generally have higher rates of manual sorting and process fewer tons, increasing the cost per ton to process. Whereas medium and larger MRFs benefit from higher automation and economies of scale, driving down the processing cost per ton. Automation can include equipment such as screens and ballistic separators, eddy current separators, steel drums, optical sorters, AI-enabled robotic sorters, air classifiers, and associated conveyor and control systems.

Additional assumptions are that small MRFs will support 1 shift per day, while medium and large MRFs support two shifts. MRF uptime is assumed to be 90%, with 8-hour shifts operating 5 days per week.

One of the primary ways facilities adjust throughput over relatively short timeframes is by adding or reducing operating shifts, allowing annual tons processed to flex without requiring immediate capital expansion. As a result, projected tons per year should be viewed as indicative rather than fixed, as actual processing capacity at a given facility may vary significantly depending on equipment configuration, staffing, and hours of operation.

Table 29. Estimated capital and operating costs for representative MRFs

MRF size	Tons/year	Equipment capital cost	Building capital	Annual CAPEX	Annual OPEX	Annual total	Cost per ton
Small	19,000	\$5,000,000	\$3,000,000	\$1,000,000	\$2,000,000	\$3,000,000	\$158
Medium	56,000	\$15,000,000	\$6,000,000	\$3,000,000	\$5,000,000	\$8,000,000	\$143
Large	187,000	\$30,000,000	\$20,000,000	\$7,000,000	\$11,000,000	\$18,000,000	\$96

Compost Facilities

Composting facilities accepting SSO are generally less capital- and operationally intensive than MRFs and typically do not require fully enclosed buildings. However, they do require a set of basic infrastructure elements to operate effectively and comply with environmental and odor control requirements. At a minimum, facilities are assumed to utilize aerated static pile or similarly managed composting systems, which provide active aeration to support consistent decomposition, temperature control, and pathogen reduction, particularly for food waste.

Core infrastructure typically includes a paved or otherwise engineered processing pad, aeration systems (e.g., blowers and piping), stormwater management features, and leachate collection or treatment as needed. Covered areas may be required for feedstock receiving, pile management, or curing, depending on climate, material mix, and regulatory conditions. Additional supporting infrastructure can include screening equipment, loaders, windrow turners (if applicable), electrical service, and basic site amenities. While facility scale and design can vary widely, these elements represent a practical baseline for facilities designed to manage SSO reliably and at scale.

Table 30. Estimated capital and operating costs for representative composting facilities

Compost facility size	Tons/year	Capital cost	Annual CAPEX	Annual OPEX	Annual total	Per ton costs
Small	<15,000	\$3,000,000	\$300,000	\$500,000	\$800,000	\$80
Medium	15,000 - 30,000	\$7,000,000	\$700,000	\$1,000,000	\$1,700,000	\$57
Large	50,000 - 70,000	\$15,000,000	\$1,500,000	\$2,000,000	\$3,500,000	\$50

Mixed Waste Processing Facilities

MWP facilities are highly complex, capital-intensive projects. The modeled costs for a large MWP facility presented in Table 31 assume a co-located operation with a MRF, high-solids anaerobic digestion, renewable natural gas production, and pyrolysis for digestate. This provides a directional estimate of the scale of investment required. For modeling purposes, the diversion scenarios assumed a large-scale MWP facility to reflect potential economies of scale and lower per-ton processing costs. Minnesota currently has MWP facilities operating at smaller scales. This report does not evaluate comparative performance across facility sizes but instead models a large facility to provide a directional estimate of potential diversion under an optimized system configuration. Facility feasibility and performance depend on feedstock composition, market access, capital structure, and regulatory context.

As with any recycling system, materials recovered from MWP must meet applicable market and regulatory standards before being counted toward recycling rates. Depending on the material and end market, this may include representative sampling or testing for contaminants to ensure recovered materials are suitable for use as manufacturing feedstock and do not introduce harmful chemicals or other unwanted constituents into new products. While mixed waste processing primarily functions as a secondary recovery mechanism, facilities that consistently produce marketable feedstock could contribute to statutory recycling goals, creating a potential incentive for investment in advanced recovery infrastructure.

Table 31. Estimated capital and operating costs for an MWP facility

Tons/year	Equipment capital cost	Cost building	Total CAPEX	Annual CAPEX	Annual OPEX	Annual total	Cost per ton processed
416,000	\$95,500,000	\$30,600,000	\$126,100,000	\$14,200,000	\$44,100,000	\$58,300,000	\$140

Diverted Material Value

Materials sent to disposal in Minnesota represent not only a lost opportunity for environmental conservation, but also a loss of economic value. Many discarded materials could instead be recovered and sold into established markets, generating meaningful financial return.

Modeled diversion scenarios estimate the total annual gross commodity value of recoverable materials at approximately \$408 million under the 90% diversion model, including both materials already recovered under current conditions and additional materials captured through expanded diversion. Table 32 presents the estimated value of additional (incremental) materials recovered under this scenario. These values should be understood as directional estimates of the economic opportunity gained through increased diversion, rather than guaranteed revenue. For some categories, such as lumber, C&D materials, and bulky waste, scrap values are not well documented, but this does not imply that the value of recovering these items is negligible. Scrap value represents only one dimension of material recycling's overall worth. Actual net economic benefit would depend on program design, commodity market conditions, and processing costs.

Commodity value has become increasingly important to municipalities over the past decade as the cost structure for private MRF processing has changed. Historically, MRFs relied on the sale of recovered commodities to cover processing costs and generated profit when commodity revenues exceeded the cost of sorting and baling materials. Over time, however, this model became less stable because commodity prices grew more volatile.

In response, MRFs increasingly shifted to contract structures in which municipalities pay a per-ton processing fee for recyclables delivered to the facility, while also receiving a share of commodity revenue. For many communities, this meant that recycling processing, once viewed as a largely no-cost service, became a direct budget item. At the same time, these arrangements gave municipalities greater visibility into how recycling market fluctuations affect program costs and revenues.

Today, processing fees are standard across the industry. As a result, municipalities generally should not expect cost savings simply from shifting material from disposal, where a tip fee is paid, to recycling, where a processing fee is paid for sorting, baling, and marketing commodities. Municipalities may receive revenue from commodity sales, but that revenue is not guaranteed and can change quickly as market conditions shift.

Finally, the economic value of reuse is not incorporated into these estimates due to the variability and challenges of documenting reuse markets. However, it is important to note that reuse often delivers significantly higher dollar-per-ton value than recycling alone.

Table 32. Estimated total scrap value of diverted material in the 90% diversion model¹⁴

Material category	Add'l source-separated recovery	Add'l mixed waste processing	Source-separated recovery value	Mixed waste processing value
Glass Non-Container	20,496	0	\$0	\$0
Glass Bottles and Jars	0	0	\$0	\$0
Aluminum Cans	14,452	7,564	\$23,542,600	\$12,322,800
Steel Cans	18,828	5,335	\$74,133,300	\$21,004,400
Ferrous Scrap	0	50,062	\$0	\$8,594,000
Non-ferrous Scrap	0	17,133	\$0	\$1,542,000
Wasted Food	129,860	173,953	\$2,597,200	\$3,479,100
Other Recyclable Wood	19,902	55,138	\$0	\$0
Leaves and Grass	22,381	44,074	\$447,600	\$881,500
Other Organics	81,905	172,000	\$1,638,100	\$3,440,000
Corrugated Cardboard	46,098	125,092	\$4,069,400	\$2,501,800
Paperboard Boxboard	37,593	11,905	\$1,837,300	\$238,100
Newspaper (ONP)	0	18,756	\$0	\$375,100
Magazines	28,932	9,736	\$1,414,000	\$194,700
White Office	14,818	20,239	\$724,200	\$404,800
Mixed Paper	40,741	118,086	\$1,991,200	\$2,361,700
Gable-top and Aseptic Cartons Combined	15,697	4,971	\$767,200	\$99,400
Compostable Paper	58,631	109,444	\$1,172,600	\$2,188,900
Plastic PET #1 Bottles	20,821	6,823	\$7,503,000	\$2,458,900
Plastic PET #1 Non-Bottle	8,810	2,349	\$3,174,800	\$846,600
Plastic HDPE #2 Bottle & Non-Bottle colored and natural combined	18,266	5,509	\$5,609,500	\$1,691,800
Plastic PS #6 Expanded Polystyrene	1,510	0	\$81,800	\$0
Plastic PP#5	31,839	8,490	\$8,465,000	\$2,257,300
Plastic Mixed Plastics Rigid #3-#7	24,939	6,651	\$811,300	\$216,300
Plastic Film	43,002	0	\$821,900	\$0
Plastic Other Plastic	22,913	55,928	\$0	\$0
Textiles	107,375	0	\$0	\$0
Electronics	0	0	\$0	\$0
C&D Other Construction and Demolition	44,520	0	\$0	\$0
HHW	18,947	0	\$0	\$0

¹⁴ The estimated value comes from a number of sources. 1) Commonly recyclables (aluminum and steel cans, corrugated cardboard, mixed paper, PET bottles, etc.) - recyclingmarkets.net, 2) Electronics - <https://ledouxandcompany.com/electronic-scrap-analysis/how-much-is-electronic-scrap-worth/> & <https://cablemanagementusa.com/escrap-pricing/>, 3) Scrap Metal - <https://www.scrapmonster.com/scrap-yards/prices/minnesota/state/3388>. Some material are marked as \$0 either because no additional tons of that material is projected to be collected or because the market value for that material is \$0 or cannot reliably be estimated.

Material category	Add'l source-separated recovery	Add'l mixed waste processing	Source-separated recovery value	Mixed waste processing value
Bulky Waste Mattresses	2,557	0	\$0	\$0
Bulky Waste Carpet	14,631	0	\$0	\$0
Bulky Waste Other Bulky Waste	14,805	0	\$0	\$0
Tires	1,494	0	\$0	\$0

Net System Cost Considerations

The capital and operating costs presented above reflect the estimated gross investment required to build and operate the infrastructure needed to achieve modeled diversion targets. These figures do not represent net system costs.

Increased diversion would reduce the volume of material requiring disposal, resulting in avoided landfill tipping fees, avoided waste-to-energy processing costs, and reduced long-term environmental management liabilities. In addition, recovered materials generate market revenue (Table 32) and support economic activity, employment, and tax revenue (Table 33, Table 34, and Table 35).

A full lifecycle cost-benefit analysis, including avoided disposal costs and long-term environmental externalities, was beyond the scope of this study. However, incorporating avoided disposal expenditures and material value recovery would reduce the net financial impact of the modeled infrastructure investments. Without these coordinated investments and a full accounting of both costs and avoided impacts, progress toward statutory recycling goals and broader improvements in system performance will remain uneven across the state.

Economic Impact Assessment

The reuse and recycling sectors in Minnesota represent a vital component of the state's economy, encompassing a wide range of activities, from the collection and sorting of recyclables to the reprocessing of recovered materials into new products, as well as the repair and reuse of goods to extend their lifecycles and reduce waste. This assessment evaluates both the baseline contribution of Minnesota's current reuse and recycling economy and the potential economic impacts of achieving a 90% diversion goal in terms of job creation and overall economic output.

The analysis was conducted using the IMPLAN input-output framework, which links industry activity to broader statewide economic effects. IMPLAN captures:

- **direct effects:** employment and output within the reuse and recycling sectors
- **indirect effects:** business-to-business activity within supply chains
- **induced effects:** economic activity generated by employee spending across the broader economy

Taken together, these components provide a comprehensive picture of how the reuse and recycling economy supports jobs, generates business activity, and contributes to tax revenues across Minnesota.

The direct, indirect, and induced contributions were measured across four key dimensions:

- **employment:** full-time and part-time positions supported
- **value added:** comparable to GDP, including labor income, business income, and taxes
- **output:** total economic activity generated, measured as sales and revenues
- **tax impacts:** fiscal contributions at the local, state, and federal levels

Methodology

The analysis began with a review of 2022 NAICS data to identify Minnesota businesses engaged in reuse, repair, and recycling (RRR) activities of materials that would be considered MSW if disposed. As such, the NAICS codes focused on consumer goods and did not include RRR activity related to automobiles, industrial equipment, tires, or construction and demolition debris.

Sixty-three relevant NAICS codes were selected and grouped into the following categories:

- **reuse:** retail and wholesale sale of used goods and merchandise
- **repair:** repair and maintenance of electronic, appliance, furniture, footwear and leather goods, home and garden, and other personal and household goods
- **rental:** rental and leasing of consumer goods, including electronics, formal wear, home health equipment, recreational goods, and office machinery, as well as general rental centers
- **collection:** curbside and drop-off collection of recyclables and organics
- **processing:** sorting and processing of material at MRFs
- **manufacturing:** production activities using recycled content, including both first-stage and second-stage manufacturing
 - **first-stage manufacturing:** facilities that convert recovered materials into intermediate feedstocks (e.g., pulp, pellets, ingots, cullet)
 - **second-stage manufacturing:** facilities that use intermediate materials to produce finished or semi-finished products

- **support services:** government, administrative, and consulting services supporting recycling and materials management

It is important to note that many sectors and/or individual manufacturers that purchase recycled scrap materials do not exclusively engage in recycling-related production but instead use a mix of recycled and virgin inputs. Because the objective of this study was to estimate the economic contribution of the RRR industry specifically, only employment and business activity directly attributable to recycling, reuse, repair, and manufacturing from recycled content were included in the analysis. As a result, total employment and output for affected industries were adjusted to reflect only the portion of activity associated with RRR-related operations. These adjustments were based on conservative assumptions informed by publicly available sustainability disclosures, peer-reviewed literature, and trade association data to avoid overstating impacts.

For example, Minnesota has five paper mills located within the state; however, only two of these mills purchase recycled feedstock, while the remaining three rely exclusively on virgin materials. Accordingly, for the paper mill industry, only the share of employment associated with mills purchasing recycled feedstock was included in the RRR industry. Similarly, downstream manufacturers that convert recycled paperboard into finished packaging products were included only in proportion to the average recycled content used in the production processes.

All economic impacts are reported in 2026 dollars and are based on 2021 IMPLAN data.

Economic Contribution of the Current Reuse and Recycling Industry in Minnesota

Jobs and Output

Minnesota's reuse and recycling industries account for 57,167 jobs and contribute more than \$17 billion in economic output through combined direct, indirect, and induced activity. A detailed breakdown of these contributions is provided in Table 33.

Table 33. Economic contributions of reuse and recycling in Minnesota

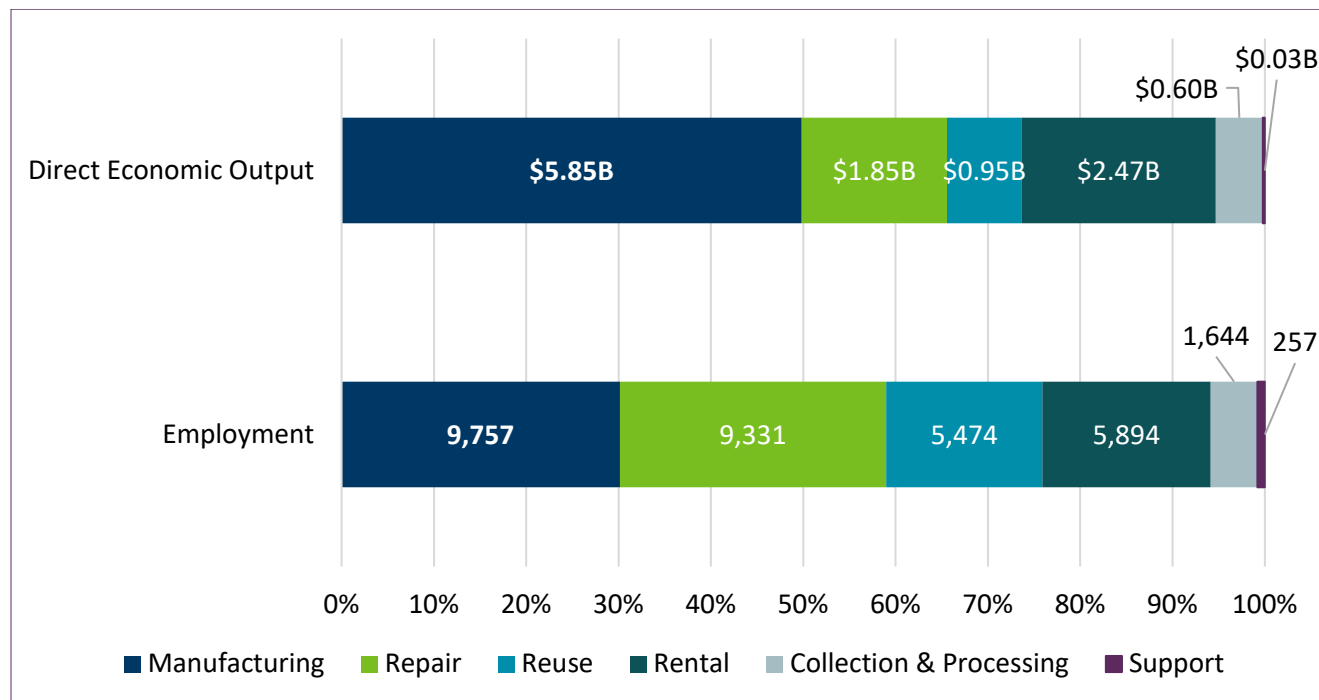
	Employment	Income	Value added	Output
Direct	32,358	\$3.41B	\$5.03B	\$11.74B
Indirect	12,305	\$1.16B	\$1.56B	\$2.87B
Induced	12,504	\$0.87B	\$1.62B	\$2.61B
Total	57,167	\$5.44B	\$8.20B	\$17.23B

The economic contribution of reuse and recycling industries can be examined not only in aggregate but also by operational focus, providing a clear picture of how different reuse and recycling functions impact the economy. For this analysis, industries were grouped into key categories that reflect their core activities: Manufacturing, repair, reuse, rental, collection & processing, and support which includes any supporting services such as recycling administration and consulting. This categorization allows for a more detailed understanding of where economic output and employment are concentrated, as well as how each segment contributes to the overall performance and sustainability of the reuse and recycling economy.

When grouped into operational categories, the reuse and recycling-related Manufacturing businesses generate the highest direct economic output, followed by repair and rental. While smaller in scale,

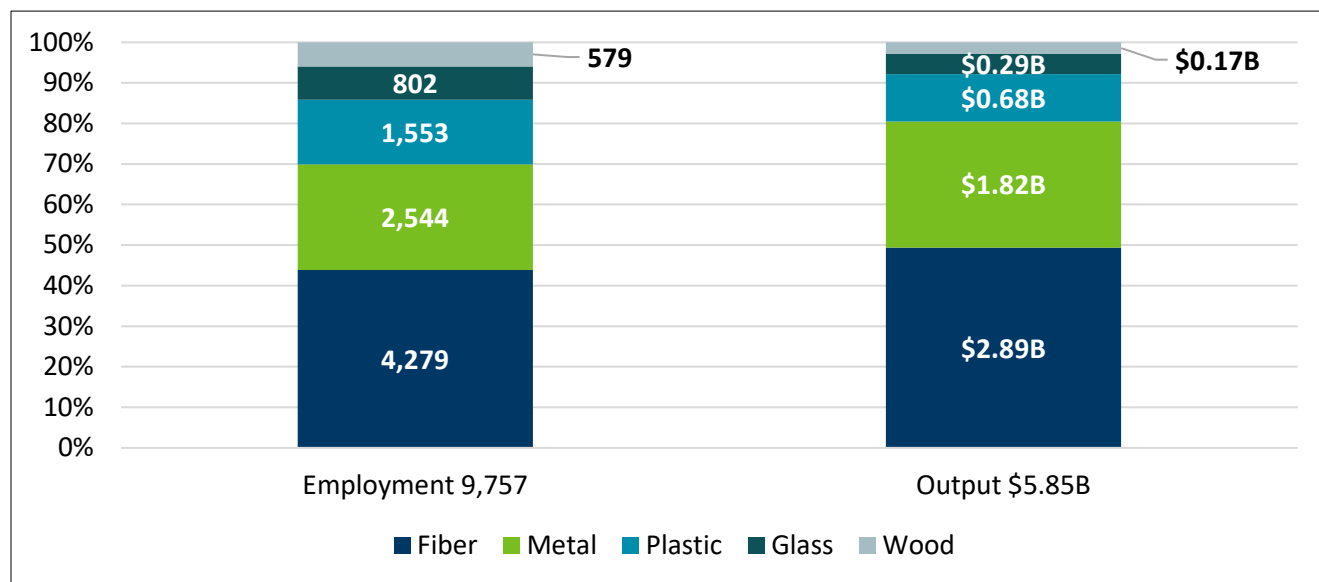
Collections & Processing remain essential contributors to both output and employment within the reuse and recycling ecosystem (Figure 31).

Figure 31. Proportion of the RRR economic output by operational focus



Recycled materials can also be viewed as raw inputs to the manufacturing process. When analyzed from this perspective, fiber-based materials such as corrugated cardboard, office paper, magazines, newsprint, and paperboard account for the largest share of employment and direct economic output within Minnesota's recycling-related manufacturing sector, followed by metals (Figure 32).

Figure 32. Proportion of the RRR direct employment and economic output by material category



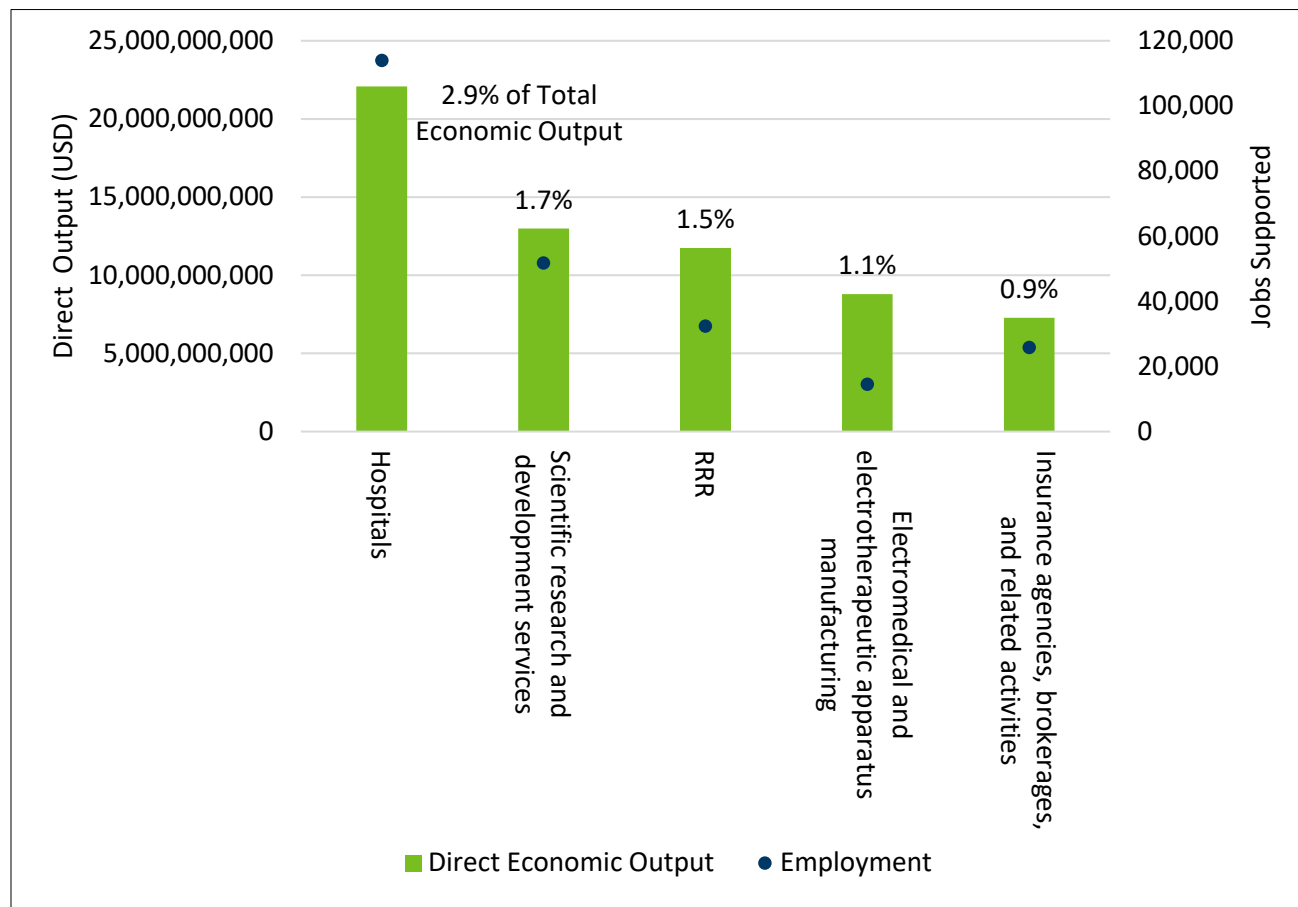
To contextualize the statewide significance of RRR industries, aggregated RRR economic impacts were compared against other industries in Minnesota. Collectively, reuse and recycling account for approximately 1.5% of the state's total economic output, a level comparable to the Scientific Research and Development sector (1.7%) and greater than other widely recognized industries, including

electromedical and electrotherapeutic apparatus manufacturing and insurance agencies, brokerages, and related activities.

The RRR economic footprint clearly demonstrates that reuse and recycling represent a substantial component of the state economy, supporting significant employment, capital investment, and supply-chain activity. Notably, among more than 500 industries represented in Minnesota’s economy, the combined RRR sectors rank within the top ten industries by total direct output, underscoring their importance as a major economic driver rather than a niche or peripheral activity.

Figure 33 provides a visual comparison of the reuse and recycling industries to other notable sectors in Minnesota.

Figure 33. Direct output of the RRR industries compared to other leading industries in Minnesota



Tax Revenue

The RRR industry generates substantial public revenues across all levels of government in Minnesota. In total, RRR-related economic activity contributes an estimated \$1.24 billion in direct tax revenues annually. The largest share is accrued to the federal government (\$564 million), reflecting income, payroll, and business-related taxes associated with RRR employment and operations. At the state level, RRR activities generate approximately \$444 million in tax revenues.

Local governments also benefit meaningfully from the sector, with an estimated \$82 million flowing to counties, \$67 million to sub-county general jurisdictions (such as cities and townships), and an additional \$82 million supporting special districts, including school districts and other local authorities. Together, these figures underscore the RRR industry’s role as a significant and diversified source of tax revenue, supporting public services and infrastructure at the local, state, and federal levels (Table 34).

Table 34. Direct annual tax revenue from the RRR sector

Sub-county general	Sub-county special districts	County	State	Federal	Total
\$67M	\$82M	\$82M	\$444M	\$564M	\$1,239M

Comparison to Previous Studies

A 2024 MPCA report, *Economic Activity Associated with Minnesota’s Value-Added Recycling Manufacturing Industry*, estimated that manufacturing activities alone support 27,348 direct jobs within Minnesota’s RRR sector. This figure is substantially higher than the estimate in this report, which identifies 9,757 direct manufacturing jobs related to RRR. The difference between these estimates is primarily attributable to methodological differences. The 2024 MPCA report relied on direct surveys of Minnesota industries to identify qualifying operations, whereas this analysis identifies RRR-related activity using NAICS codes, publicly available company information, and select proprietary databases describing company operations. A key distinction also lies in how manufacturing employment is allocated. The 2024 report analysis attributed all manufacturing employees at a given facility to the RRR sector, regardless of whether individual workers were directly engaged in recycling-related activities. In contrast, this analysis applies a fractionation approach that limits RRR employment to workers estimated to be directly involved in recycling activities, which is particularly important for facilities where recycling represents only a portion of overall operations. Given these methodological differences, direct comparison between the two reports should be approached with caution. However, given the conservative nature of assigning RRR employment used in this report, it is likely this report represents a minimum economic contribution estimate.

Economic Impact of Reaching the 90% Diversion Goal

RRS conducted an economic impact analysis to evaluate the potential effects of achieving a 90% diversion rate in Minnesota on the reuse, recycling, and repair (RRR) industry. The analysis applied projected incremental material tonnages associated with expanded collection, reuse, and recycling activities, including both source-separated programs (curbside, drop-off, and special collection) and mixed waste processing, to the *Diverted Waste* jobs-per-ton methodology presented in *More Jobs, Less Pollution: Growing the Recycling Economy in the U.S.* (Tellus Institute, 2023).

This nationally recognized methodology estimates employment impacts based on average job creation per ton of material diverted and is widely used to evaluate recycling-related economic outcomes. Additional employment impacts associated with surplus food recovery for donation were estimated using the job creation potential framework developed by ReFED (2024).

Table 35 provides the job creation factors applied per 1,000 tons of material diverted. It is important to note that additional collection jobs were applied only to increases in source-separated diversion materials, under the assumption that expanded source-separated collection would require additional collection routes, drop-off staffing, and special-collection pickups. In contrast, increases in recycling resulting from mixed-waste processing were assumed to have no effect on collection employment, as these materials would continue to be collected through existing curbside trash services.

Table 35. Jobs per 1,000 tons of diverted material

Materials	Collection	Processing	Reuse/remanufacturing	Manufacturing
Paper & Paperboard	1.23	2		4.16
Glass	1.23	2	7.35	7.85
Ferrous	1.23	2	20	4.12
Aluminum	1.23	2	20	17.63

Materials	Collection	Processing	Reuse/remanufacturing	Manufacturing
Plastic	1.23	2	20	10.3
Textiles	1.23	2	7.35	2.5
Wood	1.23	2	2.8	2.8
Other	1.23	2		2.5
Food Scraps	1.23	0.5	3.72	
Yard Trimmings	1.23	0.5		

Achieving a 90% diversion rate in Minnesota is estimated to generate substantial economic impacts across the RRR industries. As shown in Table 36, increased diversion is driven by the reuse of more than 204,000 additional tons of material and the recycling of over 2 million additional tons through a combination of source-separated programs and mixed-waste processing. These activities are estimated to support approximately 22,144 total jobs statewide. Of these, 10,823 jobs are direct positions associated with collection, processing, reuse, and recycled-content manufacturing activities. An additional 6,147 indirect jobs are supported through supply-chain purchases, while 5,174 induced jobs result from increased household spending by workers in the RRR economy. Collectively, these impacts correspond to approximately \$2.21 billion in labor income, \$3.69 billion in value added, and \$8.91 billion in total economic output, underscoring the significant economic opportunity associated with higher diversion rates.

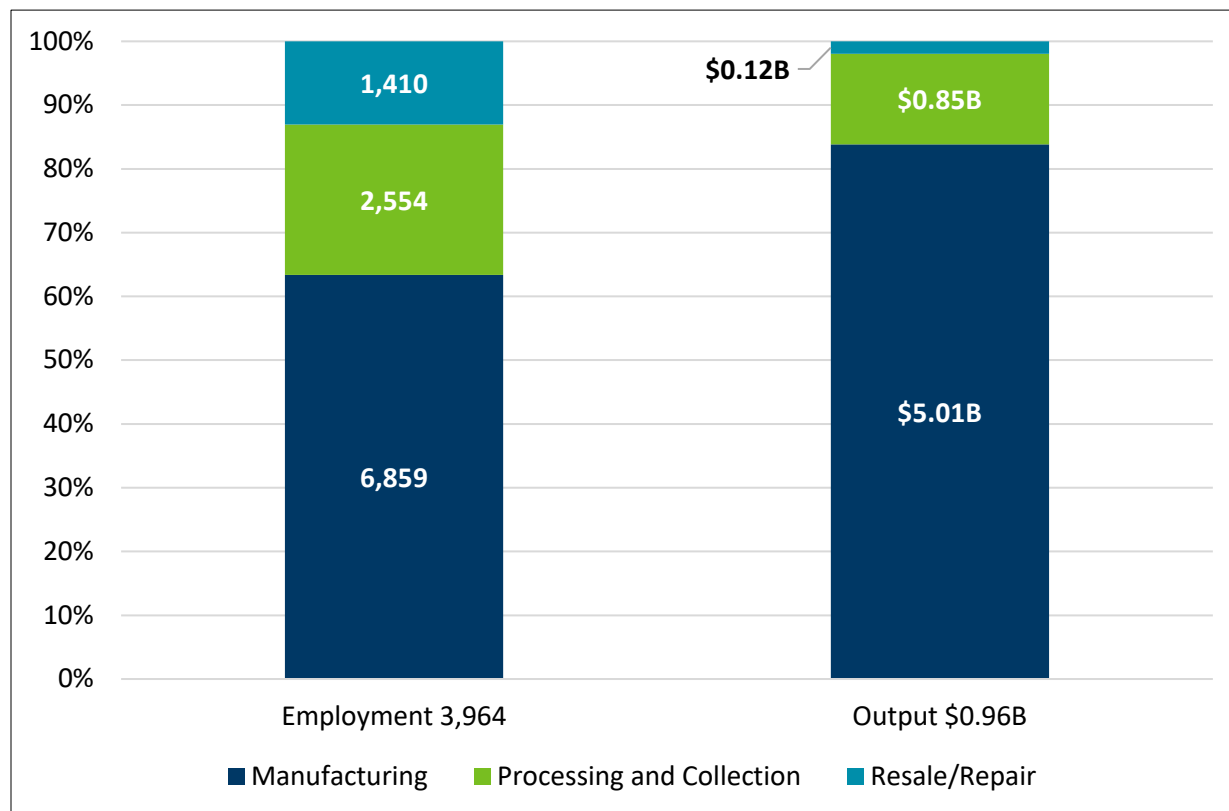
Table 36. Direct, indirect, induced and total impacts of 90% diversion scenario of RRR in Minnesota

	Employment	Income	Value added	Output
1 - Direct	10,823	\$1.23B	\$2.09B	\$5.97B
2 - Indirect	6,147	\$0.62B	\$0.93B	\$1.86B
3 - Induced	5,174	\$0.36B	\$0.66B	\$1.08B
Total	22,144	\$2.21B	\$3.69B	\$8.91B

Figure 34 provides a further breakdown of the 10,823 direct jobs supported by increased diversion, categorized by major activity type within the reuse, recycling, and repair system. Manufacturing activities account for the largest share of economic output, generating approximately \$5.01 billion, reflecting the high value associated with recycled-content manufacturing. Processing and collection activities support an estimated 2,554 jobs and generate approximately \$0.85 billion in output, driven by expanded material recovery and handling. Resale and repair activities support approximately 1,410 jobs and generate \$0.12 billion in output, reflecting the more labor-intensive but lower-output nature of these services. In total, these activities support 10,823 direct jobs and generate approximately \$5.97 billion in direct economic output, reflecting the more labor-intensive but lower-output nature of these services.

Overall, manufacturing drives the majority of economic output due to the high value of recycled-content production, while collection and processing provide essential system functions and reuse and repair activities contribute more labor-intensive employment.

Figure 34. Additional direct employment and economic output by industry type under the 90% diversion scenario



These results demonstrate that increasing diversion is not only an environmental objective but also a significant economic development opportunity, supporting job growth, strengthening local industries, and increasing economic resilience across Minnesota.

Programs, Regulatory, and Policy Initiatives

Minnesota has demonstrated a long-standing statutory commitment to reducing the impacts of solid waste, beginning with the Waste Management Act of 1980 and the SCORE legislation of 1989. These foundational laws established the state's waste management hierarchy and continue to guide solid waste planning, investment, and policy decisions.

Solid waste planning requirements differ between Greater Minnesota and the TCMA:

- **Greater Minnesota:** counties and solid waste management districts must prepare comprehensive solid waste management plans on a 10-year cycle under Minn. Stat. § 115A.46; plans address current and projected waste generation, strategies for reduction, recycling, organics recovery, and management of hazardous or problem materials, as well as financing and ordinances; plans require MPCA approval
- **TCMA:** planning framework established under Minn. Stat. §§ 473.149 and 473.803; MPCA adopts a 20-year Metropolitan Solid Waste Management Policy Plan, updated every six years; metro counties must prepare six-year plans aligned with the Policy Plan and subject to MPCA approval

In addition to these statutory frameworks, Minnesota's Climate Action Framework elevates waste reduction and composting as strategies to reduce greenhouse gas emissions and improve soil health, reinforcing the role of sustainable materials management in meeting statewide climate and equity goals.

Despite this strong foundation, challenges remain in achieving the modeled outcomes. Achieving this level of performance will require not only expanded infrastructure but also a coordinated system of policies and programs to ensure equitable access, enforceable requirements, and consistent accountability across all communities.

The following key themes highlight where Minnesota must focus policy and programmatic advancements to achieve the modeled outcomes evaluated in this analysis:

- **clearer goals and stronger accountability:** enforceable targets, consistent measurement, and transparent reporting required to reach 90% diversion; the Packaging Waste and Cost Reduction Act will support residential packaging, but many materials remain outside binding EPR frameworks
- **equity and environmental justice as cross-cutting priorities:** policies must address barriers faced by rural communities, Tribal nations, and environmental justice communities; stakeholders emphasized the need for earlier and more accessible engagement in project and facility planning
- **upstream prevention and expanded access:** the waste management hierarchy prioritizes reduction and reuse; upstream solutions such as product redesign, reuse systems, repair services, and consumption reduction critical to long-term outcomes; equitable access to reuse, repair, recycling, and organics programs required statewide
- **expanded collection access beyond single-family recycling:** infrastructure must serve multi-family housing, the CII sector, and public spaces to ensure equitable access across all demographics and property types
- **sustained and coordinated policy action:** combination of tools required, including EPR, mandatory organics collection, and expanded alternative collection systems; education and outreach must be paired with requirements such as recycling and organics ordinances, disposal bans, performance-based licensing, stronger reporting, and enforcement capacity

- **education and outreach:** efforts should extend beyond recycling instructions to highlight economic and community benefits of prevention and reuse; programs should be accessible in multiple languages and formats and engage trusted community partners such as schools, faith-based organizations, and neighborhood groups
- **enhanced planning and technical support:** state agencies require additional resources for technical assistance, planning, and compliance oversight; without this capacity, local governments may lack the tools to implement infrastructure, outreach, and enforcement effectively

The following policy options illustrate how Minnesota can translate the themes above into concrete actions that directly address the state’s waste stream. Table 37 shows the estimated tons and share of MSW that each policy could impact. Together, these measures address about 95% of generated MSW, leaving only a small residual for disposal.

Among the options, EPR for packaging and paper products, which is currently being implemented in Minnesota, has the largest modeled impact in terms of overall diversion tonnage, followed closely by mandatory organics recycling and universal access to comprehensive alternative collection systems.

Targeted EPR policies for specific materials, such as textiles, electronics, and HHW, represent smaller contributions to overall tonnage but may yield disproportionately high environmental, economic, and public safety benefits. These materials often contain toxic constituents, critical minerals, or hazardous components that pose risks when managed through disposal. Improving recovery systems for these streams can reduce contamination in the waste stream, mitigate fire risks (e.g., from lithium-ion batteries), recover valuable materials needed for domestic supply chains, and prevent harmful exposures in overburdened communities.

Accordingly, while packaging EPR drives the largest diversion gains by weight, targeted material-specific policies may warrant elevated consideration based on toxicity reduction, resource conservation, economic value, and system safety, factors not fully captured by tonnage-based modeling alone. In some cases, targeted material EPR programs may provide greater per-ton environmental benefit than high-volume material streams.

Table 37. Estimated tons and share of MSW addressed by policy approach

Policy approach	Tons of MSW addressed	Share of total MSW
EPR for Packaging and Paper Products	2,085,163	35.6%
Mandatory Organics Recycling	1,918,330	32.7%
Universal Comprehensive Alternative Collection Systems	1,231,305	21.0%
EPR for Textiles	198,022	3.4%
EPR for Electronics	52,687	0.9%
EPR for Carpet	40,804	0.7%
EPR for Tires	30,594	0.5%
EPR for HHW	25,263	0.4%
EPR for Mattresses	4,726	0.08%
Residual	276,022	4.7%
Total	5,862,915	100%
Total Proportion of the Waste Stream Addressed by Policy	5,586,894	95%

Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) for packaging and paper products is one of the most significant policy drivers of diversion in Minnesota and is currently being implemented under the Packaging Waste and Cost Reduction Act. This policy shifts the financial and operational responsibility for managing packaging materials from local governments to producers, aligning system costs with product design and use. By establishing producer-funded collection systems, performance standards, and incentives for improved packaging design, EPR has the potential to substantially increase recycling rates, expand access, and support upstream waste reduction.

More than 90% of Minnesota's MSW stream is technically recoverable, yet large volumes still end up in landfills or WTE facilities. The value of these materials is often outweighed by the costs of collection and processing, leaving local governments to carry the financial burden of recovering these materials. EPR is designed to bridge this gap but requires policy interventions that rebalance responsibility.

EPR policies shift the responsibility for managing certain materials from local governments to producers. Well-designed EPR programs expand collection and recycling services, create incentives for improved product design, and can support waste prevention, reuse, and repair. Minnesota already has experience with EPR for products containing toxic or hazardous components, including rechargeable batteries, architectural paint, and select electronics. These programs demonstrate the feasibility of producer-led collection and recycling systems.

Looking forward, EPR has the potential to drive investment in recycling infrastructure, improve collection and processing systems, and expand reuse and repair networks. By establishing clear performance standards, funding mechanisms, and producer accountability, comprehensive EPR programs can tackle materials that are currently difficult and expensive for municipal programs to manage. Done correctly, EPR can help Minnesota achieve diversion outcomes while simultaneously encouraging upstream design changes that support waste prevention and circularity.

EPR for Paper and Packaging

Policy impacts 36% of the MSW generation stream

Paper and packaging make up more than one-third of the state's MSW stream. While some materials, like corrugated cardboard and aluminum or steel cans, are easily collected and retain strong market value, others, like plastic film and expanded polystyrene, remain challenging to collect, store, and recycle. Addressing this portion of the waste stream is critical to achieving the modeled outcomes.

In 2024, Minnesota became the fifth state in the U.S. to enact EPR for packaging and paper products through the Packaging Waste and Cost Reduction Act, marking the most significant expansion of the state's EPR policy framework to date. Implementation is still in its early stages, with an advisory committee convened and a producer responsibility organization (PRO) selected to oversee compliance and system management.

A statewide needs assessment is underway to evaluate collection access, infrastructure capacity, and system costs. The assessment will inform rulemaking and stewardship planning and may reveal differences between current reported recycling rates and program-defined performance metrics, particularly as measurement methodologies are standardized under the new framework.

Unlike earlier product-specific EPR programs, the packaging law advances broader circular economic objectives. Producers will be responsible for reimbursing at least 90% of eligible system costs, shifting the financial burden from local governments to producers. The program is designed to expand access to

recycling and composting services, reduce packaging volume and toxicity, and improve material recovery outcomes.

It establishes a comprehensive framework in which, by January 1, 2032, all covered packaging and paper products must be one of the following:

- refillable and supported by a refill system
- reusable and managed through a reuse system
- recyclable and collected through a curbside or alternative collection system
- compostable and collected through a curbside or alternative collection system

The statute does not set numeric statewide targets directly in law. Instead, it requires the MPCA to establish statewide performance requirements through rulemaking, including timelines for compliance.

These requirements must address:

- recycling rates
- composting rates
- reuse rates
- return rates
- source reduction rates
- post-consumer recycled (PCR) content requirements

The PRO will then incorporate more granular performance targets aligned with these statewide requirements through its stewardship plan.

Importantly, the law introduces eco-modulated fees, which vary based on the environmental characteristics of packaging materials. These fees create financial incentives for producers to redesign packaging to reduce waste, increase recyclability, and incorporate sustainable materials.

Crucially, the law will provide sustained financial support for equitable access to curbside recycling and alternative collection systems, as well as processing infrastructure. This ensures that covered packaging is collected statewide, processed appropriately, and ultimately returned to end markets as feedstock for new products.

The effectiveness of this landmark policy will depend on strong rulemaking, ambitious statewide requirements, rigorous stewardship plan implementation, and robust oversight to ensure producer accountability and sustained investment in Minnesota's recycling and reuse systems. This approach represents a transition from county-funded recycling systems to a producer-financed model intended to internalize packaging management costs within the supply chain.

Other EPR Policies

Policy impacts 6% of the MSW generation stream

In addition to packaging and paper, Minnesota has enacted EPR programs for several targeted product categories, including architectural paint, covered electronic devices, plastic boat wrap, and rechargeable batteries (subject to watt-hour limits). Minnesota law also requires manufacturers of mercury-containing thermostats and thermostats that replace them to participate in collection and proper end-of-life management programs. While this reflects manufacturer responsibility, it differs from more comprehensive PRO-administered EPR programs with defined stewardship plans and performance requirements.

Minnesota also regulated waste tires through longstanding statutory requirements, including prohibitions on land disposal, retailer take-back requirements, and permitting and oversight of collectors and processors. These policies have supported tire recovery and end-use markets for decades, though they do not operate under formal PRO-based EPR model.

Although these materials represent a relatively small share of the municipal solid waste (MSW) stream by weight, they often carry disproportionately high management costs, toxicity risks, and environmental impacts compared to typical household waste.

Expanding or modernizing EPR frameworks could improve recovery performance, reduce local government costs, and promote more equitable cost-sharing. In EPR programs, producers or their designated organizations, are typically responsible for financing and managing collection and processing systems for covered materials.

Opportunities for Expansion

Several additional material streams present opportunities for expanded EPR approaches in Minnesota:

- **textiles (3.4% of MSW generation):** limited recycling infrastructure for non-reusable textiles; EPR could offset high processing costs and incentivize design for durability, repairability, and recyclability
- **electronics (0.9% of MSW generation):** expand scope of Minnesota's 2007 electronics law to include modern devices, especially those with embedded batteries; allow producer responsibility organization (PRO) models to streamline administration and support shared infrastructure investment
- **household hazardous waste (HHW) (0.4% of MSW generation):** current programs effective but costly for counties; EPR could shift costs and use eco-modulated fees to encourage safer product design and expand collection
- **mattresses (0.08% of MSW generation):** bulky and operationally challenging for landfill and WTE systems; proven EPR models in states such as California, Connecticut, Oregon, and Rhode Island recover steel, foam, and fabric and could be adapted in Minnesota
- **carpet (0.7% of MSW generation):** difficult-to-process material with limited recovery pathways; EPR programs in California and New York demonstrate potential for collection, recycling, and recycled content requirements to support closed-loop markets
- **tires (0.5% of MSW generation):** existing framework includes landfill bans and retailer take-back; evaluation of a formal EPR model could identify opportunities for stronger performance standards and infrastructure investment

In addition to packaging and paper, Minnesota has enacted extended producer responsibility (EPR) programs for several targeted product categories, including architectural paint, covered electronic devices, plastic boat wrap, and rechargeable batteries. While these programs vary in scope and statutory structure, they reflect Minnesota's longstanding use of product-specific EPR frameworks to manage materials with environmental, safety, or end-of-life management concerns. Some statutory provisions, including those governing batteries, are currently under review and may be updated to expand scope or improve program performance.

Organics Prevention, Reuse, Recycling Policy

Policy impacts 33% of the MSW generation stream

Wasted food is the single largest category in Minnesota's MSW stream, spanning both the residential and commercial sectors. According to the 2019-2020 Minnesota Food Waste Generation and

Composition Study Analysis, nearly half of wasted food was edible at the time of disposal, and another quarter was inedible but suitable for diversion into other uses such as livestock feed, composting, or anaerobic digestion (AD).

Achieving high diversion levels will require coordinated action across all levels of the food recovery hierarchy:

1. Prevent wasted food at the source.
2. Rescue edible food for human consumption.
3. Recycle inedible food and other organic materials through multiple pathways, including food-to-livestock, AD, composting, and other innovative processes.

Minnesota can draw from a growing body of state-level policies across the Northeast and beyond. Vermont's Universal Recycling Law bans food waste disposal statewide and provides flexibility through options like backyard composting and curbside composting collection. Massachusetts has had a large generator food waste ban in place since 2014, requiring diversion for entities producing more than one ton of food waste per week and stimulating investment in anaerobic digestion and composting facilities. Connecticut and Rhode Island require diversion for large generators located near processing infrastructure, while New York mandates both food donation and food scrap recycling for large institutions. These examples show that mandatory organics diversion policies are practical, scalable, and increasingly common across the U.S.

Policy Models from Other States

Minnesota can draw from a growing body of state policies that have successfully implemented mandatory organics diversion through phased requirements, infrastructure investment, and flexible compliance pathways:

- **Vermont – universal recycling law (Act 148):** phased-in disposal ban on food scraps beginning with large generators (>2 tons/week) and expanding to all generators by 2020; requires haulers to offer organics collection to nonresidential customers and multifamily buildings; compliance options include backyard composting, drop-off, and curbside collection
- **Massachusetts – commercial food materials disposal ban (310 CMR 19.017):** prohibits disposal of commercial organics above threshold levels (initially >1 ton/week, expanded to >0.5 ton/week in 2022); allows multiple compliance pathways (e.g., composting, anaerobic digestion, animal feed); has driven significant infrastructure investment (~\$390 million)
- **Connecticut – commercial organics recycling law (CGS 22a-226e):** requires source separation and recycling for generators above annual tonnage thresholds (reduced from 104 to 26 tons/year); includes businesses, institutions, and schools; compliance options include reduction, donation, on-site processing, and off-site recycling
- **Rhode Island – food waste ban (R.I. Gen. Laws § 23-18.9-17):** applies to large generators located within proximity to processing facilities (15-mile threshold); phased expansion to include smaller generators and educational institutions; requires source separation and recycling through hauling or on-site options
- **California – mandatory commercial organics recycling (AB 1826):** phased-in requirements beginning in 2016, with thresholds decreasing over time (from >8 cubic yards/week to >2 cubic yards/week); requires both generator participation and local jurisdiction program development
- **New York – food donation and food scraps recycling law (ENV Chapter 43-B, Article 27):** requires large generators (>2 tons/week) to donate edible food and recycle remaining scraps if

within proximity to processing facilities; phased expansion planned through 2029 with lower thresholds and expanded geographic applicability

While Minnesota has established grant programs and liability protections to support food rescue, additional infrastructure, reporting mechanisms, and policy alignment would be required to achieve the modeled recovery levels. To reduce wasted food and increase recycling in Minnesota, the following policy approaches are recommended:

- **wasted food prevention initiatives:** statewide education on meal planning, food storage, and date labeling; technical and financial assistance for commercial and institutional waste tracking and reduction programs (e.g., LeanPath, EPA Food Waste Challenge); expansion of school share tables and confidential food pickup programs; support for marketplace platforms (e.g., Too Good To Go) that connect surplus food with consumers
- **edible food diversion requirements and infrastructure:** donation requirements for large food generators where feasible; expanded support for food banks, rescue organizations, refrigerated transport, aggregation hubs, and data systems; strengthened liability protections and tax incentives; phased reporting requirements to improve transparency and performance
- **mandatory source separation of organics:** phased requirements beginning with large generators and expanding to smaller businesses and households; restrictions on landfilling or incineration of wasted food and compostable products; enforcement mechanisms such as contamination surcharges
- **hauler and generator service requirements:** requirements for licensed haulers to provide organics collection services across residential, commercial, and institutional sectors, scaled to generator type and feasibility; alignment with Minn. Stat. § 115A.93 in the TCMA; statewide standards for signage, labeling, and contamination reduction
- **financial support and market development:** expanded grants, loans, and cost-sharing for composting, anaerobic digestion, and other organics processing; investment to transition yard waste sites to SSO acceptance; support for emerging technologies such as biogas capture and nutrient recovery
- **utilizing finished products and byproducts:** incentives for compost use through tax exemptions, subsidies, and public procurement requirements; promotion of anaerobic digestion byproducts for energy generation, soil amendments, and nutrient recovery; support for co-collection of food waste and certified compostables where operationally feasible
- **expand SSO collection access:** flexible program design allowing jurisdictions to implement curbside carts, co-collection models, drop-off systems, or hybrid approaches based on local conditions

Together, these strategies represent a comprehensive approach to addressing the largest component of Minnesota's waste stream, with significant potential to increase diversion, reduce environmental impacts, and strengthen local and regional organics management systems.

Alternative Collection Systems for Hard-to-Recover Materials

Policy impacts 21% of the MSW generation stream

Nearly one-quarter of Minnesota's MSW stream consists of materials that cannot be effectively recovered through MRFs or mixed waste processing. These include items such as scrap metal, dimensional and engineered wood, pallets, painted and treated wood, bulky plastics, and C&D materials.

A key strategy to capture these materials is to ensure universal access to comprehensive alternative collection systems for both residents and businesses. “Alternative collection systems” is a catch-all term that encompasses drop-off sites, retail take-back, specialized depots, and other non-curb-side collection programs designed to capture materials that curbside recycling and organics programs cannot manage effectively.

Among these, drop-off sites remain a core component. When designed comprehensively, they can serve as one-stop community hubs that:

- **accept a wide range of materials:** materials, including SSO, corrugated cardboard, hard-to-recycle items, HHW, and bulky materials
- **support reuse, repair, and refurbishment activities:** enable reuse, repair, and refurbishment activities that extend the life of valuable goods
- **public engagement:** reinforce understanding of the economic and environmental benefits of keeping materials out of landfills and WTE facilities

The success of alternative collection systems depends on reliable end markets. Many of these hard-to-recover materials currently lack consistent outlets, which limits the viability of collection. To address this, Minnesota will need to:

- **strengthen existing markets:** expand demand for materials such as scrap metal, dimensional lumber, and certain plastics
- **develop new markets:** invest in processing and end uses for niche or emerging streams (e.g., treated wood, bulky plastics, solar panels)
- **support innovation and partnerships:** advance public-private partnerships and new approaches in reuse and remanufacturing

By aligning collection systems with viable markets and developing new outlets where gaps exist, Minnesota can ensure recovered materials are not only diverted but also reintegrated into the circular economy in meaningful and economically beneficial ways.

Coupled with strong public outreach, education, and signage, comprehensive drop-off sites can serve as hubs for diverting a variety of materials while reinforcing the environmental and economic value of keeping these materials out of landfills and WTE facilities. At a minimum, comprehensive drop-offs should accept:

- **wood products:** dimensional and engineered wood, pallets and crates, painted and treated wood
- **non-container glass**
- **scrap metal:** ferrous and non-ferrous
- **plastics:** durable and bulky plastics (e.g., crates, totes, buckets, tubs, lawn furniture, toys, housewares); plastic film and flexible packaging (e.g., retail bags, shrink wrap, mailers, agricultural film); special handling containers (e.g., oil, lubricant, and pesticide containers); other non-curb-side plastics (e.g., window blinds, insulating foam, composite plastic products); rubber and rubber-like materials
- **C&D materials:** bricks and concrete, asphalt roofing, gypsum board, and other materials (e.g., ceramics, tiles, toilets, sinks, insulation, tubs, showers, cabinets, fiberglass)
- **other bulky materials:** furniture, mattresses, solar panels

These systems complement curbside recycling, organics diversion, and EPR programs by ensuring materials outside those systems are captured and managed effectively.

Other Policy Options

Reuse, Repair, and Refurbishment

As mentioned earlier in this report, support for reuse, repair, and refurbishment activities is a preferred waste management strategy that bolsters the local economy, conserves resources, and has the potential to reduce the waste infrastructure burden often placed on low-income or marginalized communities. While Minnesota has taken steps to expand these opportunities, additional policy support is needed:

- **right to repair expansion:** Minnesota's Digital Fair Repair Act (2023, effective July 1, 2024) requires manufacturers to provide access to parts, tools, and repair information for products with digital components; impact currently limited by exemptions; opportunities include revisiting exemptions and expanding right-to-repair concepts to additional product categories (e.g., motor vehicles)
- **repair incentive programs:** international models such as Austria's repair bonus program provide vouchers covering up to 50% of repair costs; similar programs in Minnesota could reduce barriers to repair and support small repair businesses
- **funding mechanisms for reuse, repair, and refurbishment:** performance-based grants and loans for local repair businesses and reuse hubs; tax incentives or credits for repair, resale, and parts salvaging
- **repairability index:** labeling systems used in France and Belgium rate products based on repairability factors such as disassembly, parts availability, documentation, and cost; Minnesota could support similar standards or encourage voluntary adoption
- **product-as-a-service models:** leasing and subscription models that retain producer responsibility for maintenance and repair; extend product lifecycles and reduce waste; opportunities include pilot programs, procurement strategies, and public-private partnerships
- **government leadership and internal programs:** expand waste reduction, reuse, and diversion within state operations through sustainable procurement, recycling and composting, reuse of surplus materials, and agency reporting; opportunities include employee education, agency-level reuse requirements, and sustainability teams
- **sustainable purchasing and asset management:** policies that prioritize source reduction, reuse, durability, repairability, and recycled content; redistribution of assets through Admin Surplus Services; repurposing and donation of office materials to maximize reuse
- **sustainable built environment practices:** renovation and adaptive reuse of existing buildings to reduce material disposal; incorporation of deconstruction, material salvage, and reuse of building components in capital projects
- **regional and national leadership examples:** TCMA counties required to implement sustainable purchasing policies; Austin, Texas demonstrates internal sustainability leadership through employee "Green Teams," procurement policies, and reduction initiatives

Statewide Modeled Diversion Target and Minimum Diversion Requirements

As part of this report, Minnesota is required to model a scenario achieving a 90% diversion rate by 2045. While this is not a statutory statewide goal, it provides a benchmark for exploring the infrastructure, policy, and market changes needed to maximize recovery. Progress toward this modeled scenario ultimately depends on steady improvements at the local level, where counties, cities, solid waste management districts, and private companies deliver most waste and recycling services. In many jurisdictions, private haulers, processors, and contractors implement diversion activities on behalf of local governments or property owners. Their collective performance determines whether statewide

diversion outcomes can be realized, underscoring the need for clear tracking, accountability, and compliance mechanisms.

Minnesota already has some of the most ambitious statutory recycling requirements in the region. In 2014, the Legislature increased recycling targets for counties in the TCMA, requiring them to achieve a 75% recycling rate by 2030 (Minn. Stat. § 115A.551). Counties in Greater Minnesota must meet a 35% recycling rate. The Legislature also expanded recycling requirements for sports facilities and certain commercial buildings (Minn. Stat. § 115A.151) and clarified that SCORE funds may be used to support organics recycling programs (Minn. Stat. § 115A.557). These actions reinforce that both recycling and organics collection are integral to Minnesota's solid waste system.

Looking forward, minimum diversion requirements will need to be revisited and updated to stay aligned with the 2045 planning horizon. This should include realistic interim milestones, phased timelines, and funding strategies that account for local government capacity. Equity-driven policy design is essential to ensure that rural, Tribal, and historically disadvantaged communities receive adequate support and are not left behind.

Additional policy tools may also be considered to address large material streams not fully captured by current recycling statutes. For example, several states and local governments, including California, have adopted construction and demolition (C&D) debris diversion requirements that mandate a minimum percentage of building materials be reused or recycled for certain project types, building sizes, or demolition activities. Some local ordinances apply specifically to older buildings, require deconstruction instead of mechanical demolition, or establish higher diversion thresholds for public projects. Similar requirements in Minnesota, applied to public projects, private development, or both, could increase recovery of materials such as wood, concrete, metal, and architectural components while supporting local reuse and recycling markets. Given the high material intensity of the CII sector, C&D diversion requirements may represent one of the most significant opportunities to close the gap toward modeled diversion targets.

Any new legislative requirements must also be paired with adequate funding for technical assistance, infrastructure investment, and compliance mechanisms. A lack of consistent enforcement has historically limited the effectiveness of Minnesota's solid waste statutes. Building stronger accountability into the system through enforceable benchmarks, compliance reviews, and targeted support for lagging jurisdictions will be critical to advancing Minnesota's already ambitious recycling and diversion goals.

Deposit Redemption Systems

Deposit return systems (DRS) or "bottle bills" are currently in place in ten U.S. states. Evidence from these programs shows that beverage container recycling rates are demonstrably higher in states with a DRS compared to those without, and the collected materials are of higher quality, making them more likely to be used in closed loop applications (e.g. new beverage containers).

Although no new DRS law has been enacted in the U.S. since Hawaii did so in 2002, many of the existing programs have expanded the types of containers they cover and increased deposit values, reflecting the growing policy interest in high-performance recycling systems. A key emerging driver for DRS expansion is the potential to support container reuse, not just recycling.

In 2025, the Washington State Legislature considered a modernized DRS proposal that incorporated features common to recent EPR for packaging models. Under this approach, a producer responsibility organization (PRO) composed of beverage producers would oversee program implementation, ensuring

that producers share accountability for recovery and reuse outcomes (Coalition for High Performance Recycling 2025).

For Minnesota, beverage containers remain a notable portion of the MSW stream. A DRS could complement the state's new packaging EPR law by:

- **increasing recovery rates:** higher collection and recycling rates for aluminum, PET, and glass beverage containers
- **improving material quality:** cleaner material streams that support higher-value remanufacturing
- **supporting reuse systems:** opportunities to pilot and scale refillable bottle systems aligned with the state's waste management hierarchy

Recycled Content

Mandatory minimum recycled content standards require that certain products and packaging contain a defined percentage of PCR material. These policies play a critical role in ensuring stable, long-term demand for recycled materials, supporting recycling end markets, reducing dependence on virgin resources, and cutting emissions associated with the extraction and production of virgin materials.

In the past decade, many companies have announced voluntary commitments to increase recycled content, especially in the packaging sector. However, companies have often struggled to meet these commitments and had to reduce their initial goals (e.g. Coca-Cola¹⁵, Unilever¹⁶, PepsiCo, Shell¹⁷). Incorporating recycled content into products requires robust collection and processing networks, and individual producers can rarely affect all aspects of the recycling supply chain through voluntary commitment. Instead, utilization of recycled content should be established through a comprehensive legal framework that drives market development, technology innovation, and continuous improvement. Mandatory standards are needed to establish a consistent baseline across all producers and ensure that progress is not limited to market leaders. These standards send a clear demand signal to the recycling industry, catalyzing investment in collection, sorting, and processing infrastructure. Additionally, recycled content requirements must be paired with strong supply-side policies such as EPR or DRS. When implemented together, these policies reinforce one another, strengthening the recycling system from both the supply and the demand side and accelerating the transition to a circular materials economy.

Minnesota is already implementing recycled content policy through the EPR for paper and packaging law; however, the content targets are not yet set. Additionally, not all items that could incorporate recycled content are included under the EPR for paper and packaging law. When considering recycled content requirements, it is important to consider the availability of recycled feedstock, regional

¹⁵ Heffernan, Marissa. 2024. "Coca-Cola Rolls Back Sustainability Goals, Timelines." Resource Recycling, 2024. <https://resource-recycling.com/recycling/2024/12/10/coca-cola-rolls-back-sustainability-goals-timelines/>.

¹⁶ Staub, Colin. 2024. "Unilever Misses Recyclability Goals, Calls for Policy Action." Resource Recycling, 2024. <https://resource-recycling.com/recycling/2024/05/07/unilever-misses-recyclability-goals-calls-for-policy-action/>.

¹⁷ Staub, Colin. 2024. "Companies Miss or Modify Recycling-Related Goals." Plastics Recycling Update, 2024. <https://resource-recycling.com/plastics/2024/07/24/companies-miss-or-modify-recycling-related-goals/>.

processing capacity, and existing or potential demand for recycled materials before setting recycled content targets.

Other states provide relevant policy models. New Jersey enacted recycled content standards for a broad array of products, including glass containers, paper and plastic carryout bags, and plastic trash bags (Senate and General Assembly of the State of New Jersey 2021). While EPR will establish recycled content requirements for packaging, there is an opportunity to broaden the scope of products that will be required to have recycled content, such as trash bags (similar to New Jersey), boat wrap, fiberglass, and other non-packaging items. Washington State passed legislation in 2021 requiring minimum recycled content in plastic packaging and trash bags, including phased standards that escalate over time from 15% in 2023 to 50% by 2031 for plastic beverage containers (Department of Ecology State of Washington 2025).

Spurring Innovation and Supporting End Markets

Establishing and expanding robust end markets is essential to support Minnesota’s 90% diversion goal. In a survey conducted as part of this report, “weak or unstable end markets for recycled materials” was ranked as the second biggest gap in recycling by local governments, and it was the highest reported gap for jurisdictions in Southeast and Southwest Minnesota. End market instability affects both public and private stakeholders: local governments through program costs and performance, and private-sector processors and manufacturers through commodity price volatility, investment risk, and fluctuating demand. End markets are a critical part of the circular economy, and Minnesota should expand efforts to ensure the continuation of existing markets and support new or emerging markets.

By requiring manufacturers to incorporate PCR material into their products, these policies create a predictable and sustained demand for recycled commodities, such as paper, plastics, glass, and metals. This demand helps stabilize the recycling system by making it economically viable for processors and MRFs to invest in higher-quality sorting and contamination reduction. Additionally, strong end markets incentivize innovation in material recycling and product design, fostering a circular economy in which recycled materials are continuously reintroduced into the supply chain. To maximize impact, these standards should be paired with procurement policies and infrastructure investments that prioritize products made with recycled content, further reinforcing the market for recovered materials.

Minnesota should be thoughtful about avoiding circularity of hazardous additives in plastics by not promoting “recycling” pathways that reintroduce persistent, bioaccumulative, or toxic chemicals (e.g., certain brominated flame retardants and PFAS) into consumer products. Market development and public funding should prioritize feedstocks and processes that demonstrably reduce chemical hazards over the product life cycle.

- **safer material design:** support substitution of hazardous additives and development of safer polymer formulations; use eco-modulated EPR fees to discourage problematic chemistries
- **controlled applications only:** limit outputs from plastics containing legacy additives to controlled, non-consumer applications with documented exposure controls and end-of-life management
- **testing and disclosure:** require representative testing for restricted additives at inbound and outbound stages and ensure transparent disclosure to downstream users
- **technology guardrails:** require chemical recycling technologies to meet contaminant removal performance standards before outputs qualify as recycling; exclude outputs that retain regulated additives above thresholds or are used as fuels
- **procurement standards:** prioritize state purchasing of recycled resin that meets verified safer chemistry specifications

Minnesota already supports prevention, reuse, recycling, and market development through a range of grant programs, low-interest loans, technical assistance initiatives, and targeted funding for organics and waste reduction infrastructure. These efforts have helped seed pilot projects, expand local capacity, and strengthen material recovery systems across the state. However, as diversion targets increase, additional mechanisms that systematically identify and accelerate high-impact business models may further enhance statewide performance.

One program method Minnesota may consider building upon is NextCycle, a multi-state innovation accelerator that identifies, recruits, vets, and supports projects focused on waste prevention, reuse, recycling, composting, and end-market development. Through structured innovation challenges and technical assistance, NextCycle helps new and expanding businesses, nonprofits, and local governments refine business models, attract investment, and scale material recovery solutions. States such as Michigan, Colorado, and Washington have implemented NextCycle programs to accelerate circular economy initiatives and strengthen material supply chains. A similar structured accelerator model could complement Minnesota's existing grant and technical assistance programs by providing targeted business development support for high-potential projects.

Additionally, as wasted food is a focus for reaching 90% diversion, Minnesota can support market development for finished compost by supporting the role local governments can play to increase the demand of that material. In 2019, King County, Washington approved its Organics Market Development Plan, which provided strategies and recommendations that the county could use to spur market demand for finished compost, specifically utilizing the bulk purchasing power of local governments. King County put together a [Technical Assistance program for local governments](#), which included awarding a universal contract to purchase compost from one provider, developing resources and tools for public agency employees, hosting trainings, and developing pilot programs for compost use. Minnesota should consider supporting a similar initiative to spur end markets as wasted food collection and processing continues to grow.

Colorado provides an example of a state taking an active role in end market development. It is supporting a circular economy through the state-led initiative, the Circular Economy Development Center, which is a program of the Colorado Department of Public Health and Environment. The CEDC supports projects for materials that comprise the waste stream but have traditionally been more challenging to divert, like tires, down-filled textiles, C&D, plastic film, shingles, and textiles. Additionally, Circular Colorado works on expanding and creating end markets for recyclable materials, helps connect manufacturers to recycled materials, supports transportation, and assists companies in securing grant and investment funding.

Disposal Bans

Minnesota has enacted disposal bans for a range of products, including yard waste, certain battery chemistries, selected electronic devices, motor oil, fluorescent lamps, and household hazardous waste. These bans play an important role in signaling to residents, businesses, and institutions that specific materials do not belong in the disposal system, while encouraging more responsible handling through recycling or other diversion pathways.

However, disposal bans alone are not sufficient to drive meaningful increases in recycling. Without being coupled with enabling policies such as EPR, recycling requirements, or access to comprehensive drop-off programs, disposal bans often fail to translate into actual diversion. They must be part of a broader systems approach that ensures the infrastructure, funding, and accountability mechanisms to support proper collection and processing.

To strengthen the effectiveness of future bans, Minnesota could benefit from a structured and transparent evaluation process with clear criteria to determine which products or materials are appropriate for restrictions. Beyond hazardous items, new bans could consider:

- **EPR alignment:** whether the material is covered or under consideration for inclusion in an EPR program
- **waste stream significance:** share of the overall MSW stream
- **environmental impact:** factors such as carbon intensity, toxicity, and potential to disrupt landfill operations

Equally important, disposal bans must be supported by:

- **education and outreach:** ensure generators and haulers understand restricted materials, compliance requirements, and proper management pathways; requires sustained funding, multilingual materials, and dedicated staff capacity for consistent statewide messaging
- **compliance and enforcement:** monitoring, contamination checks, and penalties paired with technical assistance to support implementation; historically under-resourced relative to statutory requirements, requiring dedicated staffing and programmatic funding

When strategically aligned with supporting policies and backed by education, infrastructure, and enforcement, disposal bans can be a powerful tool within a coordinated materials management strategy.

Local Policy Considerations

While state-level policies set the framework for Minnesota’s waste diversion efforts, local governments are on the front lines of implementation. Cities and counties can adopt ordinances and programs that ensure equitable access, improve compliance, and engage residents directly. Potential local policy approaches include:

Collection and Access

- **adequate/equal space ordinance:** require multi-family, commercial, and institutional properties to provide equivalent space for recycling and organics alongside trash; integrating these requirements into planning and permitting ensures long-term cost-effective access.
- **universal service requirements:** mandate recycling and organics services for commercial, industrial, and institutional generators, with consistent collection and education provided by haulers
- **CII education and enforcement programs:** require property owners or managers to provide recycling and organics services, signage, and tenant education; designate a “zero-waste lead” and require annual diversion plans; establish administrative penalties with cure periods; dedicate fee revenue to education, enforcement, and technical assistance
- **staffing and technical assistance:** train local staff to conduct site visits, support compliance, and provide direct education to property managers and tenants
- **reuse-friendly zoning:** ensure zoning codes allow reuse facilities to accept donations and resell goods, supporting integration into community development and local economies
- **reporting requirements:** require regular reporting on waste generation, diversion, and disposal from large generators and haulers to improve transparency and inform decision-making
- **emergency management planning:** integrate solid waste and recycling systems into emergency preparedness to ensure continuity during disruptions

Community-scale organics and behavior change

- **grasscycling**: encourage residents to leave grass clippings on lawns to reduce yard waste and fertilizer use
- **backyard composting**: support residents with training and equipment for home composting of food scraps and yard waste
- **community composting**: facilitate small-scale composting hubs at schools, gardens, and urban farms to manage organics locally and increase engagement

Funding Considerations

Minnesota currently supports waste reduction and diversion through a combination of formula-based funding, recurring competitive grants programs, and periodic one-time appropriations. Together, these funding mechanisms provide a foundation for local recycling programs, organics management, market development, and infrastructure investment.

Formula-Based Funding (Stable and Recurring)

Minnesota's core funding structure includes formula-based allocations that provide predictable annual support to counties:

- **SCORE Grants**: established in 1989, allocate state revenues to counties to support recycling programs, household hazardous waste (HHW) management, public education, and waste reduction initiatives; counties retain flexibility to tailor implementation to local needs
- **Local Recycling Development Grants (LRDG)**: provide ongoing funding to metropolitan counties within the TCMA to support regional recycling and organics initiatives

These formula-based programs form the backbone of Minnesota's diversion infrastructure and provide consistent support for education, operations, and compliance activities.

Recurring Competitive Grant and Loan Programs

The MPCA administers several competitive grant and financing programs that support prevention, reuse, recycling, and market development. Some are ongoing, while others are offered in periodic funding rounds based on legislative appropriations and available funding. They include:

- statewide environmental assistance grants
- environmental assistance loans
- statewide recycling market development grants
- statewide prevention of wasted food and food rescue grant
- Greater Minnesota waste reduction, reuse, recycling, and composting grants
- Solid Waste Processing Facilities Capital Assistance Program (CAP)
- small business environmental improvement loans

These programs support innovation, expand infrastructure capacity, and strengthen end markets for recovered materials.

One-Time or Periodic Appropriations

In addition to ongoing programs, Minnesota has periodically provided targeted appropriations to accelerate system development or address emerging needs. These have included:

- statewide organics management grants
- statewide waste reduction and reuse grants
- statewide wood waste utilization grants

- sustainable building and materials management grants
- C&D management planning grants
- other targeted organics or infrastructure investments tied to specific budget cycles

While these one-time investments have played an important role in expanding capacity and supporting planning efforts, they are not currently structured as recurring funding streams.

Achieving Minnesota's 90% diversion goal by 2045 will require continued alignment between funding mechanisms and modeled diversion pathways. This includes:

- Ensuring stable and predictable funding for education, outreach, compliance, and technical assistance.
- Supporting regional partnerships that allow shared infrastructure and coordinated programming across jurisdictions.
- Expanding capital financing tools to support composting, organics processing, transfer infrastructure, and market development where needed.
- Maintaining flexibility to deploy targeted appropriations for emerging technologies or infrastructure gaps.

Enhanced technical assistance capacity, including dedicated staffing and interagency coordination, will be critical to supporting implementation, particularly in rural and underserved communities.

Funding Principles

Implementation costs attributable to packaging and product systems should primarily be borne by producers under EPR frameworks, rather than counties or the general fund. Public funding should prioritize equity gaps, data systems, education and enforcement capacity, and transition support to ensure statewide access and program integrity.

A mixed funding model combining formula allocations, competitive grants, targeted appropriations, private capital, and producer responsibility will be necessary to support Minnesota's long-term transition toward a high-diversion, resource-efficient system.

Recommendations in this report will be supported by a mixed funding model; however, implementation costs attributable to packaging and product systems should be borne by producers under EPR, not by counties or the general fund. Public funds should target equity gaps and public-interest functions (e.g., data, enforcement, and transition support).

Funding and Statewide Support Example: Colorado

The [Colorado Circular Communities \(C3\)](#) is a statewide program dedicated to supporting Colorado's communities, businesses, nonprofits, schools, institutions of higher learning, and tribes with resources to advance the state's transition to a circular economy. The program is funded through fees on solid waste disposed of in Colorado landfills (as authorized by [HB24-1449](#)), and it provides grants and technical assistance to expand waste reduction, reuse, recycling, and market development efforts that advance the state's transition to a circular economy.

Under this law, user fees are imposed on operators of solid waste disposal sites to finance recycling economic opportunity programs. This modest fee requires operators of sites located outside of the front range of Colorado a fee of either 2 or 4 cents per load transported for disposal and operators in the front range (approximately \$0.54 or \$1.08 per ton, assuming an average load of 1.5 tons) and a fee of 78 cents per cubic yard per load transported for disposal (approximately \$15.21 per ton, assuming 0.6

tons/cubic yard). For comparison, Virginia’s current law, under [9VAC20-90-114](#), charges an annual fee for landfills at \$0.115 per ton (2011 base fee rate).

This model is noteworthy not because of the specific fee structure, but because it demonstrates how dedicated statewide funding mechanisms can directly support local governments, nonprofits, and businesses in advancing diversion and market development. Minnesota already has a strong funding tool in place. The Solid Waste Management Tax (SWMT) applies to mixed municipal solid waste collection and other waste management activities and generates substantial revenue. While the commonly cited rate for mixed MSW collection is 17%, the tax structure includes additional rates and categories for residential, commercial, industrial, roll-off, and other waste streams.

Looking ahead, Minnesota could consider dedicating a greater portion of this existing revenue stream (or establishing a similar enterprise-style structure) to more directly and transparently support waste reduction, reuse, recycling infrastructure, and market development initiatives across the state.

Measurement and Tracking

Minnesota is already recognized as a national leader in solid waste measurement and tracking. For example, it is one of the few states that publishes solid waste and diversion data in an interactive dashboard, and MPCA collects comprehensive information through SCORE reporting, facility permits, and state GHG inventories. This provides a strong foundation for transparent reporting and data-driven decision-making.

However, there are opportunities to modernize and expand what is tracked, how it is analyzed, and how the information is communicated to residents, businesses, and policymakers. Improvements should build on existing strengths while filling gaps in current systems.

Core data Minnesota already collects

- **waste diversion:** tons collected, recycled, composted, and disposed, including capture rates and contamination residue
- **facility reporting:** data from MRFs, mixed-waste MRFs, RDF facilities, SSO facilities, WTE facilities, and landfills
- **recycling contamination and capture rates:** material audits, recycling capture efficiency, and contamination trends
- **climate impacts:** GHG emissions associated with the waste sector and reductions achieved through diversion
- **economic indicators:** recycling sector jobs, recycling tonnages, commodity values, and disposal versus recycling and composting tip fees

Areas for expand measurement

- **per capita trends:** waste generation and disposal per resident alongside recycling rates to track overall system performance
- **waste composition analysis:** continued implementation of periodic statewide studies with consistent funding, transparent reporting, and integration into policy and modeling
- **source reduction:** development of standardized metrics to capture prevention, repair, and reuse activities not reflected in current systems
- **equity and environmental justice indicators:** tracking service access (curbside, drop-off, HHW, reuse), affordability, and environmental impacts such as air quality and truck traffic; disaggregation by demographics including income, language, housing type, and disability status

- **language access in outreach:** tracking whether materials are translated into commonly spoken languages and whether translation improves participation outcomes
- **climate resilience:** linking diversion and organics recovery to soil health, flood mitigation, GHG reduction, and other adaptation benefits
- **circular economy investment:** monitoring public and private investment in recycling, reuse, and organics infrastructure, as well as business and job growth in the sector

Together, these policy tools and system supports provide the foundation needed to implement and sustain Minnesota's highest-impact diversion strategies. While EPR, organics diversion, and universal access drive the majority of modeled outcomes, these supporting policies ensure system performance, market stability, and equitable implementation. Reducing disposal at scale requires a coordinated, multi-strategy approach. There is no single solution capable of achieving this outcome. Success depends not only on selecting effective strategies, but also on building the institutional, financial, and policy infrastructure needed to support them over time.

Human Health and Cumulative Risks

Overview

A human health risk assessment (HHRA) is a systematic process that evaluates the potential adverse health effects from various hazards, often environmental contaminants and pollutants. It is meant to provide framework for estimating the likelihood and severity of negative health impacts based on exposure of these contaminants. This is primarily done with hazard identification, dose-response assessment, exposure assessment, and risk characterization.

To create a framework of risk for MSW facilities, contaminants and pollutants of concern were identified through peer-reviewed literature and publicly available reporting from the MPCA. These contaminants were assessed to determine the exposure points (sources) and exposure pathways (e.g., ingestion, inhalation, and dermal contact), and whether the pathways are considered completed, potential, or eliminated.

The U.S. Centers for Disease Control and Prevention's (CDC) Agency for Toxic Substance and Disease Registry (ATSDR) provide a framework for assessing exposure across current, past, and future scenarios. This pathway incorporates the source, the transport of contaminants, the exposure point, the exposure route, and individuals who may be exposed. A completed pathway includes all five elements; a potential pathway includes one or more elements where the presence or absence of a contaminant cannot be confirmed; and an eliminated pathway represents conditions where exposure is unlikely or not possible. The ATSDR exposure assessment works best when monitored data near each potential exposure is available. Therefore, the categorization of pathways for the HHRA of MPCA's waste facilities involves uncertainty due to limited site-specific continuous monitoring data.

Health impacts were evaluated for each contaminant group using available literature and established health benchmarks, including Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for drinking water, Reference Doses (RfDs) and Reference Concentrations (RfCs), and cancer slope factors. Publicly available reporting from Minnesota's environmental monitoring programs was reviewed to provide context on observed conditions and identify contaminants of concern. While this assessment draws on reported data and literature, it does not include direct analysis of facility-level monitoring datasets. As a result, risk characterization reflects a screening-level evaluation and involves uncertainty, relying on available data and reasonable assumptions rather than site-specific quantitative modeling. Site-specific assessments of human health impacts should be conducted with a high degree of rigor and minimal reliance on assumptions.

More detailed, site-specific risk characterization can be conducted using established modeling tools and monitoring datasets, such as MNRisks and other facility-level assessment tools used by the MPCA for permitting and regulatory review. These analyses incorporate facility-specific emissions, environmental conditions, and exposure assumptions to quantify potential human health and ecological risks. However, conducting this level of analysis for all facilities statewide was beyond the scope of this report and would require significant additional data and modeling resources.

Finally, the social vulnerability of populations near Minnesota's MSW facilities were evaluated for each diversion scenario. The Social Vulnerability Index (SVI), developed by the CDC's ATSDR, identifies communities and areas that are at an increased risk of harm from environmental hazards and other public health challenges. While the HHRA framework evaluates exposure pathways and potential health risks, social vulnerability influences how those risks are experienced, including the ability of individuals and communities to anticipate, respond to, and recover from environmental stressors. Vulnerable

populations may experience greater exposure, have fewer resources to mitigate health impacts, and have confounding factors that would cause a negative compounding effect on health. Determining the percentage of facilities in each quartile, for current operations and the two diversion scenarios, assists in assessing the most equitable scenario in terms of environmental justice.

A summarization of the methodology and criteria used for the HHRA can be found below:

- **contaminants and pollutants of concern:** commonly associated with waste management and disposal activities based on peer-reviewed literature and regulatory assessments; identified in MPCA air, surface water, groundwater, and landfill leachate monitoring data and other state agency reports; known or suspected to have adverse human health impacts
- **exposure points and pathways:** inhalation of emissions and particulate matter; ingestion through groundwater, vegetation, fish, livestock, and animal byproducts (e.g., dairy, eggs); dermal contact with soil, groundwater, and vectors
- **ATSDR exposure pathways classification:** completed, potential, and eliminated pathways used to characterize exposure likelihood
- **health impact metrics:** maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG) for drinking water; reference doses (RfDs) and reference concentrations (RfCs) for ingestion and inhalation; cancer slope factors; observed health impacts at documented dosages in the literature; potential exposure levels supported by MPCA data
- **Social Vulnerability Index (SVI):** socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation factors

Taken together, this analysis highlights that decisions about waste management systems are not only operational and economic but also have direct implications for human health and how those impacts are distributed across communities. While this assessment does not provide site-specific risk quantification, it establishes a framework for understanding potential exposure pathways, identifying areas of concern, and highlighting where more detailed analysis may be warranted. These considerations are essential for evaluating the relative benefits and tradeoffs of different diversion strategies and for informing future policy, planning, and investment decisions.

Municipal Solid Waste Facility Profiles in Minnesota

MSW facilities can release a diverse assortment of contaminants and pollutants, many of which have a known potential to negatively impact human health. To assess the risk and prevalence of contaminants in Minnesota's various waste facilities, contaminants were grouped into specific categories. Each group of contaminants was assessed based on 1) the possibility of presence within and surrounding Minnesota's MSW facilities, based on literature; 2) the known or potential health implications, especially when attributed to MSW facilities; 3) their regulatory concern, current or emerging.

Potential exposure pathways were identified for each group of contaminants in relation to specific types of MSW facilities. Although contaminant concentrations extrapolated to dosages were not available, the potential health implications of these contaminants found from exposure to MSW facilities were evaluated. Health impacts were prioritized based on prior epidemiological studies that showed correlation between the potential presence of the contaminant in MSW facilities, and the health implication reported.

To assess each individual contaminant that may be associated with each waste facility, Table 38 characterizes the primary MSW facility types that are operating or have operated in Minnesota, as well

as potential future facility types. Each facility has potential contaminant groups associated with its type and the most likely exposure pathways. These facility profiles outline the evaluated risks for the HHRA.

Table 38. Facility profiles for contaminants and exposure pathways in Minnesota MSWs

Facility type	Likely contaminants of concern	Exposure pathways
Municipal Solid Waste (MSW) Landfill	Particulate Matter, Toxic & Heavy Metals, PFAS, Pharmaceuticals and Personal Care Products, VOCs, Noxious Gases, Microplastics, Phthalates & Phenols, Bioaerosols & Microbes, Pesticides	Inhalation: air pollution and landfill gases Ingestion: leachate and runoff infiltration into surface water, groundwater, soil, and consumed food products Dermal: deposition of particulate matter on topsoil
Waste-to-Energy (WTE) Facility, Ash Landfill, Pyrolysis	Dioxins, Furans, PCBs, PAHs, Toxic & Heavy Metals, Particulate Matter, VOCs	Inhalation: atmospheric emissions, fly ash and bottom ash Ingestion: ash and residue infiltration into groundwater, surface water, soil, and consumed food products Dermal: combustion residue, deposition of particulate matter on topsoil
Composting (SSO & Yard Waste) Facility	Pharmaceuticals and Personal Care Products, VOCs, Noxious Gases, Microplastics, Phthalates & Phenols, Bioaerosols & Microbes, Pesticides	Inhalation: bioaerosols, noxious gases, airborne particulate matter Ingestion: leachate and runoff infiltration into surface water, ground water and soil and stormwater runoff Direct: skin contact with pesticides and microbes (for workers)
Materials Recovery Facility (MRF)	Particulate Matter, Toxic & Heavy Metals, PFAS Pharmaceuticals and Personal Care Products, VOCs, Noxious Gases, Microplastics, Phthalates & Phenols, Bioaerosols & Microbes, Pesticides	Inhalation: bioaerosols, noxious gases, airborne particulate matter Ingestion: Stormwater discharge, spillage or runoff Direct: skin contact with contaminated materials and biological hazards (for workers)
Mixed-Waste Processing (MWP) Facility	Particulate Matter, Toxic & Heavy Metals, PFAS, Pharmaceuticals and Personal Care Products, VOCs, Noxious Gases, Microplastics, Phthalates & Phenols, Bioaerosols & Microbes, Pesticides	Inhalation: bioaerosols, noxious gases, airborne particulate matter Ingestion: Stormwater discharge, spillage or runoff Direct: skin contact with contaminated materials and biological hazards (for workers)

While the magnitude and route of exposure for pollutants may vary by facility type, the cumulative burden on human health by Minnesota’s MSW infrastructure is driven by facility conditions, presence and mobility of contaminants, proximity to humans, and social vulnerability of populations.

For the HHRA, terminology of certain facilities may vary, due to the lack of differentiation in literature. For instance, literature does not distinguish between types of composting facility names (i.e., SSO and yard waste), therefore many terms are used interchangeably.

Influencing Factors

Each type of MSW facility has distinct exposure risks based on its operational design, waste inputs and potential contaminants, and likelihood of human exposure. Throughout the risk assessment, multiple influencing factors are identified for each pollutant of concern. However, there are numerous influencing factors that are present across the different types of MSW facilities.

Influencing factors for WTE facilities include the age of the facility, the type of fuel used (e.g., feedstock, refuse-derived fuel), how that fuel was created (e.g., pyrolysis, gasification, direct combustion), and the types of air pollution control devices in place. Older facilities, or those without sufficient air pollution control devices, do not limit the level of emissions of pollutants compared to facilities with modern, well-maintained equipment.

Emissions from WTE facilities are influenced by the type and condition of air pollution control systems, operational practices, and maintenance. Minnesota has strong permitting requirements for air emissions control equipment, which establish performance standards, monitoring requirements, and enforceable emission limits. Within this regulatory framework, differences in control technologies and facility operations may result in variation in emission levels, although facilities are required to operate within permitted limits.

Landfill leachate and airborne particles are key factors influencing potential exposure at landfill facilities. Leachate may reach environmental receptors through exposure pathways such as infiltration, surface runoff, and precipitation-driven flow, particularly if containment systems are compromised or under certain site-specific conditions. Modern landfills are designed with engineered liner and leachate collection systems to minimize these risks; however, older or legacy facilities, including those with unlined or less advanced containment systems, may present a higher potential for contaminant migration to groundwater and soil.

Closed landfills continue to be managed through post-closure care and monitoring, but site conditions, maintenance practices, and system performance can influence long-term exposure potential. Waste composition, tonnage, and operational practices such as compaction also affect the generation and movement of leachate and landfill gas.

Airborne particle exposure may occur through wind-driven dispersion of dust or other materials, particularly if cover systems are inadequate or disturbed. Landfills are typically managed with daily or intermediate cover (e.g., soil, geomembranes, or alternative materials) to reduce these risks. Weather conditions can further influence exposure potential, as wind may increase particulate dispersion and precipitation may increase runoff and leachate generation.

MRFs and MWP have multiple influencing factors that affect potential environmental and human health risks, often depending on the type of waste processed and facility design. Key factors include wastewater management practices, the potential for contaminated stormwater runoff, and the use and effectiveness of pollution control devices. Facility design and operational controls play a significant role in determining the extent to which contaminants may be released to the surrounding environment.

Pyrolysis is a thermal process that may occur within certain waste management systems and can influence the types and quantities of contaminants generated. While pyrolysis may be used at WTE facilities as part of the combustion process, it can also occur at dedicated facilities or in systems that process mixed waste or recovered materials for use as feedstock. Because pyrolysis can occur across multiple facility types, it is considered as a distinct process in this assessment and evaluated as an influencing factor for certain contaminants and facility operations.

Across facility types, proximity to human populations and environmental receptors is a key factor influencing potential exposure. Facilities located near densely populated areas may increase the number of individuals exposed and may contribute to cumulative environmental burdens, particularly in areas with existing sources of pollution such as industrial facilities, hazardous waste sites, or agricultural operations. Proximity to groundwater and surface water resources is also critical, especially where these resources are used for drinking water, irrigation, or livestock. In these cases, potential contamination pathways may increase the likelihood of human exposure and associated health risks.

Pollutants of Concern

Municipal solid waste (MSW) management systems are associated with a range of chemical and biological contaminants that may be released to air, water, and soil through processes such as combustion, decomposition, material handling, and leachate generation. These include combustion byproducts (e.g., dioxins, furans, particulate matter), heavy and toxic metals, volatile organic compounds (VOCs), PFAS and other emerging contaminants, as well as biological hazards and microplastics.

Exposure to these contaminants may occur through multiple pathways, including inhalation of air emissions, ingestion of contaminated water or food, and direct contact with contaminated materials. The presence and potential impact of these contaminants vary depending on facility type, design, operational practices, and proximity to sensitive receptors. In Minnesota, these risks are managed through a combination of permitting requirements, monitoring programs, and operational standards.

Detailed descriptions of contaminant groups, exposure pathways, and associated health effects are provided in Appendix B.

Summary of Contaminants and Pollutants of Concern

The following tables reiterate the findings for the HHRA contaminants of concern. Each contaminant has been assessed as to the likelihood of existing in each MSW facility compared to the other facilities, and whether the existence would cause health impacts. This is an estimation from literature and MPCA reports and does not reflect a definitive existence for each contaminant and facility type. It also does not take into consideration influencing factors that would increase or decrease prevalence and magnitude of exposure. As an example, PCDDs, PCDFs, and PCBs are combustion byproducts, so they are more likely to be found in WTE facilities and ash landfills, compared to facilities without incineration. Therefore, the likelihood is considered “high” compared to the other facilities but does not mean there is a definite high prevalence of PCDDs, PCDFs, and PCBs in Minnesota’s WTE facilities and ash landfills. Table 39 is meant to show a comparison on which contaminants have a higher likelihood of being prevalent when comparing the existing and potentially future types of MSW facilities but should not be used to determine the risk of specific facilities in Minnesota’s MSW infrastructure. A reiteration of health impacts for each contaminant group can be found in Table 40.

Table 39. Assessed contaminant groups and the likelihood of prevalence in different waste facilities

Contaminant	MSW landfills	WTEs & ash landfills	MRFs	MWP	SSO / compost
PCDDs, PCDFs, PCBs	Low	High	Low	Low	Low
PAHs	Low	High	Low	Low	Low
Particulate Matter	Medium	High	Medium	High	Medium
Heavy Metals	High	High	Medium	High	Low
PFAS & 1,4-dioxane	High	Low	High	High	High
PPCPs	High	Low	High	High	High
VOCs	High	High	Medium	High	Medium
Noxious & Odorous Gases	High	High	Medium	Medium	High
Microplastics	High	Low	High	High	High
Phthalates & Phenols	High	Low	High	High	Medium
Microbials & Biological Hazards	High	Low	High	High	High
Pesticides	High	Low	Medium	High	High

Table 40. Reiteration of health impacts from contaminants of concern

Contaminant	Health impacts from exposure
PCDDs, PCDFs, PCBs	Increased risk of cancer; pulmonary and cardiovascular diseases; hormonal interference; reproductive and developmental toxicity resulting in congenital malformations; developmental delays; cardiovascular diseases; hypertension
PAHs	Increased risk of cancer; cardiovascular disease; myocardial infarction, hypertension; thrombosis; reproductive toxicity
Particulate Matter	Increased risk of cancer; decreased lung function; asthma; COPD; myocardial infarction; stroke
Heavy Metals	Increased risk of cancer; liver and kidney toxicity; developmental toxicity; damage to cardiovascular and neurological systems; hypertension; intestinal lesions; hair and fingernail loss; dermatitis
PFAS & 1,4-dioxane	Endocrine disruption; developmental delays and toxicity; behavioral changes; reproductive toxicity; increased risk of cancer; liver and kidney toxicity; intestinal lesions; hypertension; ulcerative colitis; decreased immune system efficacy; damage to mucous membranes
PPCPs	Increased AMR bacteria; exposure to medications
VOCs	Increased risk of cancer; damage to the nervous system; reproductive and developmental toxicity; liver and kidney toxicity; neurological symptoms; damage to mucous membranes
Noxious & Odorous Gases	Increased risk and irritation of existing cardiovascular and respiratory diseases; increased risk of lung cancer; neurological symptoms; decrease in mental health; damage to mucous membranes
Plastics & Plasticizers	Developmental and reproductive toxicity; transportation of other pollutants; increased AMR; damage to cardiovascular and respiratory systems
Microbials & Biological Hazards	Infections from bacteria, viruses, fungi, and parasites; AMR bacteria; illness from endotoxins and exotoxins
Pesticides	Liver and kidney toxicity; endocrine disruption; reproductive and developmental toxicity; damage to the nervous, digestive, and immune systems; increased risk of cancer

Additional Hazards

Health impacts from other hazards exist for populations and workers near or in different MSW facilities. Mental health has been shown to decline for populations near landfills, and studies have shown individuals adjust their daily activities based on the odors emitted from the landfills (Tomita et al., 2020; Heaney et al., 2011). Anxiety levels have also shown to be increased in waste workers across different types of waste facilities (Nguyen, 2021).

Occupational hazards, such as injuries to the back and knees, are higher for facilities where manual labor is required. Musculoskeletal injuries are higher for waste workers in facilities that required repetitive lifting, consistent awkward movements such as twisting, and getting in and out of machinery (Dorevitch & Marder, 2001). These movements contribute to high rates of back, shoulder, knee, and other joint pain. Injuries from cuts and punctures for workers at MWPFs and MRFs is higher compared to other industries, and risk of trips, slips, and falls is more common amongst waste workers than most other industries (Dorevitch & Marder, 2001).

Precautions and protections can minimize the risk of occupational injury at MSW facilities. Proper personal protective equipment (PPE) such as respirators or masks, protective coveralls, safety eyeglasses and gloves, minimize the risk of injury. Proper training of employees for safety awareness, good personal hygiene, monitoring of contaminants, and medical surveillance have been found to decrease occupational hazards (European Agency for Safety and Health at Work).

Social Vulnerability and Environmental Justice

Social Determinants of Health, Environmental Justice, and Social Vulnerability

Social determinants of health (SDOHs), or the non-medical factors such as age and the environments where people work, live, learn, play, congregate, etc., have long been known to impact people's health, well-being, and overall quality of life. Environmental justice, or the fair treatment of all people regardless of their social determinants of health, such as race, national origin, and income, is a critical factor when assessing the burden, or social vulnerability, of a population. Economic stability, safe housing and neighborhoods, reliable transportation, access to quality education, job opportunities, generational income, access to healthcare and nutritious foods, physical activity opportunities, language and literacy skills, racial and ethnic discrimination and violence, and pollution of air and water are all social determinants of health that have major impacts on health disparities and inequities. These SDOHs often work together as confounding factors to impact long term health outcomes of communities. For instance, lack of access to reliable transportation while living in a food desert with a lack of grocery stores results in surrounding communities often having poorer nutrition. This raises the risk of various health conditions such as diabetes, obesity, and heart disease, and lowers the life expectancy of that population (ODPHP, 2020). With property taxes often helping fund schools in a community, quality of education varies between neighborhoods based on affluence, which in turn impacts career opportunities that impact financial stability and access to healthcare. This results in a decrease in prevalence of preventative care and higher rates of progressed diseases and chronic illnesses, creating a greater burden on those in the community (ODPHP, 2020).

Marginalized communities including people of color, indigenous communities, and low-income populations suffer health impacts from air and water pollution, chemical exposure, hazardous waste, and climate change at a significantly higher rate than other populations (APHA, 2026). These communities have been shown to live in close proximity to waste facilities at a disproportionate amount in the United States. Numerous studies spanning multiple decades support a correlation between race, income or financial stability, and increased exposure to hazards from waste facilities, especially those near noxious facilities (Margai, 2001; Taylor, 2000; Lavelle & Coyle, 1992; Goldman & Fitton, 1994; Bullard et al., 2007; Anderton et al., 1994, Oakes et al., 1996; Sinha et al., 2024). Furthermore, studies throughout the U.S. and Europe have a correlation between increased risk of cancer, respiratory diseases, cardiovascular diseases, neurological diseases, and developmental disabilities for socially vulnerable populations due to increased waste exposure, especially from landfills and incineration facilities (APHA, 2026; Martuzzi et al., 2009; Harper et al., 2009; Laurian, 2008; Forastier et al., 2009; Sinha et al., 2024). Therefore, prioritizing environmental justice and assessing SDOHs and social vulnerability is critical when creating and modifying waste policies and regulations.

Overview of Social Vulnerability Index

The Centers for Disease Control and Prevention (CDC) and Agency for Toxic Substances and Disease Registry (ATSDR) use a Social Vulnerability Index (SVI) to assess a specific region's increased risk of public health emergencies, and which are more susceptible to environmental injustice. There are four

overarching themes used to determine the CDC/ATSDR SVI of a region, with each category having an individual SVI quantity or score.

SVI quantities range from 0 to 1, with 0 being the lowest possible vulnerability, and 1 being the highest. A higher SVI quantity suggests that a community or area is at an increased risk of harm from environmental hazards and other public health challenges. Vulnerable populations may experience greater exposure, have fewer resources to mitigate health impacts, and have confounding factors that would cause a negative compounding effect on health

To better categorize each SVI score per zip code or county, quartiles were created and correspond with a certain level of risk. For instance, the highest risk populations fall into the fourth quartile and consist of populations that would be most impacted by health burdens from exposure to MSW facilities. The four quartiles are divided below:

- **1st quartile:** SVI between 0 and 0.25; lowest SVI and lowest risk of environmental justice impacts
- **2nd quartile:** SVI score between 0.26 and 0.50; second lowest SVI and second lowest risk of environmental justice impacts
- **3rd quartile:** SVI score between 0.56 and 0.75; second highest SVI and second highest risk of environmental justice impacts
- **4th quartile:** SVI score between 0.76 and 1; highest SVI and highest risk of environmental justice impacts

There are four overarching themes used to determine the SVI of a region, with each category having an individual SVI score. These four categories assess the socioeconomic status, household characteristics, racial and ethnic minority status, and housing types and transportation for a given zip code, county, or designated census area. Individuals that are institutionalized, and therefore not residing in their corresponding zip code or county, are not included in the CDC's SVI analysis.

Socioeconomic Status

The socioeconomic status theme of the SVI considers poverty, unemployment, housing cost-burdens, annual income, high school education, and insurance, including:

- individuals living below 150% poverty
- individuals above the age of 16 that are unemployed
- housing cost-burdened occupied housing units with an annual income less than \$75,000 where 30% or more is spent on housing costs
- individuals above the age of 25 that do not have a high school diploma
- total individuals that do not have health insurance

Household Characteristics

The household characteristics theme of the SVI considers age, disability status, single parent households, and an ability to speak and understand English, including:

- individuals that are 65 years of age and older
- individuals that are 17 years old and younger
- individuals with a disability
- single parent households with children under the age of 18 years
- individuals above the age of 5 years old who "speak English less than well"

Racial and Ethnic Minority Status

The racial and ethnic minority status theme of the SVI evaluates the prevalence of populations that fall into certain groups:

- Hispanic or Latino of any race
- Black and African American, not Hispanic or Latino
- American Indian and Alaska Native, not Hispanic or Latino
- Asian, not Hispanic or Latino
- Native Hawaiian and other Pacific Islander, not Hispanic or Latino
- other races, not Hispanic or Latino

Housing Types and Transportation

The housing type and transportation theme of the SVI evaluates the housing structures, houses with more people than rooms, availability of vehicles, and individuals living in group quarters, including:

- housing in structures with 10 or more units
- mobile homes in the area
- more individuals than rooms per household (i.e., crowding)
- individuals living in group quarters
- households with no vehicles available

Each category, or SVI theme, is given a specific quantity between 0 and 1. A weighted average, based on confounding factors, is calculated to determine an overarching SVI quantity. The weighted average is most often used to assess vulnerability, unless certain factors are to be excluded when comparing similar populations.

Social Vulnerability of Minnesota's Population

SVIs for the state of Minnesota range from 0.0116 to 0.9884. Both zip code and county SVIs were used to assess the risk of burden to human health for each diversion scenario. Figure 36 and Figure 36 show a county and zip code heat map of SVI quantities for the Minnesota communities.

Figure 35. SVI heat map by county

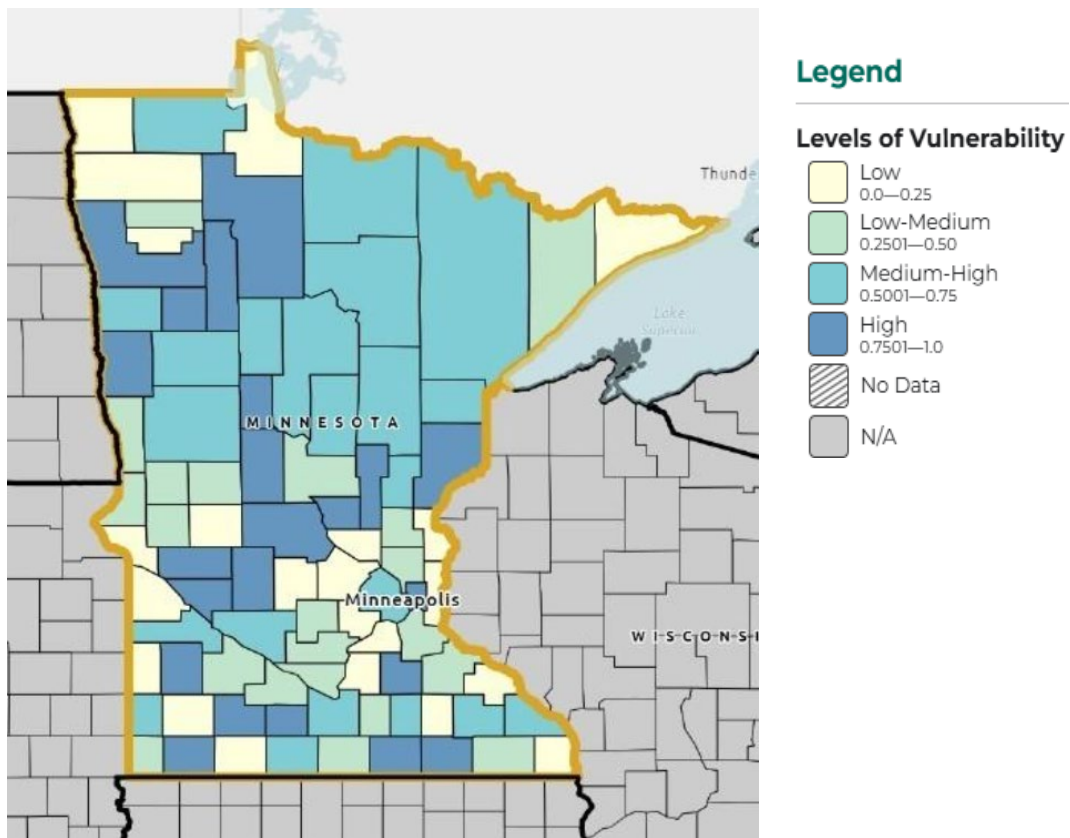
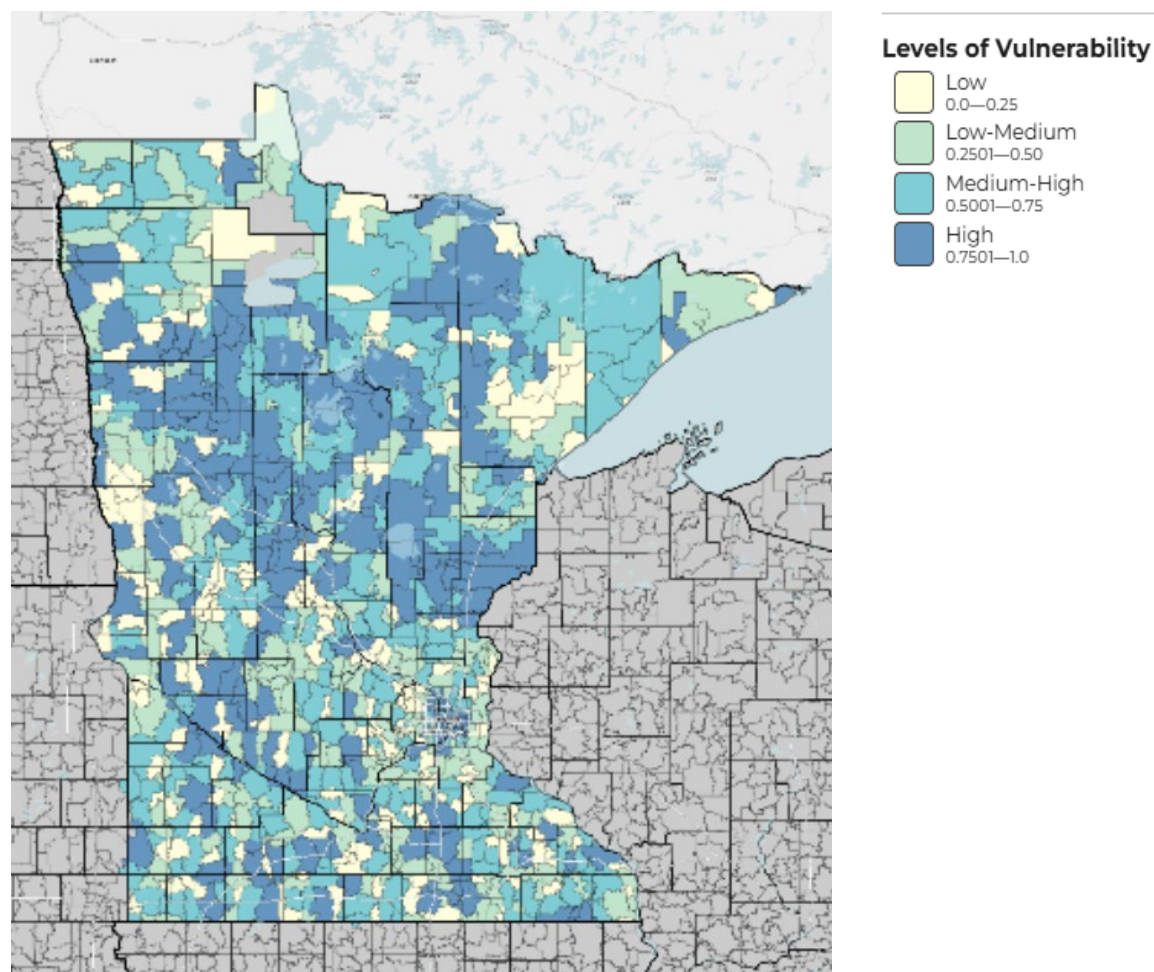


Figure 36. SVI heat map by zip code



Both SVI heat maps show a level of variability per region. High density population areas, such as downtown Minneapolis, and many rural communities show a higher level of vulnerability. SVI quantities are unavailable in a select few areas, including the counties of Beltrami, Clearwater, and Lake of the Woods, all of which have indigenous reservations. These areas have an increased risk of environmental justice challenges and should be treated similarly to 4th quartile groups.

Population Near Waste Facilities

To assess the populations or areas at an elevated risk of contamination and health impacts from waste facilities in Minnesota, each waste facility's zip code and county was cross referenced against the SVI score for that zip code. The social vulnerability of populations near Minnesota's MSW facilities were evaluated for current waste facilities and each diversion scenario to assist in assessing the most equitable scenario in terms of environmental justice. Figure 37, Figure 38, and Figure 39 include SVI by county for current waste operations, 90% diversion including WTE facilities, and 90% diversion without WTE facilities but including landfills. Figure 40, Figure 41, and Figure 42 plot the three scenarios but by SVI zip code.

Figure 37. Baseline waste operations by SVI by county

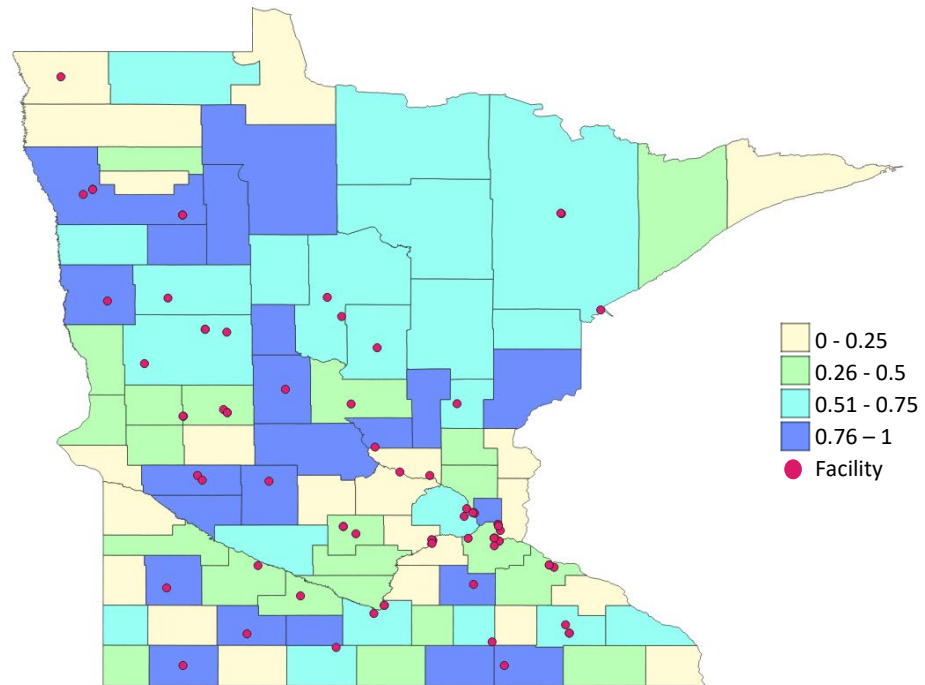


Figure 38. Scenario with WTE facilities operating by SVI by county

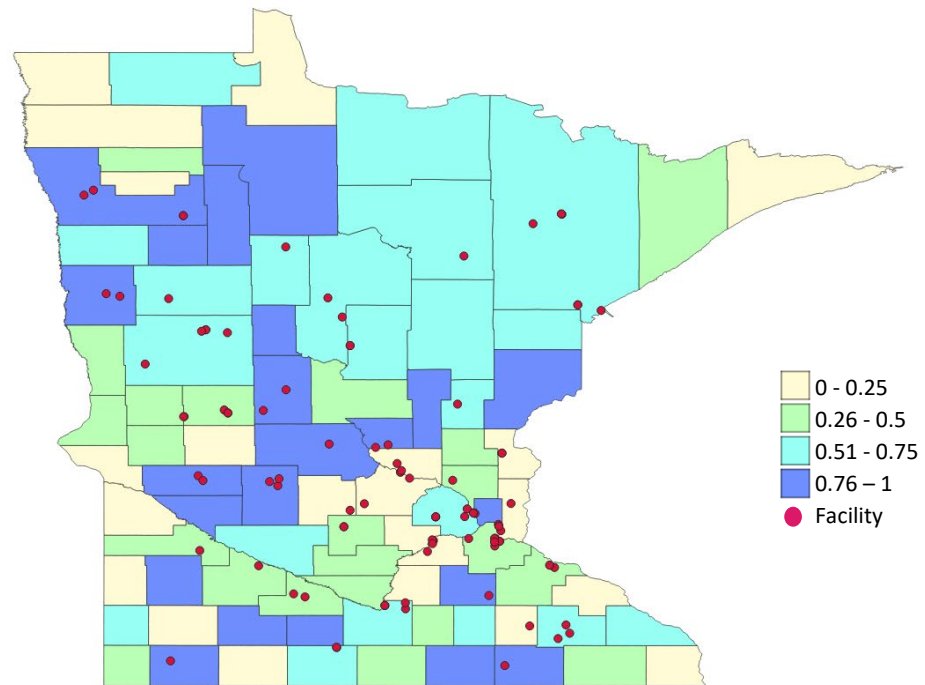


Figure 39. Scenario without WTE facilities operating by SVI by county

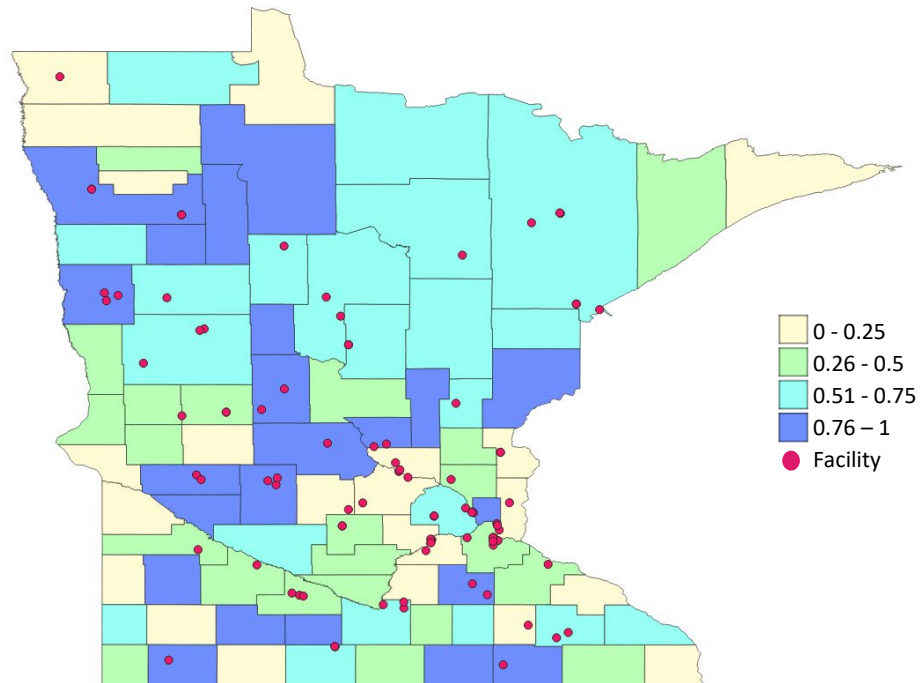


Figure 40. Baseline waste operations by SVI by zip code

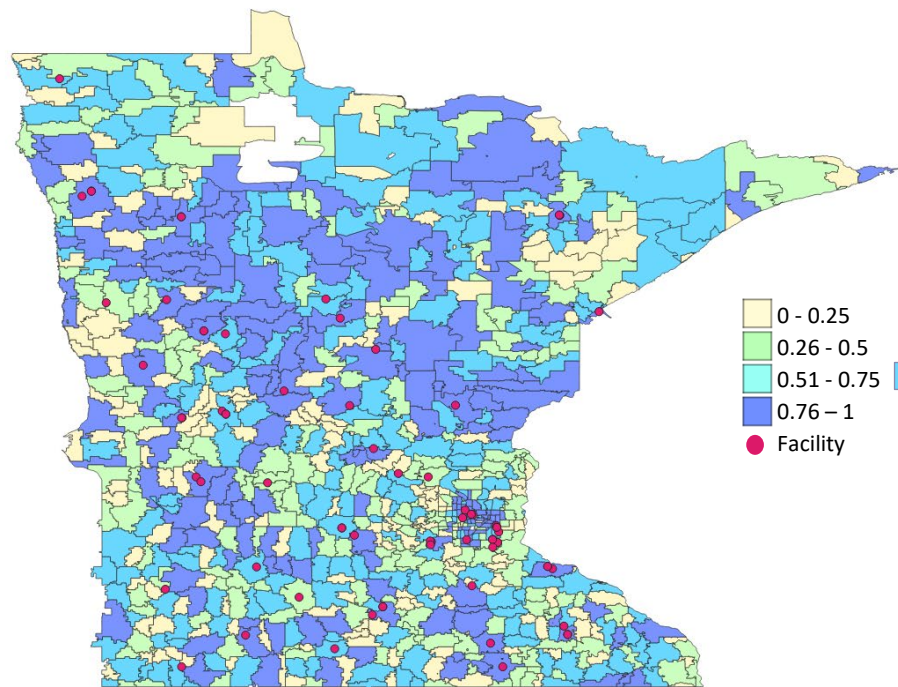


Figure 41. 90% diversion with WTE facilities operating by SVI by zip code

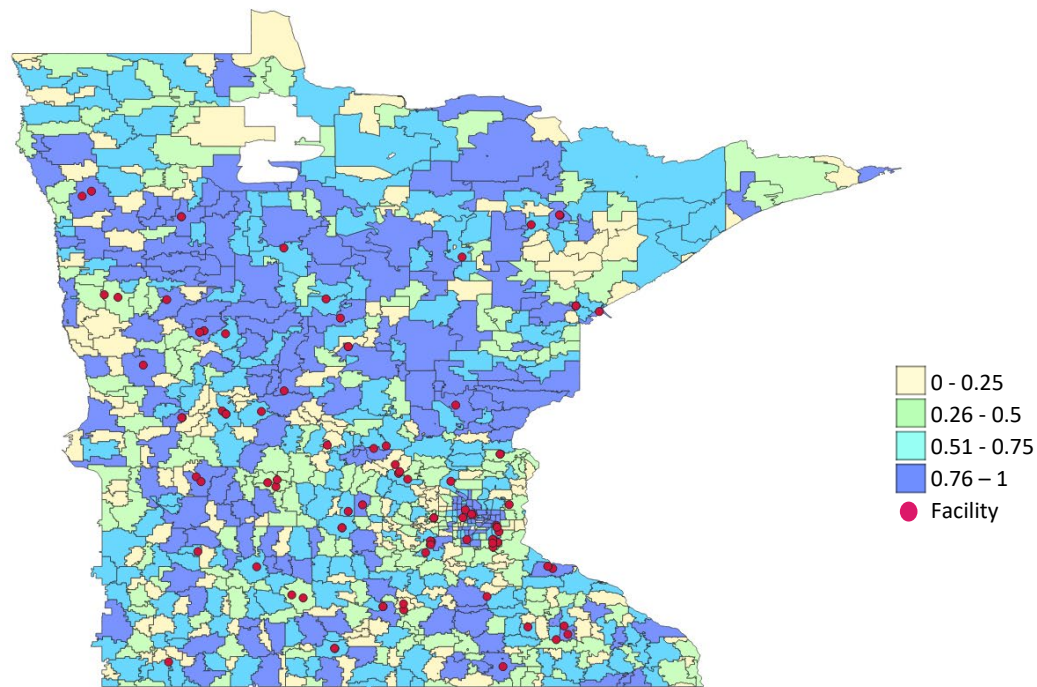
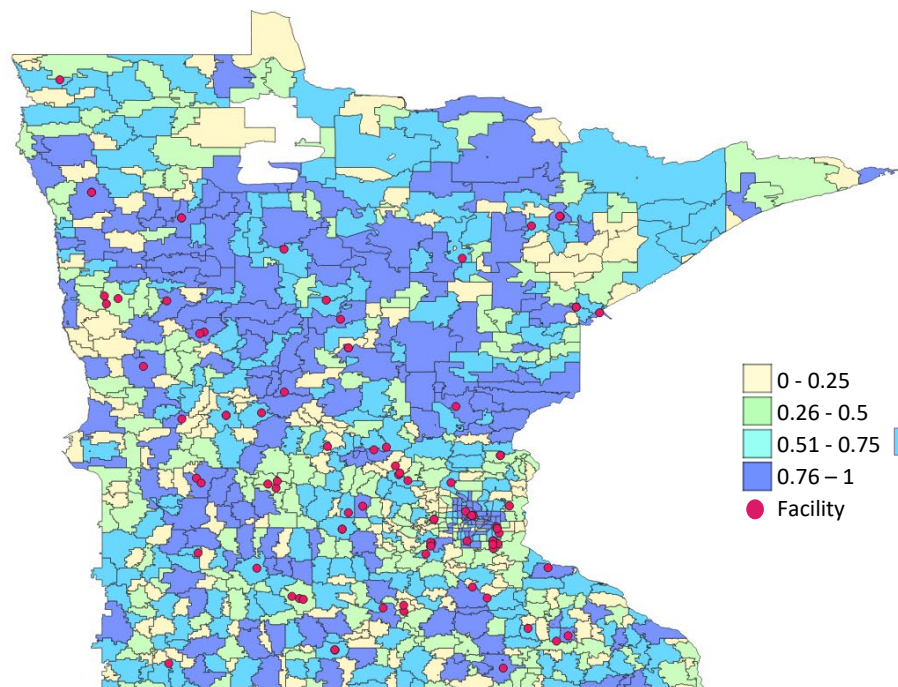


Figure 42. 90% diversion without WTE facilities operating by SVI by zip code



The overall change in total facilities by SVI quartile is found Figure 43 and Table 41, while Figure 44 includes the percent change in total facilities for each diversion scenario compared to current operations.

Figure 43. Waste facilities per SVI quartile for the baseline and scenarios

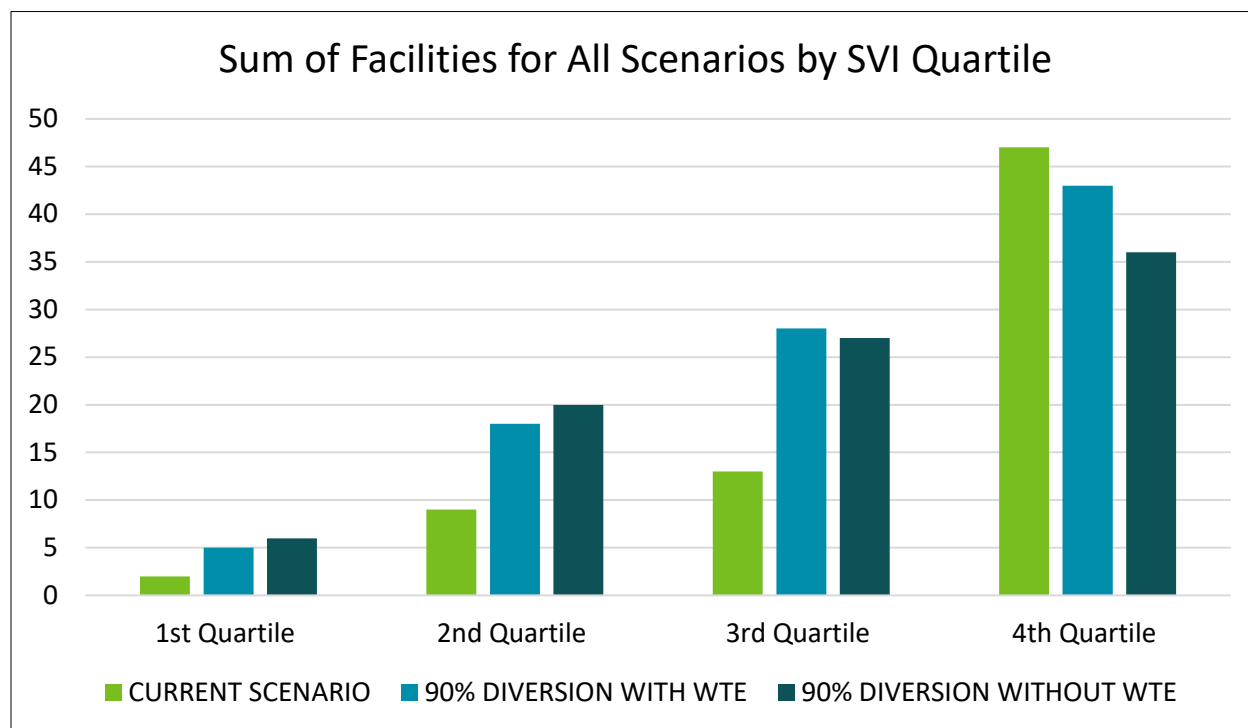
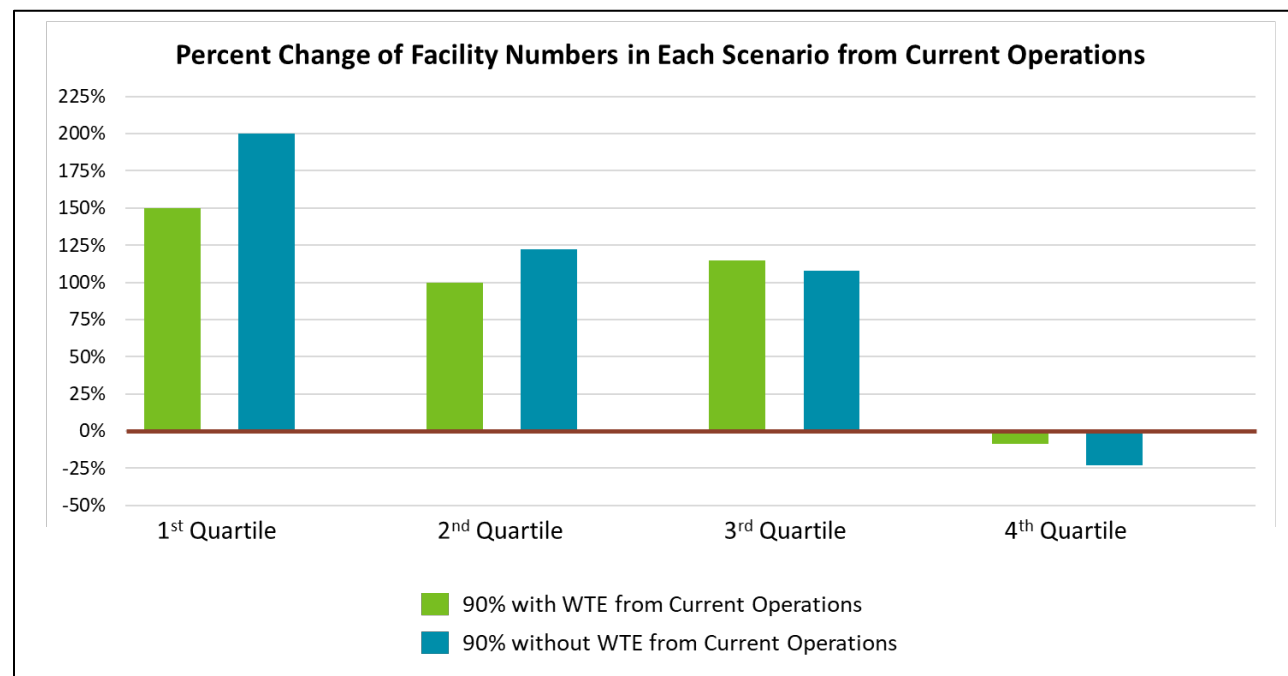


Table 41. Waste facilities per SVI quartile for the baseline, scenario with WTE, and scenario without WTE

Quartile	Current scenario	90% diversion with WTE	90% diversion without WTE
1 st quartile	2	5	6
2 nd quartile	9	18	20
3 rd quartile	13	28	27
4 th quartile	47	43	36

Figure 44. Percentage change of facility numbers in each scenario from baseline operations per SVI quartile



Current operations have a disproportionate number of waste facilities in the 4th quartile zip codes and counties, with a decreasing number of total facilities per quartile below the 4th Quartile. Current operations show a stark difference in the total number of facilities between the 1st and 4th Quartiles, with only two facilities in the 1st and 47 operational facilities in the 4th quartile. These 47 facilities in the most vulnerable areas may create an added burden on the health of those communities that has a greater impact to health than lower quartiles.

Both diversion scenarios show an increase in facilities for all quartiles except the 4th quartile, or the most vulnerable to negative health impacts from nearby waste facilities, meaning the current operations put the largest burden on the 4th quartile compared to other scenarios and quartile populations. The diversion scenario including WTE facilities, and subsequently ash landfills, increases the number of facilities at a lesser percentage than the scenario without WTE facilities for 1st and 2nd quartile populations. The scenario does increase the total facilities in the 3rd quartile compared to current operations but decreases the total number of facilities in the 4th quartile. However, the scenario without WTE facilities increased the number of facilities in 3rd quartile populations, but at a lesser percentage than the scenario including WTE and decreases the number of facilities in 4th quartile zip codes against the current operations and at a greater decrease than the other diversion scenario. This suggests that the diversion scenario without WTE facilities and ash landfills is the most equitable for the most vulnerable populations of the 4th quartile in Minnesota but does add a bit more burden to the 3rd quartile populations compared to current operations for facilities except WTE, ash landfills, and MSW landfills.

Figure 45 shows the regional distribution of facilities for each SVI quartile across the three scenarios, with Figure 46, Figure 47, and Figure 48 representing the same information separately. The Northwest and TCMA regions have the most facilities in the 3rd and 4th quartiles, or the areas with populations who are especially vulnerable to environmental injustice. The current operations and the scenario with WTE facilities operating have an equal count of facilities operating in 4th quartile areas in the Northwest and TCMA, with both diversion scenarios having a larger number of operating facilities in the 3rd Quartile for these regions. The diversion scenario without WTE facilities has the lowest number of facilities operating in the 4th Quartile areas in the Northwest and TCMA, an equal number of facilities in the 3rd quartiles of the Northwest compared to current operations, and the highest number of facilities operating in 3rd quartiles of the TCMA.

The diversion scenarios also spread the facilities across regions more equitably, as current operations have less facilities operating in the Central, Southeast, Southwest, and Northeast. In the Southwest, Southeast, and Northeast regions, current operations have a large majority of facilities (73.91%) in 4th quartile regions. The diversion scenario with WTE and ash landfills reduces the percentage of facilities in 4th quartile regions (49.74%), with the diversion scenario without WTE and ash landfills having the lowest percentage of facilities in 4th quartile regions (33.33%). However, similar to the Northwest and TCMA regions, the change in facilities may impact 3rd quartile populations more than the current scenario for the Southwest, Southeast, and Northeast regions. In the Central region, 4th quartile populations lived closest to the greatest number of facilities currently, but the distribution is the most even across all four quartiles compared to the other regions. The diversion scenarios would have minimal effect on 3rd and 4th quartile populations but would increase the number of facilities in 1st and 2nd quartile populations.

Figure 45. Facility count by region for each SVI quartile for all scenarios

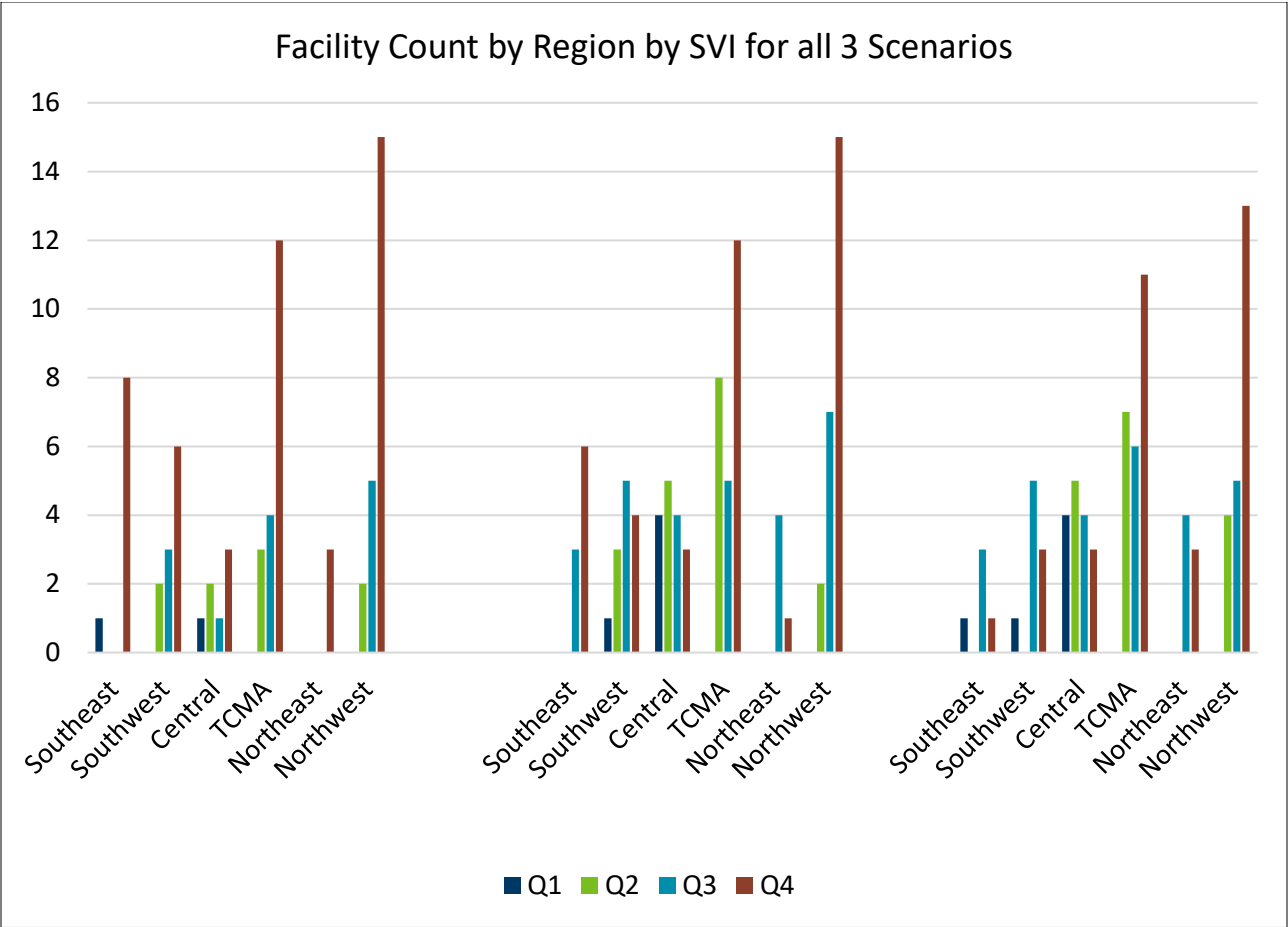


Figure 46. Facility count by region and SVI for baseline operations

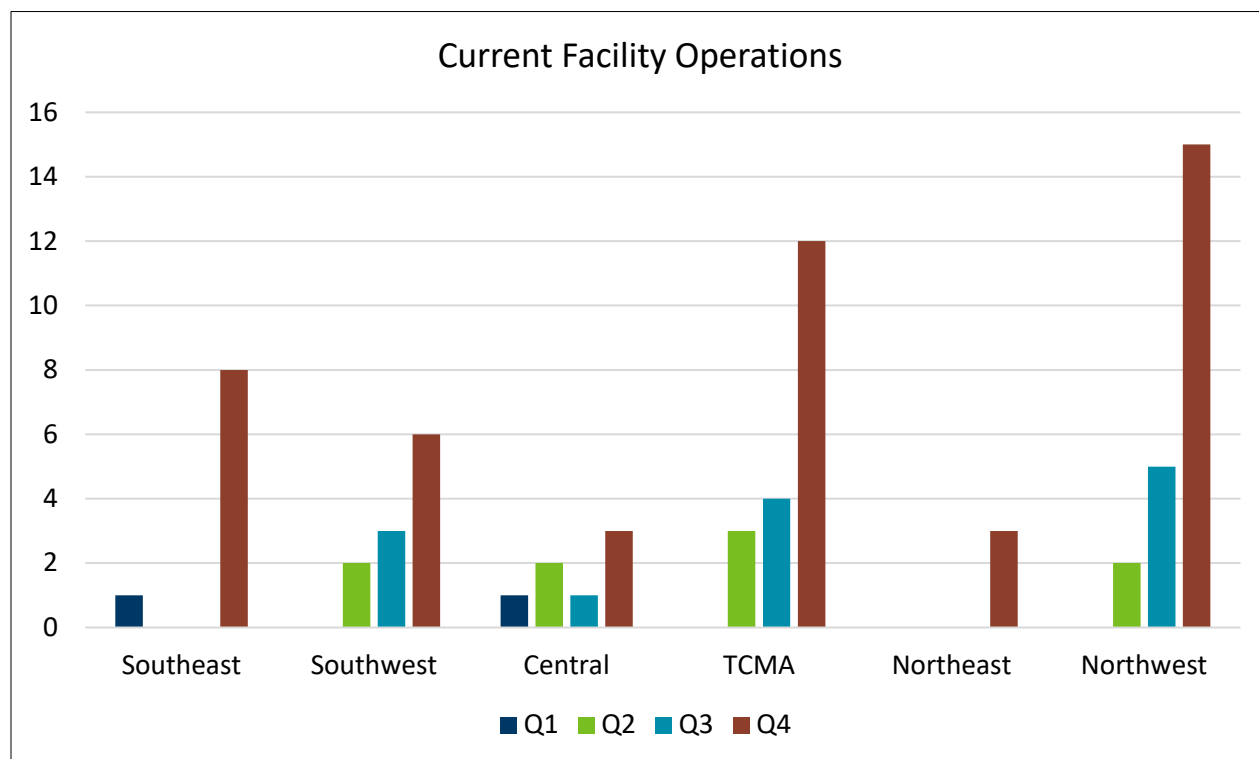


Figure 47. Facility count by region and SVI for scenario with WTE facilities operating

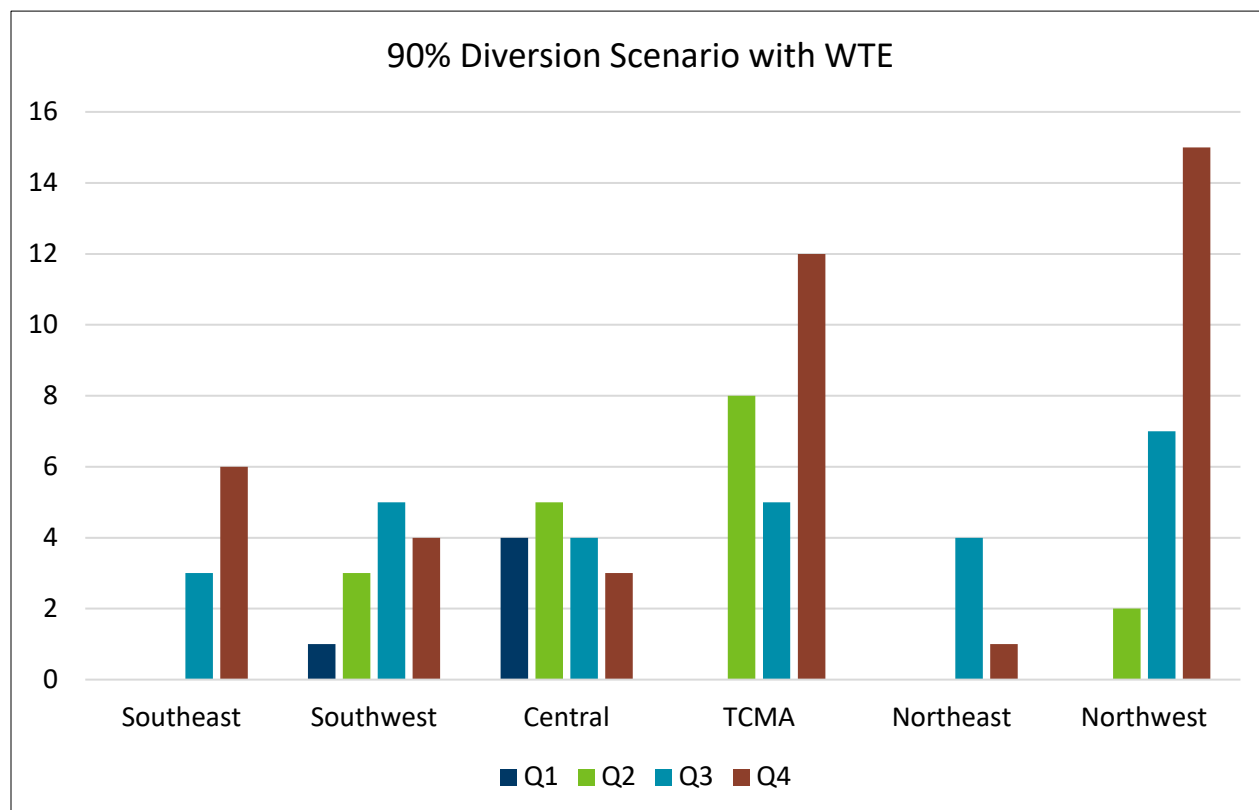
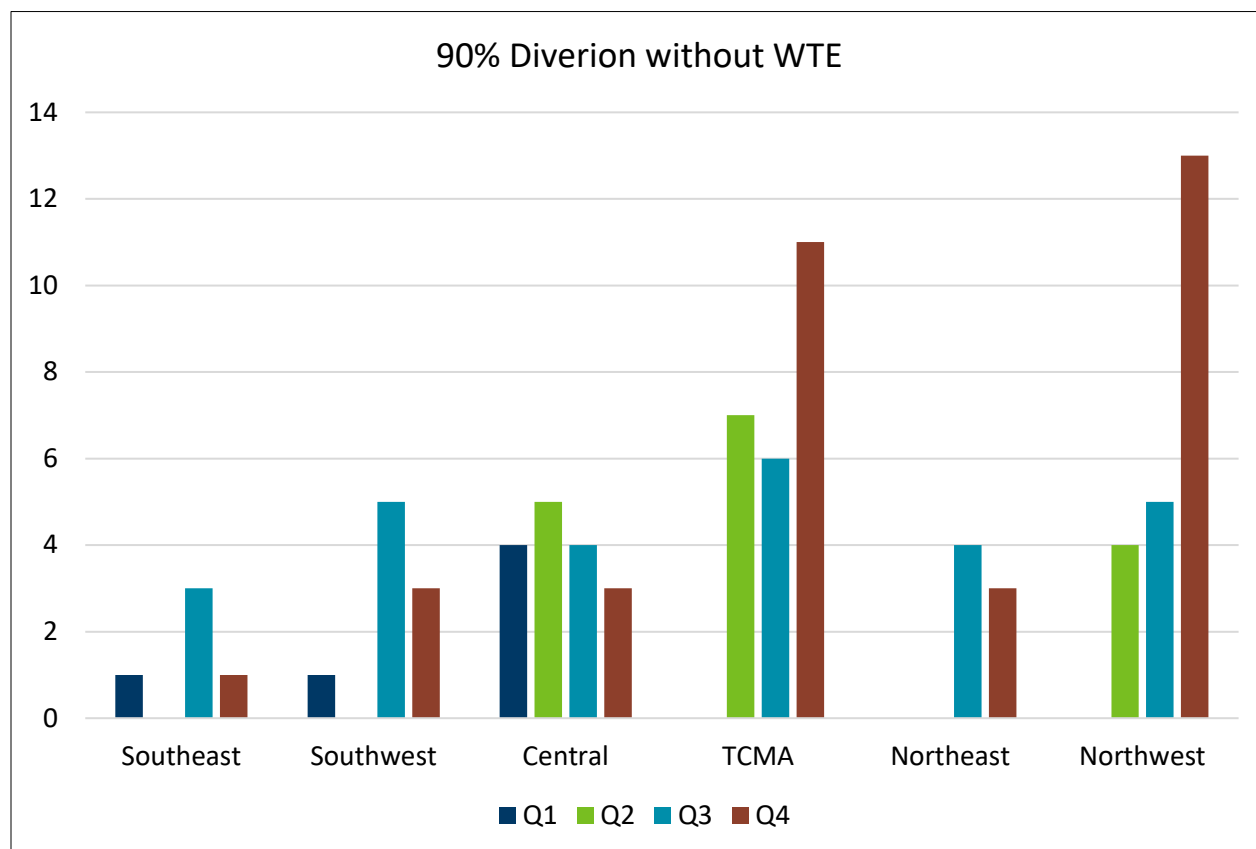


Figure 48. Facility count by region and SVI for Scenario without WTE facilities operating



As certain waste facilities likely present a greater risk to human health compared to others, a more detailed visual of the scenarios by quartile can be found in Figure 49, which illustrates the change in prevalence of each type of facility across the scenarios by quartile. Table 42, Table 43, and Table 44 include the quantities of each facility type, by scenario and quartile, while Table 45 and Table 46 show the change in the number of facilities per facility type and quartile. The two diversion scenarios have the same changes in the number of added MRFs, MWPFs, and SSO compared to current operations. The difference in facility count is due to the elimination of either WTE facilities, ash landfills, and MSW landfills.

Due to the perceived and actual risks associated with landfills, both MSW and ash, and WTE facilities, the change in the number of these three facility types per quartile for each scenario should be especially assessed. Risk of closed landfills (currently closed or closed due to the specific diversion scenario) cannot be assessed for each scenario. However, closed landfills still present a risk in their closed status, albeit a lesser risk than when operating. The diversion scenario with WTE operations continuing eliminates one MSW landfill from populations part of the 1st quartile, five from the 2nd quartile, two from the 3rd quartile, and eight from the 4th quartile. There is no change in the number of WTE facilities or ash landfill for this scenario. The diversion scenario without WTE eliminates two MWS landfills for populations from the 2nd quartile, one from the 3rd quartile, and 6 from the 4th quartile. This scenario also eliminates one ash landfill from the 2nd quartile, one ash landfill and one WTE facility from the 3rd quartile, and three ash landfills and six WTE facilities from the 4th quartile. The total number of eliminated facilities that are either MSW landfills, ash landfills, or WTE facilities in the scenario without WTE operations is three facilities located in 2nd quartile areas, three facilities in the 3rd quartile, and 15 facilities in the 4th quartile. Therefore, there is a greater number of MSW landfills, ash landfills, and WTE facilities eliminated by the scenario with WTE operations for the 1st and 2nd quartiles, or the lesser vulnerable

populations, and more eliminated in the scenario without WTE operations for the 3rd and 4th quartiles, or the more vulnerable populations. This is supported by Figure 50.

Figure 49. Number of waste facilities by type per SVI quartile for baseline and scenarios

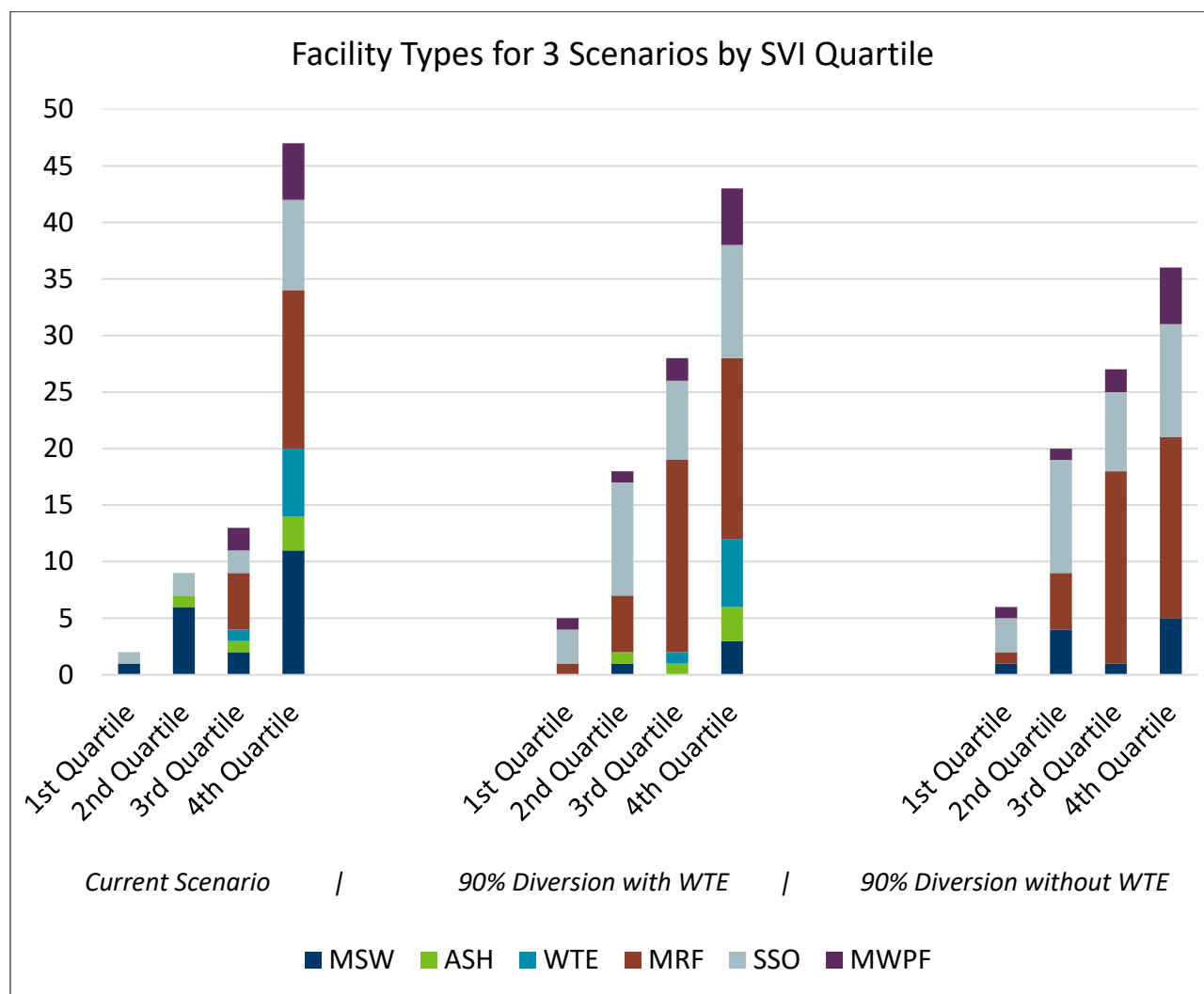


Table 42. Number of MSW facilities per quartile for baseline

Quartile	MSW Landfills	Ash Landfills	WTE	MRFs	SSOs	MWPFs
1 st Quartile	1	0	0	0	1	0
2 nd Quartile	6	1	0	0	2	0
3 rd Quartile	2	1	1	5	2	2
4 th Quartile	11	3	6	14	8	5

Table 43. Number of MSW facilities per quartile for scenario with WTE

Quartile	MSW Landfills	Ash Landfills	WTE	MRFs	SSO	MWPFs
1 st Quartile	0	0	0	1	3	1
2 nd Quartile	1	1	0	5	10	1
3 rd Quartile	0	1	1	17	7	2
4 th Quartile	3	3	6	16	10	5

Table 44. Number of MSW facilities per quartile for scenario without WTE

Quartile	MSW Landfills	Ash Landfills	WTE	MRFs	SSO	MWPFs
1 st Quartile	1	0	0	1	3	1
2 nd Quartile	4	0	0	5	10	1
3 rd Quartile	1	0	0	17	7	2
4 th Quartile	5	0	0	16	10	5

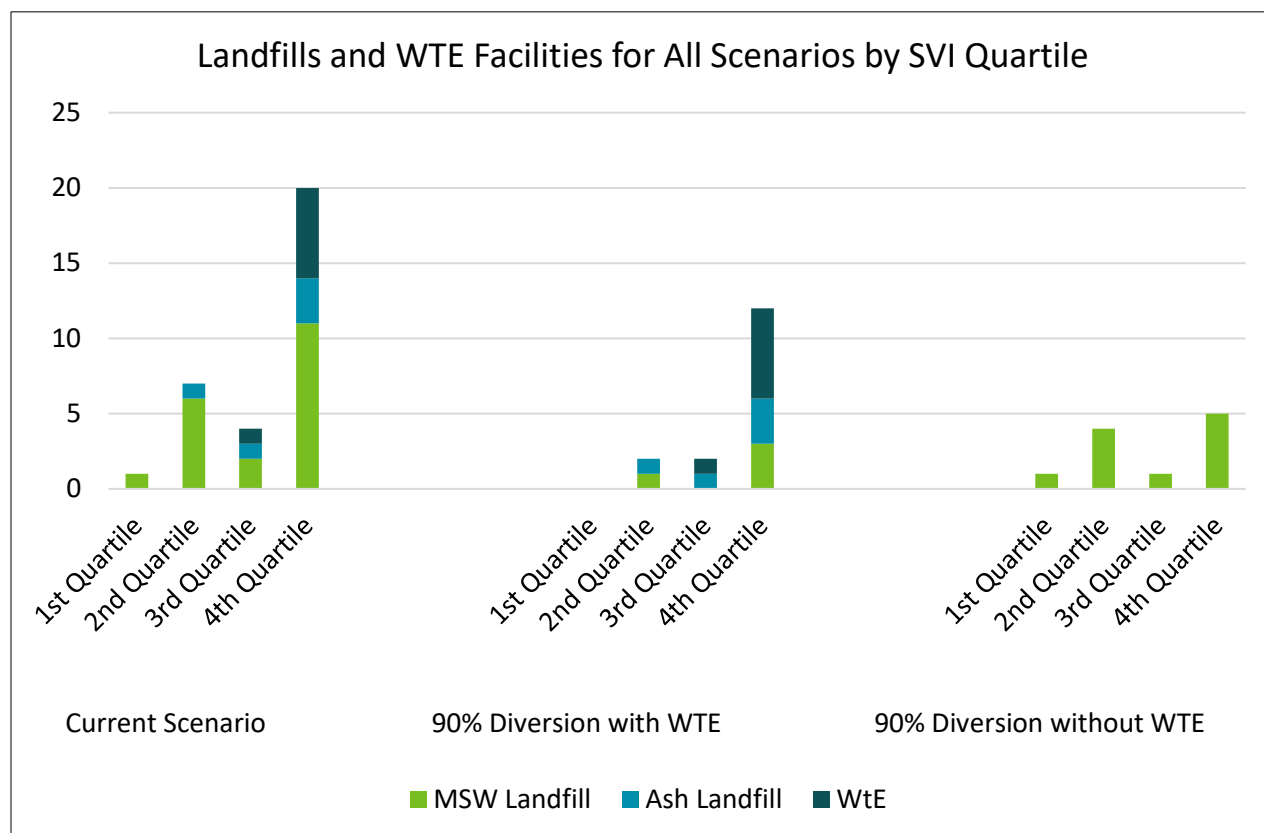
Table 45. Difference in facility count by facility type between baseline and scenario with WTE

Quartile	Scenario	MSW Landfills	Ash Landfills	WTE	MRFs	SSO	MWPFs
1st	Current	1	0	0	0	1	0
	Scenario	0	0	0	1	3	1
	Difference	-1	0	0	+1	+2	+1
2nd	Current	6	1	0	0	2	0
	Scenario	1	1	0	5	10	1
	Difference	-5	0	0	+5	+8	+1
3rd	Current	2	1	1	5	2	2
	Scenario	0	1	1	17	7	2
	Difference	-2	0	0	+12	+5	0
4th	Current	11	3	6	14	8	5
	Scenario	3	3	6	16	10	5
	Difference	-8	0	0	+2	+2	0

Table 46. Difference in facility count by type between baseline and scenario without WTE

Quartile	Scenario	MSW Landfills	Ash Landfills	WTE	MRFs	SSO	MWPFs
1st	Current	1	0	0	0	1	0
	Scenario	1	0	0	1	3	1
	Difference	0	0	0	+1	+2	+1
2nd	Current	6	1	0	0	2	0
	Scenario	4	0	0	5	10	1
	Difference	-2	-1	0	+5	+8	+1
3rd	Current	2	1	1	5	2	2
	Scenario	1	0	0	17	7	2
	Difference	-1	-1	-1	+12	+5	0
4th	Current	11	3	6	14	8	5
	Scenario	5	0	0	16	10	5
	Difference	-6	-3	-6	+2	+2	0

Figure 50. MSW and ash landfills, and WTE facilities for all scenarios by SVI quartile



To further highlight the change in MSW landfills, ash landfills, and WTE facilities, Figure 51, Figure 52, Figure 53 show the total of these three types of facilities per region for current operations and each scenario. Although previous data showed the Northwest and TCMA regions as having the greatest number of total facilities currently operating in the 4th quartile populations, the Northwest and Southeast regions have the most MSW landfills, ash landfills, and WTE facilities currently operating that fall into 4th quartile areas. Although the diversion scenario with WTE facilities operating does minimize the total number of facilities in the Northwest and Southeast, they still have the most facilities operating

in 4th quartile regions. The diversion scenario without WTE facilities and ash landfills is the most equitable in terms of equal dispersion.

Figure 51. Sum of MSW and ash landfills, and WTE facilities per region by SVI quartile for baseline

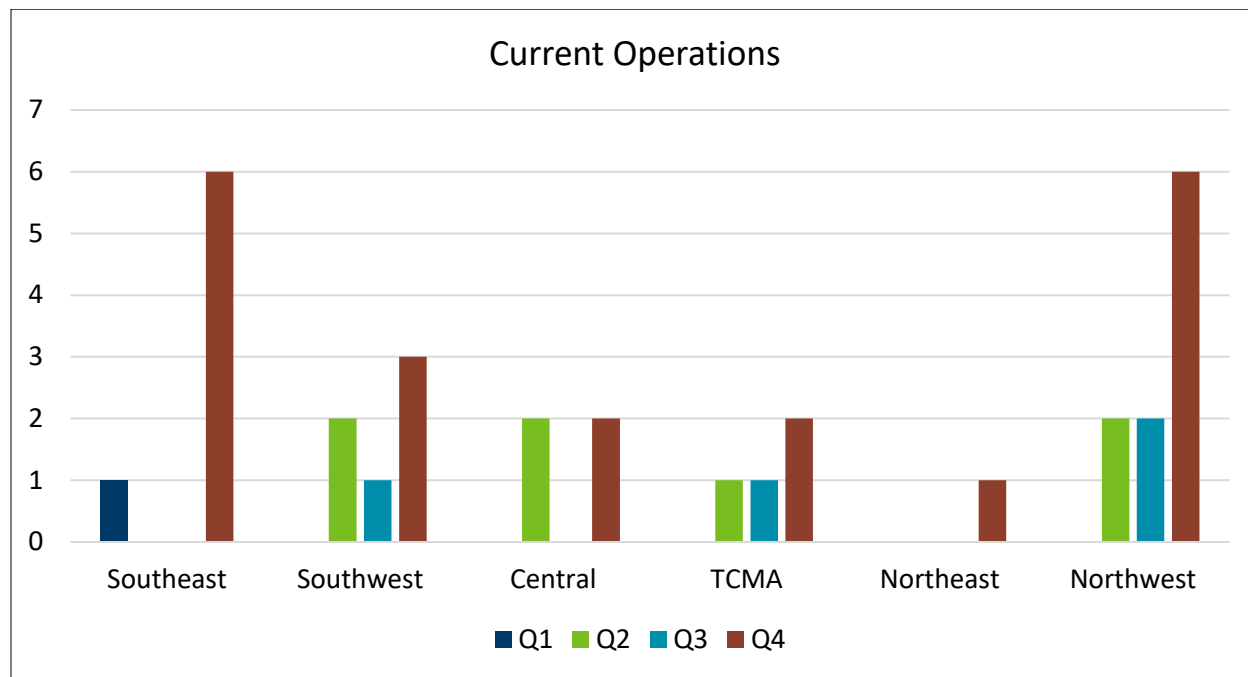


Figure 52. Sum of MSW and ash landfills, and WTE facilities per region by SVI quartile for scenario with WTE

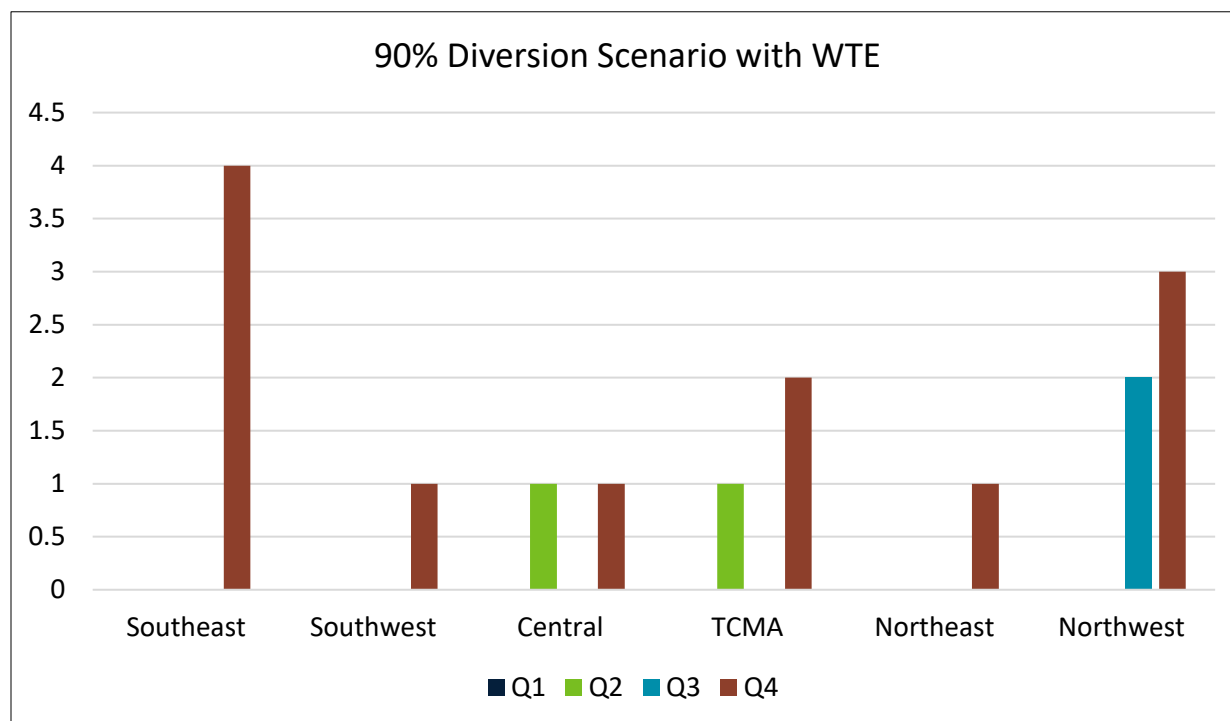
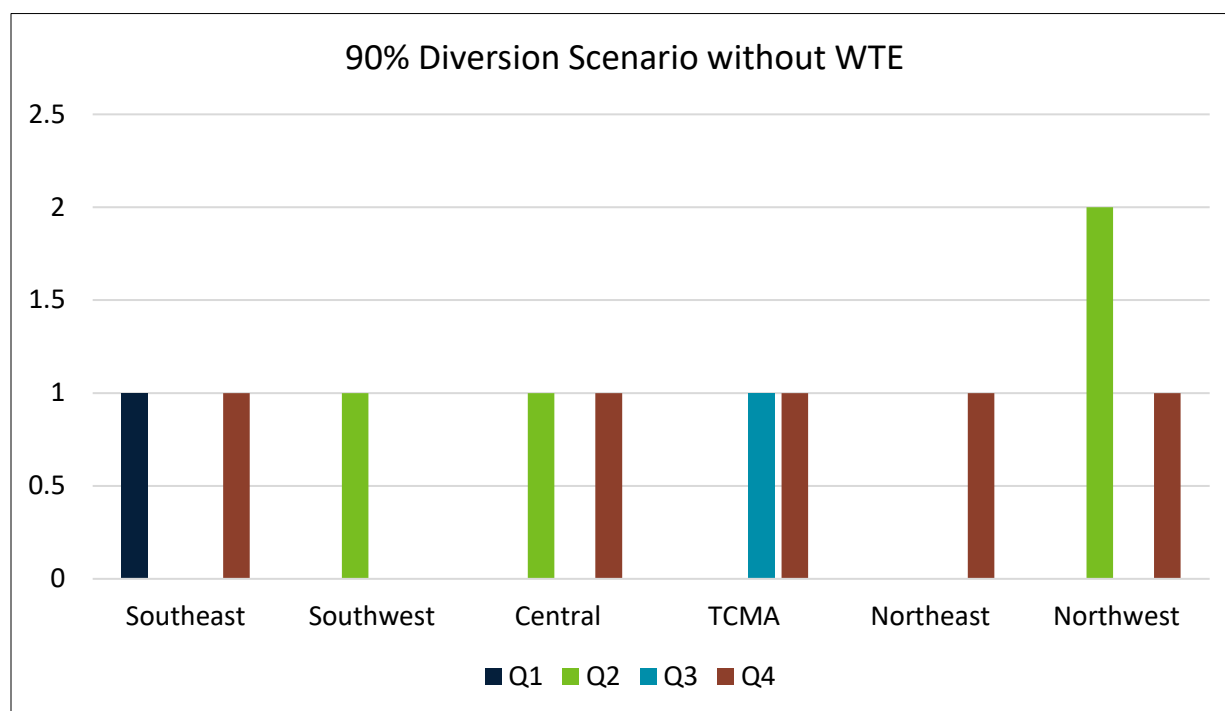


Figure 53. Sum of MSW and ash landfills, and WTE facilities per region by SVI quartile for scenario without WTE



Although more monitoring and analysis should be done near current and future facilities to assess true exposure, comparing scenarios with the assumption that each facility type has a similar exposure can help assess the most equitable scenario in terms of environmental justice. When comparing the total number of facilities for current operations and each diversion scenario per quartile, the scenario without WTE facilities operating reduces the exposure to 4th quartile populations at a greater rate than current operations of the diversion scenario with WTE facilities operating. This scenario also reduces the number of facilities in the regions with the highest number of facilities operating in 4th quartile communities, the Northwest region and the TCMA. This same scenario of no WTE facilities or ash landfills operating also has the most equal distribution of facilities operating in the 4th quartile across all regions of Minnesota, as well as the state as a whole. Therefore, the diversion scenario without WTE facilities and ash landfills operating may be the most equitable in terms of environmental justice and social vulnerability. However, monitoring potential exposures near the actual facilities may determine that certain facilities are of greater risk currently and could potentially shift the narrative.

Uncertainty & Limitations

The type of risk analysis that can be conducted for MSW facilities depends on the types and resolution of data available for each level of analysis. While screening-level analyses can be performed using available datasets, more precise evaluation of risk at a specific facility may incorporate additional, site-specific information. Data gaps, including limitations in the resolution, completeness, or consistency of some water and air monitoring data near MSW facilities, can limit the ability to perform more precise analyses to characterize risk at the facility level. The influencing factors discussed for each contaminant can affect exposure and potential health impacts, but without detailed information on those factors, risk cannot be quantified with a high degree of specificity.

All WTE facilities operate under air permits and may report air toxics emissions to the MPCA on a periodic basis, depending on applicable requirements. In contrast, fewer than 25% of landfill facilities have air permits and report air toxics emissions directly. For the remaining landfill facilities, air toxics

emissions are estimated using modeling approaches, with annual waste throughput serving as a primary variable that is then combined with atmospheric processes to form an air dispersion model.

These facilities may report emissions based on a combination of continuous emissions monitoring for certain pollutants, periodic stack testing, and emissions calculations using established methodologies. For pollutants that are not continuously monitored, emissions may be estimated using stack testing data, emission factors, or engineering calculations, depending on applicable regulatory requirements. This can include certain hazardous air pollutants (HAPs) where required, but not all air toxics are subject to reporting, and reporting obligations vary based on applicable state and federal regulations. These data reflect facility-specific information developed through regulatory testing and reporting processes.

Differences in how emissions data are generated across facility types result in varying levels of detail, frequency, and direct measurement, which affects the level of confidence in characterizing emissions.

The Minnesota Air Toxics Risk Screening tool (MNRISKS) displays the cumulative impact of air pollution across Minnesota. MNRISKS uses emissions data from multiple sources to estimate relative potential risk from the multiple sources. These risk values are then summed at the census block group level to display the cumulative air impacts. Emissions from WTE and landfill facilities can be incorporated into the tool to estimate relative risk levels associated with those sources. However, these estimates rely on emissions data reported to or estimated by the MPCA and are therefore dependent on the accuracy, completeness, and methodological assumptions of those data. Because of these limitations and the lack of detailed site-specific inputs, MNRISKS is most appropriately used as a screening-level tool to identify potential areas of concern rather than to quantify facility-specific risk.

A more refined, site-specific evaluation of air emissions risk may be conducted using detailed air dispersion and risk assessment methods (referred to here as Air Emissions Risk Analysis, or AERA). These analyses are not defined in rule but represent a higher-resolution approach that incorporates site-specific information, such as emission rates, stack characteristics, and meteorological conditions, to estimate concentrations of air toxics near a facility. These concentrations can be used to estimate risk levels at a facility and evaluate both inhalation and multipathway exposure risks.

For both WTE and landfill facilities, approximately 21% have completed an AERA, with most conducted in the early 2000s. Because many of these assessments are now several decades old, they may not reflect current facility operations or emission control technologies. Given the limited number of completed AERAs and the reliance on MNRISKS as a screening tool, quantifying and comparing risk from individual WTE or landfill facilities remains challenging.

MNRISKS and higher-resolution air dispersion and risk assessment methods (referred to here as AERA) are focused on air emission impacts and do not evaluate potential impacts from water discharges or climate-related effects. These approaches support different levels of analysis, with MNRISKS used for screening-level evaluation and more detailed methods applied in limited cases where sufficient site-specific data are available. In practice, both approaches are not typically available for the same facility. Differences in data type, resolution, and availability influence the level of precision that can be achieved.

For landfills, groundwater monitoring systems and other permit-required data collection provide important information about environmental conditions at and around facilities. However, more refined characterization of contaminant prevalence and exposure potential would require additional site-specific information, such as higher-frequency groundwater monitoring, expanded analyte coverage, or improved linkage between environmental concentrations and exposure pathways. The availability of these data is variable and may be limited by existing monitoring requirements and resource constraints. Landfill characteristics such as age, capacity, liner systems, cover types, and proximity to receptors are generally available through permits and reporting, but not all data needed for higher-resolution analysis are consistently available in a form that supports direct comparison or modeling across facilities.

For WTE operations, facility-specific risk assessments such as AERAs can be conducted using available data. Annual emissions totals alone may not fully capture differences in concentration or short-term variability that can influence potential health impacts. Key inputs for dispersion modeling, such as emission rates, stack parameters, control technologies, and meteorological data, are available for many facilities through permitting, reporting, and prior analyses. The model can account for temporal resolutions such as hourly variability or seasonal variability at a facility.

There are limited studies investigating health impacts specifically associated with WTE facilities, as most research focuses on general waste incineration. Only two studies were identified that directly evaluated populations living near WTE facilities. While factors such as facility age and pollution control technologies are discussed in the literature, specific design and operational details are often not included, limiting the ability to draw conclusions about modern facilities. It is also unclear whether limited evidence of health impacts reflects reduced risk due to improved technology or insufficient time for long-term effects to be observed. Studies often do not distinguish between facility types, feedstocks, or combustion technologies.

Taken together, the ecological and human health effects described in this report are supported by a broad body of scientific literature, although the strength of evidence varies across contaminants and exposure pathways. Strong evidence exists for well-characterized contaminants such as nutrients, metals, PFAS, and certain air toxics, where exposure pathways and associated effects are well established. Moderate evidence supports the relevance of these pathways across Minnesota-specific settings, although the magnitude of impacts may vary by location and facility conditions. For emerging contaminants and less-studied pathways, available evidence is more limited and reflects evolving scientific understanding.

Proper maintenance, monitoring, and occupational safety practices are recognized as important factors influencing exposure risk at MSW facilities. However, these operational variables are generally not captured in epidemiological studies, contributing to uncertainty in understanding facility-specific risks. Additionally, limited research is available on design and operational variables for MRFs and MWPFs, and occupational studies are often based on conditions outside the United States. Exposure pathways such as stormwater runoff are also difficult to isolate in existing studies, further contributing to uncertainty.

Further Assessment & Planning

To strengthen the risk assessment, long-term monitoring data is needed for surface water, groundwater, and air quality at and around all facilities. Monitoring near facilities that are in proximity to other sources of pollution, such as industrial facilities and urban areas, that may cause a compounding effect should be especially prioritized. Where feasible, biomonitoring of nearby populations and workers at MSW sites should be conducted to evaluate current contaminant prevalence and confirm exposure. This data should be compared to regulatory limits and guideline values identified in the HHRA to identify areas of elevated concern. In addition, results should be assessed alongside regional social vulnerability indices and ecological assessments to highlight areas where contaminants may migrate more readily.

The two diversion scenarios do not eliminate risk from MSW facilities but distribute risk differently across Minnesota's MSW infrastructure. Risk based on vulnerability of populations is most evenly distributed across the 90% diversion scenario compared to current operations.

All MSW facilities pose potential risks to nearby populations, as they can introduce a wide range of contaminants into air, surface water, groundwater, soil, vegetation, and livestock, each serving as an exposure pathway. While facility characteristics vary, the literature consistently indicates that MSW landfills, ash landfills, and WTE facilities historically present the greatest risks to human health. This is

largely due to the prevalence of specific contaminants of concern, the heightened difficulty of effective pollution control, and the severity of associated health impacts.

In contrast, MRFs, MWPFs, and SSOs are generally associated with lower population-level risks in the literature, aside from elevated risks to sanitation workers from biological exposures. Numerous influencing factors discussed in this report introduce uncertainty in assessing individual facility risks. For example, a well-maintained, modern WTE facility with stringent pollution controls may pose less risk than a poorly maintained MRF. The variability across studies and conditions results in contingent risk levels, meaning that eliminating a single facility type should not be assumed to consistently shift human health risks in one direction.

For future assessments, it is important to incorporate careful design, long-term planning, systematic monitoring, and targeted improvements, particularly for MSW landfills, ash landfills, and WTE facilities. These complementary measures can help reduce risk and positively influence any future scenarios envisioned for Minnesota's MSW infrastructure. The human health risk assessment should serve as a foundation for analyzing and prioritizing facilities, guiding the development of complementary measures, mitigation strategies, and scenario-specific actions.

Ecological Risk Potential Assessment

Overview

This assessment evaluates the potential for MSW infrastructure in Minnesota to affect sensitive ecosystems. Results highlight regions where facility density, contaminant pathways, and ecological sensitivity coincide, resulting in elevated ecological risk potential. Certain facility classes (e.g., waste-to-energy, MSW landfills, and ash disposal) consistently exhibit higher concern levels relative to other infrastructure types. Ecological receptors of particular sensitivity include groundwater-dependent ecosystems, trout streams, wetlands, and prairie potholes. These findings provide MPCA with preliminary indicators of where diversion, siting safeguards, and enhanced monitoring may be most protective of ecological integrity.

Problem Formulation and Methodology

Context and Scope

Ecological risk assessment (ERA) is a tool for identifying the potential for stressors associated with MSW management to adversely affect ecological receptors. This assessment was conducted at a screening level consistent with U.S. EPA guidance (1–3) and MPCA programmatic priorities. The analysis evaluates current and projected diversion scenarios (90% diversion scenario with Waste to Energy and a 90% diversion scenario without Waste to Energy facilities) using Minnesota planning regions to identify relative differences in ecological risk potential across the state. This work supports MPCA’s broader goals of sustainable materials management and environmental protection.

Municipal solid waste (MSW) management systems also contribute to climate change through greenhouse gas (GHG) emissions. Landfills are a significant source of methane, a potent GHG generated through the anaerobic decomposition of organic materials. Waste-to-energy (WTE) facilities emit carbon dioxide and smaller quantities of other GHGs during combustion. While modern landfill gas collection systems and energy recovery at WTE facilities can reduce net emissions compared to uncontrolled releases, MSW infrastructure remains a contributor to statewide GHG emissions and is an important consideration in long-term system planning.

Climate change may further influence ecological risk potential across Minnesota by modifying hydrological regimes, contaminant transport processes, and receptor sensitivity. Projected increases in precipitation intensity, seasonal drought variability, and rising temperatures have the potential to alter leachate generation rates, runoff connectivity, groundwater recharge dynamics, and dilution capacity in receiving waters. These changes may increase the likelihood of contaminant mobilization from MSW infrastructure and amplify stress on sensitive aquatic and wetland ecosystems, particularly groundwater-dependent systems. Although climate-related drivers were not explicitly modeled in this screening-level assessment, they are recognized as important contextual factors contributing to uncertainty and future risk.

Groundwater and surface water systems are among the most ecologically vulnerable components of Minnesota’s landscape. Their sensitivity stems from complex hydrological dynamics, limited capacity for rapid recovery, and the potential for long lag times between contaminant release and ecological response. Groundwater, in particular, exhibits heterogeneity in flow paths and residence times that can delay the manifestation of ecological effects for years or even decades (4,5). In some cases, persistent chemical loading or physical alterations, such as land subsidence, can result in irreversible degradation,

including species loss and long-term habitat alteration (6–8). These lag effects, combined with the potential for cross-boundary contaminant transport, complicate detection and management, underscoring the need for precautionary strategies in ecological risk assessment.

MSW facilities are a key anthropogenic source of stress to these systems. Landfills, waste-to-energy plants, composting operations, and materials recovery facilities all generate contaminants with the potential to migrate into groundwater and surface water. These include per- and polyfluoroalkyl substances (PFAS), volatile organic compounds (VOCs), metals and metalloids, nutrients, pharmaceuticals, and emerging pollutants such as microplastics and industrial additives (9,10). Many of these compounds are highly persistent, resistant to degradation, and mobile across hydrological boundaries, making them disproportionately consequential for aquatic and wetland ecosystems.

Freshwater and wetland systems across Minnesota, including coldwater trout streams, seepage lakes, calcareous fens, and riparian wetlands, depend on stable contributions of groundwater to maintain their structure and function (11–13). Collectively referred to as groundwater-dependent ecosystems (GDEs), these systems play critical roles in sustaining biodiversity, regulating water quality, and buffering hydrological extremes (14). Because groundwater and surface water are highly interconnected in Minnesota’s glacial and karst landscapes, degradation of groundwater quality or flow conditions can propagate downstream, impairing surface water quality, habitat integrity, and ecological function.

For these reasons, GDEs and hydrologically connected surface waters are treated as priority receptors in this assessment. The ecological risk framework developed here evaluates how scenario-based changes in Minnesota’s MSW infrastructure may alter contaminant exposure pathways, with the goal of identifying priority ecological concerns and informing future monitoring and management.

Method

Assessment Framework

Municipal waste facilities release a diverse suite of chemical contaminants, many of which exhibit high persistence, environmental mobility, and potential for ecological harm. To establish a defensible list of chemicals of potential concern (COPCs) for this analysis, we synthesized evidence from peer-reviewed research, EPA ecological risk frameworks, and Minnesota-specific documentation on solid waste facilities and water quality. Key references included MPCA’s *Closed Landfill Program* datasets, the *Evaluation of Emerging Contaminant Data at Solid Waste Facilities* (2020), the *Condition of Minnesota’s Groundwater Quality* report (2018–2023), Minnesota’s *PFAS Blueprint* (2021), and applicable state water quality standards under Minn. R. ch. 7050 and the Draft Water Quality Standards Work Plan (2025–2027).

Contaminants were prioritized using five screening criteria:

1. Association with municipal waste facilities: documented linkage to landfill leachate, ash residues, composting runoff, or WTE stack emissions.
2. Inherent toxicity to aquatic or wetland biota: established chronic or acute effects on fish, amphibians, invertebrates, or aquatic vegetation, as reflected in EPA ECOTOX endpoints or Minnesota Class 2 surface water standards.
3. Environmental persistence and mobility: demonstrated capacity to persist or migrate in soil, groundwater, or surface waters under Minnesota hydrogeologic conditions, with particular concern for PFAS, and chlorinated solvents.
4. Detection in Minnesota monitoring programs: confirmation in MPCA’s ambient groundwater monitoring network, Closed Landfill Program wells, or statewide surface water monitoring datasets.

5. Regulatory and emerging concern: inclusion in EPA or MPCA priority lists, current or proposed state water quality criteria, or recognition as contaminants of emerging concerns.

This structured approach ensured inclusion of both legacy contaminants with long-standing regulatory thresholds (e.g., arsenic, mercury, dioxins/furans) and emerging substances such as PFAS and 1,4-dioxane that are increasingly detected at Minnesota waste facilities.

For comparative analysis, prioritized COPCs were organized into seven groups based on dominant environmental behavior and exposure pathways: (1) hydrophilic organics (e.g., PFAS, 1,4-dioxane), (2) heavy and trace metals, (3) volatile organic compounds, (4) brominated flame retardants, (5) combustion byproducts (e.g., dioxins/furans, PAHs), (6) inorganic nutrients and ions, and (7) polymers and synthetic additives. Grouping contaminants in this way facilitated cross-facility comparisons and highlighted how chemical properties intersect with receptor vulnerability in groundwater-connected and surface water ecosystems.

To maintain transparency, Table 47 presents representative contaminants from each group alongside their potential exposure pathway. The complete inventory of COPCs, including CAS numbers and regulatory designations, provided in the Appendix B - Human Health and Cumulative Risks, summarizes the major contaminant groups included in the ERA, their regulatory anchors, and dominant exposure pathways.

Table 47. Contaminant groups of potential concern (COPCs) in Minnesota's MSW infrastructure

Contaminant group	Representative COPC	Regulatory context	Potential exposure pathways
Hydrophilic Organics	PFOA, PFOS, 1,4-dioxane, pharmaceuticals (carbamazepine, DEET)	EPA Health Advisories (PFOA/PFOS); MPCA Health Risk Limits (HRLs)	Leachate migration to shallow groundwater; surface water discharge
Volatile Organic Compounds (VOC's)	TCE, PCE, benzene, vinyl chloride	EPA MCLs; MPCA HRLs; EPA Priority Pollutants	Volatilization and groundwater infiltration
Heavy Metals	Lead, cadmium, arsenic, mercury, lithium	EPA MCLs; MPCA HRLs; EPA Fish Tissue Criteria	Leachate transport; ash runoff; atmospheric deposition
Brominated Flame Retardants (BFRS)	Polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD), tetrabromobisphenol A (TBBPA)	EPA Priority Pollutants	Leachate transport, groundwater infiltration
Combustion Byproducts (POP's& PAH's)	Dioxins/furans, pentachlorophenol, hexachlorobenzene, PAHs	EPA Priority Pollutants; MPCA Air Toxics; EPA Fish Advisories	Atmospheric deposition from WTE; ash storage runoff
Inorganic Nutrients & Ions	Nitrate, ammonia, phosphorus, chloride	EPA Nutrient Criteria; MPCA Impaired Waters List	Leachate, shallow subsurface flow, eutrophication pathways
Polymers & Synthetic Additives	Microplastics, DEHP, bisphenol A, polyethylene	Emerging MPCA monitoring interest	Runoff, wind dispersal, landfill leachate

Conceptual Site Model

A screening-level Conceptual Site Model (CSM) (Table 48) was developed to organize the relationships between municipal waste facility operations, contaminant groups, transport mechanisms, and sensitive

ecological receptors under Minnesota’s hydrogeologic context. Whereas the facility-based profiles (Section 2.1.1) describe site-specific exposure mechanisms and risk potential-influencing conditions.

The model identifies major contaminant groups associated with facility types, characterizes their potential environmental transport mechanisms, and highlights the receptors most likely to encounter exposure. Pathways are categorized as complete, potential, or site-specific, providing a consistent reference point for evaluating exposure completeness across the state.

Table 48. Conceptual site model of MSW-related contaminant pathways in Minnesota

Source type	Contaminant group	Primary transport mechanisms	Ecological receptors	Exposure pathway status
Landfill	PFAS, 1,4-dioxane, PPCPs	Leachate migration to shallow groundwater and discharge	Groundwater-fed wetlands, trout streams, seepage lakes	Complete
Landfill	Heavy metals (Pb, Cd, As, Hg)	Leachate transport, surface runoff	Sediment-dwelling invertebrates, amphibians, wetland birds	Complete
Landfill	VOCs (benzene, vinyl chloride)	Volatilization	Coldwater streams, amphibians, invertebrates	Complete
Landfill	Inorganic nutrients (NO_3^- , NH_4^+)	Leachate, shallow subsurface flow	Prairie wetlands, fens, eutrophication-sensitive systems	Complete
Landfill	Microplastics, phthalates	Leachate, runoff, wind dispersal	Invertebrates, fish, sediment grazers	Potential (limited data)
WTE	Dioxins, furans, PAHs	Atmospheric deposition, ash runoff	Wetlands, streambeds, benthic invertebrates	Complete
WTE	Heavy metals (Hg, Cd)	Air deposition, ash storage runoff	Fish, amphibians, wetland vegetation	Complete
WTE	VOCs (historical/incidental)	Stack emissions, leachate from ash landfills	Wetlands, GDEs	Potential (site-specific)
SSO	PPCPs, nutrients, phthalates	Leachate, runoff from organics piles	Wet meadows, riparian zones	Complete
MRF	Microplastics, VOCs, phthalates	Stormwater discharge, dust/airborne particulates	Urban-adjacent wetlands, invertebrates	Potential to Complete
MWP	PAHs, residual metals, plastics	Leachate from ash/char piles, emissions runoff	Benthic invertebrates, groundwater-fed systems	Complete (data limited)

Model Design and Approach

This assessment applies the EPA ecological risk assessment (ERA) framework (1,2) and adapts it for a statewide, scenario-based screening design. Screening-level ERAs are intended to provide transparent and precautionary evaluations in contexts where detailed fate-and-transport modeling is constrained by data availability and assessment scale, but where comparative insights are needed to inform planning and management decisions (15). The present analysis emphasizes a representative subset of contaminants with demonstrated associations to Minnesota’s MSW infrastructure, ensuring ecological

risk potential is characterized in a manner that is both tractable and relevant. Although not exhaustive, this targeted contaminant list captures pollutants most likely to influence aquatic and wetland ecosystems under alternative diversion and disposal scenarios, thereby maintaining validity for decision-making.

Risk characterization was structured within a Pressure $\times$ Exposure $\times$ Vulnerability ($P \times E \times V$) modeling framework as seen in Figure 54. This composite approach integrates: (i) facility-level pressure (waste intensity and operational characteristics), (ii) exposure potential (hydrological transport and environmental pathways), and (iii) receptor vulnerability (ecological sensitivity, rarity, and dependence on groundwater/surface water systems). Multiplicative models of this type are widely applied in ecological assessments because they reflect the principle that risk is most consequential when anthropogenic pressure, transport pathways, and sensitive receptors co-occur (Vörösmarty et al. 2010; Suter 2016). By structuring risk potential as the product of interacting dimensions, the model reduces the likelihood of overstating hazard in situations where one factor is elevated but others are minimal (e.g., high facility throughput in landscapes of comparatively low ecological sensitivity).

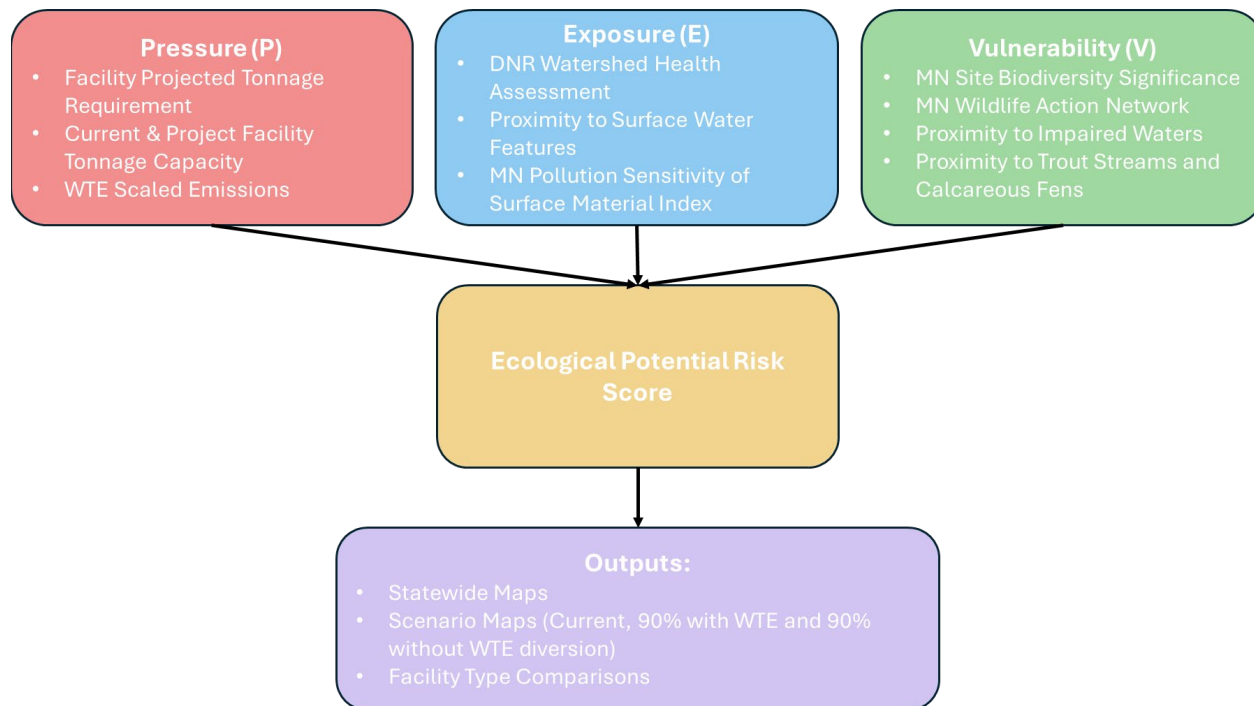
Pressure (P): Represents the relative intensity of waste handling and emissions, normalized to a 0–1 scale under each diversion scenario. Annual throughput (tonnage) provides the baseline proxy for facility pressure, supplemented by waste stream characteristics (e.g., mixed MSW, organics, biosolids) that influence contaminant profiles. For WTE facilities, reported stack emissions (e.g., metals, dioxins/furans) are incorporated to capture direct release potential. These variables reflect both the scale and contaminant intensity of MSW operations.

Exposure (E): Captures the likelihood of contaminant transport to ecological receptors, using spatial indicators such as the Watershed Health Assessment Framework (WHAF) Hydrology Component Score, proximity to surface waters, wetlands, and streams, and the WHAF Hydrological Component Score's pollution sensitivity of surface-materials. These factors represent hydrological connectivity and infiltration potential, key drivers of ecological exposure. The layers were rasterized and normalized to create a composite exposure surface, with higher scores reflecting greater transport potential.

Vulnerability (V): Reflects the ecological sensitivity and conservation value of receptors near each facility. Input datasets include Minnesota Wildlife Action Network (WAN) biodiversity rankings, Minnesota County Biological Survey (MCBS) sites of biodiversity significance, designated trout streams, and mapped calcareous fens and groundwater-dependent ecosystems and proximity to impaired surface waters. These features represent habitats and species assemblages with high conservation value and low tolerance to chemical or hydrological stressors (Suter 2007). Higher vulnerability scores indicate systems where even modest exposures may result in disproportionate ecological impacts.

The resulting composite risk potential index highlights areas of relative ecological concern. This approach is precautionary, making it well-suited for planning-level assessments that compare statewide waste management scenarios and inform long-term ecological risk potential mitigation. A full list of datasets and layers can be found in Appendix B - Human Health and Cumulative Risks.

Figure 54. Conceptual framework of the ecological risk potential modeling approach



Analysis

Exposure Assessment

The assessment characterizes how contaminants associated with Minnesota’s MSW infrastructure may reach ecologically sensitive receptors. The objective of this assessment is not to attribute observed effects to individual facilities, but rather to identify potential areas of concern where scenario-based changes in waste management could increase exposure potential across the landscape. This spatially explicit approach highlights priority zones where monitoring, mitigation, or site-level evaluation may be warranted, while also establishing the linkage between facility operations, contaminant transport mechanisms, and ecological vulnerability.

Facility-based Exposure Pathways

Table 49 below characterizes the primary MSW facility types operating in Minnesota in terms of their typical contaminant profiles, potential exposure pathways, and infrastructure conditions that influence environmental release. Each facility type presents distinct potential exposure risks based on its operational design, waste inputs, and hydrologic setting. By linking contaminants of concern to key release mechanisms, the table supports a comparative understanding of how different components of the MSW system may contribute to contaminant mobility in surface and groundwater systems. These facility profiles synthesize key aspects of the exposure evaluation and provide a foundation for identifying potential infrastructure-related drivers of ecological risk across the state.

Table 49. Facility-based exposure profiles for Minnesota MSW infrastructure

Facility type	Likely contaminants of concern	Dominant exposure pathways	Risk-influencing facility conditions
Landfill	PFAS, heavy metals VOCs, Nutrients, pharmaceuticals, chloride	Leachate infiltration through compromised liners ; surface runoff during precipitation or	Aging liner systems, unmonitored closed landfills, variable waste age and redox phases, shallow

Facility type	Likely contaminants of concern	Dominant exposure pathways	Risk-influencing facility conditions
		snowmelt; volatilization of VOCs and ammonia (18,19)	unconfined aquifers, seasonal freeze-thaw degradation
WTE	Dioxins, furans, PAHs, mercury, cadmium, metals	Atmospheric deposition of stack emissions; leachate and runoff from ash storage (fly ash, bottom ash) (20,21)	Legacy ash monofills without containment, outdated air pollution controls, proximity to surface waters, winter inversion conditions
Ash landfill	Heavy metals, dioxins/furans, PAHs, chloride, sulfate, trace PFAS	Leachate generation and infiltration to shallow groundwater; surface runoff and erosion of ash particulates; wind dispersion of dry ash fines (20,21)	Unlined or legacy ash monofills; exposed ash surfaces; permeable sandy or karst substrates; shallow groundwater tables; proximity to wetlands or surface waters; freeze-thaw cracking of cover materials
Composting Facility	Nutrients, pharmaceuticals, microplastics, persistent organic additives	Leachate seepage into permeable soils; stormwater runoff; volatilization of ammonia and VOCs; particulate drift (22,23)	Open windrow systems, biosolids acceptance, lack of impermeable pads or runoff diversion, proximity to riparian zones
Transfer Stations & MRF	Heavy metals, VOCs (benzene, toluene), nutrients, phthalates, plastic particulates	Stormwater discharge from uncovered tipping floors; airborne dispersion of contaminated dust; incidental spillage or leachate runoff (24,25)	Unenclosed operations, inadequate wash water capture, lack of vegetative buffers, aging infrastructure with high impervious surface coverage (MPCA 2023).
Mixed-Waste Processing / Pyrolysis	PAHs, unreacted synthetic polymers, trace metals, halogenated organics	Leachate from exposed ash/char storage; emissions from feedstock heating; runoff from unlined processing areas (26)	Limited emissions data, inconsistent process controls, on-site residue accumulation, siting on sandy or karstic substrates

Exposure Potential from Infrastructure Conditions

While the scale and persistence of exposure vary by facility type, the cumulative ecological burden of Minnesota’s MSW infrastructure is shaped by the interaction of facility operations, contaminant mobility, and the susceptibility of surrounding landscapes. These dynamics are reinforced by the ways contaminants move through hydrologic and ecological networks, linking waste-handling sites with sensitive receptors across surface and groundwater systems. The facility profiles outlined above illustrate recurring pathways of concern, including groundwater leachate migration, ash and stormwater runoff, and airborne deposition, each of which contributes to long-term ecological stress in hydrologically connected systems. Because facility-specific engineering features (e.g., liner presence, leachate system performance) were not uniformly available across the statewide dataset, this assessment does not differentiate exposure potential based on containment infrastructure. Instead, it uses facility type and landscape context to characterize risk in a precautionary manner.

Ecological Effects

Receptor Sensitivity and Vulnerability

Groundwater-connected ecosystems in Minnesota are treated as priority receptors in this assessment because of their ecological significance and heightened vulnerability to contamination from MSW-related activities. These systems, ranging from calcareous fens and groundwater-fed wetlands to coldwater trout streams, seepage lakes, and riparian wet meadows, exhibit hydrological and biological traits that both sustain biodiversity and increase susceptibility to stressors (6,11,27). Their reliance on consistent groundwater discharge, coupled with low buffering capacity and limited natural attenuation, makes them highly sensitive to persistent and mobile contaminants.

Ecosystems occur within distinct regions across Minnesota, each with characteristic vulnerabilities. In the karst landscapes of the southeast, rapid groundwater flow through fractures and conduits bypasses soil filtration, enabling direct contaminant delivery to springs and streams (28,29). In the central glacial outwash plains, sandy soils with high permeability permit rapid infiltration and little chemical attenuation (30). West-central prairie pothole wetlands, with long water residence times and limited flushing capacity, are prone to chronic nutrient and contaminant accumulation. Northern seepage lakes and coldwater headwater streams are sustained by groundwater inputs that regulate temperature and baseflow but are easily disrupted by chemical perturbations. Despite their regional differences, these systems share a functional dependence on groundwater that maintains ecological stability and resilience (31).

Groundwater-connected ecosystems support disproportionately high levels of biodiversity relative to their spatial extent (4). They provide critical functions including thermal buffering, baseflow regulation, nutrient cycling, and habitat provisioning for taxa sensitive to hydrological and chemical changes (14,32). Groundwater-connected ecosystems sustain rare or endemic species, such as brook trout (*Salvelinus fontinalis*) in coldwater streams and the state-threatened Kitten-tail (*Besseyia bullii*) in fen–prairie complexes and form ecological “nodes” that maintain connectivity across fragmented agricultural and urban landscapes (33,34,35). Many are recognized as conservation priorities, with calcareous fens protected under Minn. Stat. § 103G.223 and coldwater streams designated as Class 2A waters for aquatic life protection (36,37). Minnesota Biological Survey rankings further identify many of these areas as having “Outstanding” or “High” biodiversity significance.

The vulnerability of these systems is amplified by the contaminant profiles associated with MSW infrastructure. Mobile substances such as PFAS and VOCs can migrate long distances in groundwater, while metals, dioxins, and other hydrophobic organics persist in sediments and bioaccumulate through benthic food webs (9,10). Ecological receptors include sediment-dwelling invertebrates, amphibians, and fish reliant on stable groundwater discharge for spawning and recruitment. The persistence of contaminants such as PFAS and methylmercury, coupled with the low dilution capacity of fens, wetlands, and small streams, increases the likelihood of chronic exposure and population-level effects.

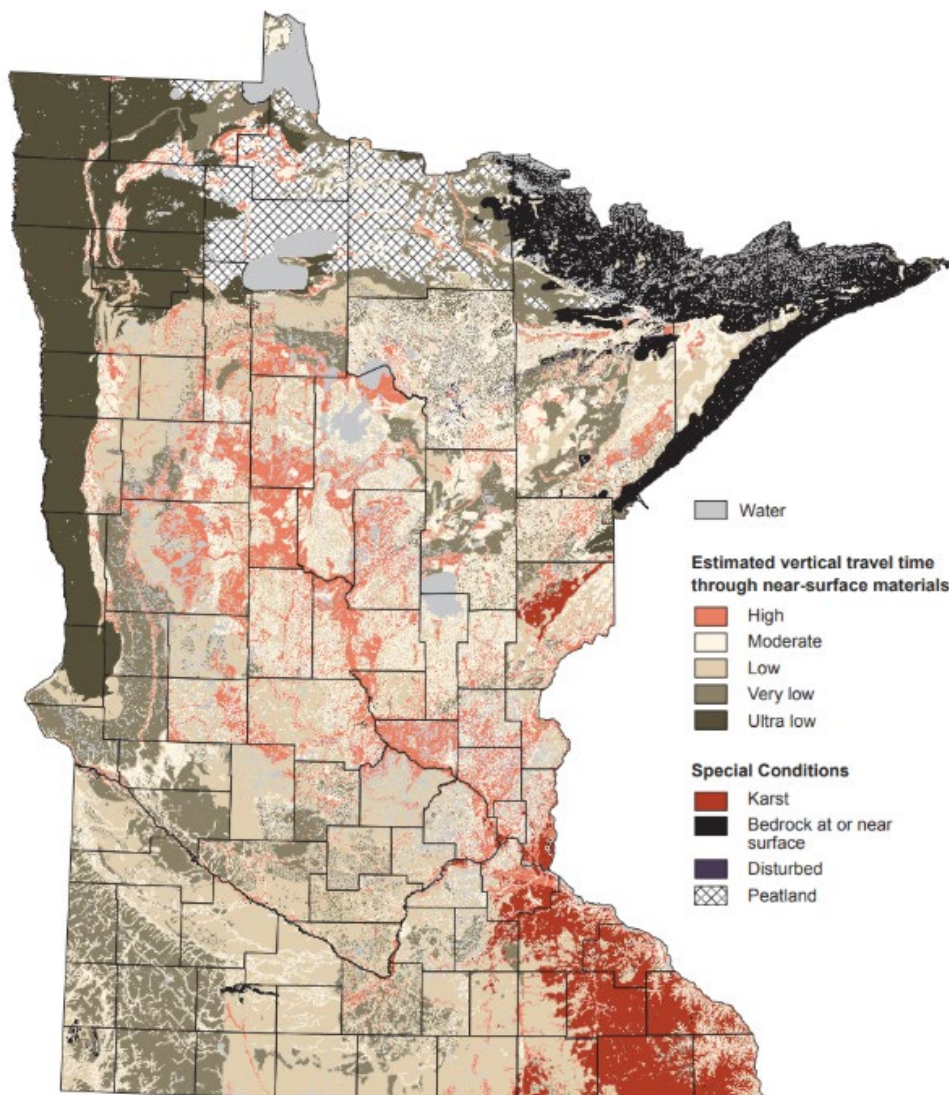
Hydrogeologic context is a critical determinant of ecological risk potential, as it governs the speed and extent of contaminant transport once released into the environment. As shown in Figure 55, Minnesota’s near-surface pollution sensitivity exhibits pronounced spatial variation, with estimated vertical travel times ranging from “ultra-low” in glacial till and peatland systems to “high” in areas underlain by karst and sandy outwash deposits (38). Regions dominated by karst bedrock in the southeast and coarse glacial outwash in central Minnesota are particularly vulnerable. In these landscapes, contaminants can infiltrate rapidly through fissures, conduits, or highly permeable substrates, bypassing attenuation processes and enabling direct connections between waste facility releases and aquifers, streams, or wetlands. Conversely, areas with thick till or peat layers exhibit slower infiltration and greater sorptive capacity, which can temporarily moderate contaminant mobility but

may still result in long-term accumulation. This hydrogeologic heterogeneity interacts with climate variability to amplify risk in sensitive settings. Periods of high precipitation can accelerate leachate migration through fast-draining soils, while drought and low-flow conditions reduce dilution capacity in receiving waters. The result is a landscape where ecological risk potential is unevenly distributed and strongly conditioned by substrate type and groundwater–surface water connectivity.

In addition to hydrogeologic variability, projected climate change across Minnesota may influence both contaminant transport dynamics and ecological receptor sensitivity. Regional climate projections indicate increasing frequency of intense precipitation events, greater seasonal variability in soil moisture and groundwater recharge, and rising surface water temperatures. These shifts may alter exposure pathways associated with municipal solid waste infrastructure by modifying leachate generation rates, surface runoff connectivity, and dilution capacity in receiving waters.

For example, high-intensity rainfall and snowmelt events may accelerate contaminant mobilization from landfill surfaces, ash storage areas, and waste handling infrastructure, particularly in landscapes characterized by permeable substrates or shallow aquifers. Conversely, drought conditions and reduced baseflow may increase contaminant residence time and concentration in groundwater-connected ecosystems such as calcareous fens, seepage wetlands, and coldwater streams. Elevated water temperatures may further modify species' sensitivity to chemical stressors by influencing metabolic rates, dissolved oxygen dynamics, and reproductive timing.

Figure 55. Pollution sensitivity of near-surface materials in Minnesota



Source:(38). Areas in red and orange denote substrates with high and moderate infiltration potential, such as karst and sandy outwash deposits, which pose potential elevated ecological risk when overlain by waste facilities due to rapid contaminant travel times through the substrate.

Monitoring programs underscore these vulnerabilities but also highlight data gaps. The Minnesota Department of Natural Resources' (MDNR) statewide pollution sensitivity model consistently identifies areas underlain by permeable substrates as highly vulnerable to groundwater contamination (38). The MPCA's Closed Landfill Program has documented contaminant detections, including nitrate, ammonia, chloride, and heavy metals, in downgradient wells and surface waters, confirming pathway completeness at numerous sites (39). Yet long-term ecological monitoring of discharge zones, residence times, and cumulative effects remains limited, constraining the ability to establish thresholds for sensitive taxa and ecosystems.

In summary, groundwater-connected ecosystems represent both ecological keystones and exposure interfaces in Minnesota's risk landscape. Their hydrological sensitivity, biodiversity value, and regulatory importance justify their prioritization in this assessment. Their proximity to MSW facilities, combined with documented contaminant detections and intrinsic vulnerability, necessitates their early inclusion in

risk screening frameworks. Protecting these systems is essential not only for sustaining rare and sensitive species but also for maintaining broader ecological integrity across Minnesota's landscapes.

Ecological Effects by Contaminant Group

The ecological risks posed by Minnesota's MSW system are best understood by examining contaminants not in isolation, but as classes defined by their shared behaviors in the environment. Grouping by fate, transport, and exposure potential allows patterns of ecological vulnerability to emerge that would otherwise remain diffuse. What follows is a series of contaminant group profiles that trace the pathways from facility release to ecological consequence. Each profile highlights how key chemical properties may intersect with Minnesota's hydrogeology and sensitive ecosystems, groundwater-dependent ecosystems, and considers the implications for receptor taxa across trophic levels. Taken together, these profiles provide a non-exhaustive but coherent picture of the contaminant pressures most relevant to present and future waste management scenarios.

Hydrophilic Organic Contaminants (e.g., PFAS, 1,4-dioxane, PPCPs)

Hydrophilic organic contaminants, including per- and polyfluoroalkyl substances (PFAS), 1,4-dioxane, and pharmaceuticals and personal care products (PPCPs), represent persistent ecological concern because of their solubility, mobility, and chronic biological activity. These compounds exhibit high water solubility and low sorption affinity, allowing them to bypass natural attenuation processes such as sediment binding and soil filtration, which makes them highly mobile in both groundwater and surface water systems (9,39). Within Minnesota's MSW system, PFAS and 1,4-dioxane are most strongly associated with landfill leachate derived from consumer products, plastics, and solvents, while PPCPs are released through leachate and stormwater runoff from composting facilities accepting biosolids, food waste, or compostable packaging (39,40). State monitoring confirms these pathways: detections of PFAS, 1,4-dioxane, and PPCPs have been recorded in downgradient wells, trout streams, and groundwater-fed wetlands (39,40,41). A notable example is the Washington County Landfill, a legacy unlined landfill and known PFAS disposal site, where PFAS have been detected in shallow aquifers hydraulically connected to wetlands and streams. These observations emphasize how leachate-borne contaminants can rapidly migrate through groundwater-dependent ecosystems in settings lacking modern containment and monitoring controls (42).

These hydrogeological connections make sensitive ecosystems such as calcareous fens, seepage wetlands, and coldwater streams disproportionately vulnerable. These systems rely on stable groundwater inflows and often have limited dilution capacity, meaning that even low-level chronic contamination can destabilize ecological function. Receptors within these habitats, amphibians, coldwater fish, and groundwater-dependent plant communities, exhibit narrow ecological tolerances and are particularly susceptible to pollutant stress (27). The persistence of hydrophilic organics ensures that exposure is continuous and cross-trophic, magnifying ecological consequences over time.

Ecotoxicological evidence highlights a range of chronic and sublethal effects. PFAS, particularly PFOS and PFOA, are strongly linked to thyroid hormone disruption, impaired reproduction, and immunosuppression in fish and amphibians (43). Pharmaceuticals such as gemfibrozil and norgestrel interfere with lipid metabolism and reproductive signaling pathways in fish, while anticonvulsants such as carbamazepine persist in aquatic environments and disrupt neural function in invertebrates at trace concentrations (44,45). Although many PPCPs are only moderately bioaccumulative, the persistence of inputs from MSW facilities results in chronic exposure scenarios. By contrast, PFOS is highly bioaccumulative and biomagnifies through aquatic food webs, with documented risks to piscivorous birds and mammals in the Upper Midwest (46,47). Mixture studies further suggest additive or synergistic effects between PFAS and PPCPs, amplifying ecological risks beyond those predicted for

single contaminants (48). Hydrophilic organic contaminants constitute a diffuse but persistent ecological stressor within Minnesota's waste system. Their widespread detection, biological potency at low concentrations, and potential for trophic transfer highlight the importance of accounting for leachate and runoff pathways in statewide screening.

Brominated Flame Retardants (BFRs)

Brominated flame retardants (BFRs), including polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD), and tetrabromobisphenol A (TBBPA), represent a class of synthetic halogenated organics used extensively in plastics, textiles, electronics, and building materials. Despite regulatory restrictions on certain congeners, particularly PBDEs, BFRs continue to circulate in Minnesota's waste stream due to their prevalence in older consumer goods, demolition debris, and discarded electronics (49). As such, landfills, waste-to-energy (WTE) facilities, and ash monofills remain ongoing point sources of BFR release.

The environmental behavior of BFRs is defined by their hydrophobicity, strong affinity for organic matter, and resistance to degradation. Partition coefficients (K_{ow}) ranging from approximately 5.1 for mono-BDEs to 8.7 for deca-BDEs indicate a strong tendency to bind to sediments and biota, facilitating persistence in benthic habitats and trophic transfer in aquatic systems (50). Within MSW infrastructure, landfill leachate provides a complete exposure pathway, particularly under conditions that mobilize hydrophobic organics (e.g., in the presence of surfactants or polymer degradation products) (51). Waste to energy processes contribute further through fly ash residues and atmospheric release of BFR-laden particulates, which may undergo regional or long-range transport before deposition into surface waters and wetlands (52).

Once in aquatic environments, BFRs accumulate in organic-rich sediments and enter food webs through benthic invertebrates, leading to biomagnification in fish, amphibians, and piscivorous birds. Ecological effects are diverse but are most strongly associated with endocrine disruption, particularly thyroid hormone dysregulation, and neurodevelopmental toxicity (50,53,55). Experimental and field studies demonstrate that PBDE exposure can impair growth, delay development in amphibians, and reduce reproductive success in fish (53,54). Invertebrate studies, though more limited, suggest impaired feeding and molting processes under environmentally relevant exposures. Long-term monitoring in the Great Lakes and Upper Mississippi basin has detected PBDEs in fish at concentrations associated with reduced hatching success, suppressed immune function, and altered behavior (55). These findings underscore the trophic-level consequences of BFR persistence, even in regions where production and use have been phased out. Minnesota's shallow wetland complexes, prairie potholes, and groundwater-fed streams are particularly vulnerable to BFR accumulation due to their high sediment organic content and limited hydrological flushing. These ecological settings favor long residence times and chronic exposure for sediment-dwelling organisms. Amphibians breeding in wetland habitats and coldwater stream fish species represent especially sensitive receptors, with risks compounded by the potential for mixture toxicity alongside other halogenated contaminants such as dioxins, PCBs, and PFAS (56).

Brominated flame retardants remain a persistent and bioaccumulative stressor within Minnesota's MSW system. Despite declining production of certain congeners, legacy inputs from demolition waste and electronics ensure continued relevance. Their strong sediment affinity demonstrated capacity for trophic transfer, and endocrine-disrupting effects at environmentally relevant concentrations make BFRs an enduring ecological concern. From a screening perspective, their significance lies in both legacy contamination risks and ongoing diffuse inputs, with sediment-rich aquatic systems and biodiversity-sensitive habitats likely to bear the greatest ecological burden.

Heavy Metals (e.g., lead, arsenic, cadmium, mercury)

Heavy metals, including lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), and lithium (Li), remain among the most consequential contaminant groups in MSW system. These elements are persistent and non-degradable, entering waste streams from common products such as batteries, electronics, treated wood, paints, and consumer packaging (57). Metals are mobilized primarily through landfill leachate, combustion residues (e.g., fly ash and bottom ash from waste-to-energy facilities), and stormwater runoff from transfer stations or MRFs. Waste to energy fly ash, in particular, is frequently enriched in cadmium and lead, while landfill leachate has been documented to contain dissolved and colloidal forms of arsenic, mercury, and chromium (57,58).

Environmental transport of metals occurs via multiple pathways, establishing complete linkages between MSW infrastructure and sensitive ecosystems. Potential leachate migration from landfill cells introduces dissolved metals into unconfined aquifers, a pathway of heightened concern in southeastern Minnesota's karst landscapes and shallow aquifer systems. Runoff and erosion from ash monofills may mobilize particulate-bound metals into surface waters, while atmospheric deposition of WTE emissions disperses metal-containing particulates across regional airsheds. The persistence and ecological consequences of these pathways are mediated by geochemical conditions; metals may sorb strongly to sediments and organic matter under oxidized, neutral pH conditions, limiting short-term mobility but increasing long-term accumulation. Conversely, acidic or reducing environments, common in anaerobic landfill zones, wetlands, and fens, enhance solubility and bioavailability. In such settings, microbial methylation of mercury produces methylmercury, a highly bioavailable form that biomagnifies through aquatic food webs (59,60).

Pathway completeness is reinforced by empirical monitoring. The MPCA's Closed Landfill Program has documented elevated concentrations of lead, cadmium, and arsenic in downgradient wells, sediments, and surface waters, frequently exceeding ecological screening values (39). Mercury contamination, including methylmercury, is well established in Minnesota surface waters, with fish tissue concentrations exceeding state and federal advisory thresholds even in remote lakes, demonstrating the diffuse nature of deposition (61). Similarly, lithium, an emerging contaminant associated with the rising disposal of consumer electronics and rechargeable batteries, has been detected in landfill leachate and downgradient monitoring wells within the Closed Landfill Program network (39). While ecotoxicological data remain limited, recent laboratory studies suggest lithium may impair growth and neuromuscular development in fish and aquatic invertebrates at sub-mg/L concentrations (62). Its recurring detection in Closed Landfill Program wells highlights that lithium is transitioning from an emerging issue to a measurable ecological risk factor in Minnesota's waste system.

The ecological effects of metals are diverse and extend across taxa and trophic levels. Cadmium and mercury disrupt osmoregulation, growth, and reproductive success in fish and amphibians, while methylmercury in particular impairs neural development and survival in piscivorous birds and mammals (62,63,64). Arsenic has been associated with developmental deformities and immunosuppression in amphibians (65), while hexavalent chromium (Cr(VI)) induces oxidative stress and tissue damage in fish and invertebrates(66). Sediment-dwelling invertebrates, such as amphipods, oligochaetes, and chironomids, are particularly vulnerable to benthic exposure, where metals accumulate in depositional zones.

Minnesota's ecological receptors most at risk include shallow groundwater systems, coldwater streams, and organic-rich wetlands, all of which provide limited buffering capacity and high receptor density. Prairie potholes and fens, in particular, create biogeochemical conditions that intensify metal solubility during anoxic events, exacerbating exposure during sensitive reproductive or developmental life stages. The persistence and potential for bioaccumulation further extend risk to higher trophic levels, including *Esox lucius*, *Sander vitreus*, various amphibian species, and wetland birds such as *Gavia sp.* and various

species in the family *Podicipedidae*. Heavy metals represent a class of non-degradable contaminants with multiple, well-documented exposure pathways linking MSW infrastructure to Minnesota's most vulnerable ecosystems. Their capacity for sediment accumulation, trophic transfer, and chronic toxicity across taxa justifies their prioritization in screening-level ecological risk assessment. The continued detection of legacy metals alongside emerging contaminants such as lithium underscores the dual challenge of addressing both historical waste burdens and evolving consumer trends within Minnesota's waste system.

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs), including benzene, vinyl chloride, dichloromethane, chloroform, and legacy chlorinated solvents such as carbon tetrachloride and trichloroethylene (TCE), are low-molecular-weight contaminants commonly associated with landfill gas, leachate, and WTE emissions. These compounds are characterized by high vapor pressure, moderate water solubility, and strong partitioning across air, water, and soil, allowing them to migrate readily between environmental media (67)

Release pathways from MSW infrastructure are well established. In landfills, decomposition of organic matter and breakdown of chlorinated solvents contribute to landfill gas formation, while VOCs simultaneously dissolve into leachate, enabling subsurface transport into aquifers. In WTE systems, stack emissions have been shown to release VOCs directly to the atmosphere, with some residuals concentrated in ash and subsequently mobilized through runoff or wind dispersal. Chlorinated VOCs such as TCE and carbon tetrachloride are particularly concerning because they may persist as dense non-aqueous phase liquids (DNAPLs), migrating vertically through fractured bedrock or sandy aquifers and bypassing engineered containment (68). Monitoring by the MPCA has confirmed VOC detections in groundwater downgradient of active and closed landfills (39).

Volatile organic compounds exert both acute and chronic toxic effects on aquatic organisms. Low-level benzene exposure (≈ 0.1 mg/L) has been shown to disrupt developmental processes in zebrafish, producing skeletal deformities and transcriptomic changes in neural and immune pathways (69). Chlorinated solvents further amplify ecological risk; dichloromethane and chloroform act as narcotics that impair locomotion and feeding, while TCE has been experimentally linked to developmental abnormalities in amphibian embryos (70). Such sublethal effects, including reduced growth, impaired reproduction, and altered behavior, can cascade through food webs, particularly in systems where organisms are already stressed by habitat loss or thermal shifts. Amphibians and benthic invertebrates are especially vulnerable due to their reliance on permeable integuments and close contact with sediment, where volatilized and dissolved compounds re-enter aquatic environments.

At the ecosystem level, repeated contaminant inputs, including VOCs, can suppress benthic macroinvertebrate richness and abundance, thereby reducing food availability for higher trophic levels (71,72). Amphibian deformities and reproductive failures can destabilize populations in vernal pools and riparian wetlands, while reduced fish fecundity may shift trophic structures in headwater streams and coldwater fisheries. These effects are amplified in groundwater-connected habitats such as calcareous fens, trout streams, and seepage wetlands, where limited dilution capacity prolongs exposure. Legacy chlorinated VOCs exacerbate ecological risk by degrading into even more toxic daughter products (e.g., TCE to vinyl chloride), prolonging ecological stress long after initial disposal. In Minnesota, regions with historical unlined landfills, sandy outwash deposits, or karst aquifers are of particular concern, as these hydrogeologic settings promote plume migration and vapor intrusion. Coldwater streams intersecting contaminated groundwater discharge zones represent some of the most plausible exposure pathways, especially during spring recharge when groundwater-surface water exchange is highest.

Combustion Byproducts and Polycyclic Aromatic Hydrocarbons (PAHs)

Combustion byproducts, including polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, and chlorinated aromatics such as pentachlorophenol (PCP), are generated during the incomplete thermal degradation of organic materials. These contaminants are closely associated with Minnesota's WTE incinerators, historical municipal incineration practices, open burning, and landfill fires. They share defining traits with other persistent organic pollutants; strong hydrophobicity, high lipophilicity, and resistance to environmental degradation, particularly under anaerobic conditions (59).

The dominant release pathways from MSW infrastructure include atmospheric emissions from WTE stack gases, deposition of particulate-bound contaminants onto soils and surface waters and leaching or erosion of residuals from ash storage sites. In older facilities with suboptimal combustion efficiency, emissions historically contained elevated concentrations of dioxins and PAHs. Once released, these compounds bind tightly to organic matter, black carbon, and fine particulates, leading to persistence in soils, sediments, and aquatic biota (73). Their transport is governed by particle deposition, with subsequent accumulation in depositional environments such as wetlands, streambeds, and lake sediments, where low oxygen and limited hydrologic turnover inhibit degradation and facilitate long-term sequestration (74). Stormwater runoff from ash monofills or eroded residuals represents an additional pathway to surface waters, particularly during high-flow or snowmelt events. Once incorporated into sediments, these compounds pose significant risks to benthic invertebrates and fish via dermal and dietary exposure (74). Biomagnification of dioxins and related congeners has been observed in aquatic food webs, resulting in elevated tissue concentrations in predatory fish and piscivorous birds.

The specific ecological effects differ by compound, yet they commonly converge in producing chronic stress on aquatic and wetland systems. PAHs such as benzo[a]pyrene induce CYP1a enzyme activity in fish, leading to oxidative stress, liver damage, disrupted steroid synthesis, and increased disease susceptibility (75). Amphibians exposed to PAH-contaminated sediments show reduced larval survival and developmental abnormalities, including limb malformations (76). Dioxins and furans exert toxicity primarily through aryl hydrocarbon receptor (AhR) activation, which alters gene regulation and disrupts developmental pathways. Early life stages of fish are particularly sensitive, with exposure leading to blue sac disease and high larval mortality (77).

Sediment-dwelling organisms, such as chironomids, oligochaetes, and mollusks, are especially vulnerable to combustion byproducts because of their prolonged contact with contaminated substrates. In Minnesota, prairie pothole wetlands, oxbow lakes, and low-flow coldwater streams represent high-concern receptors due to their depositional nature, organic-rich sediments, and limited capacity for dilution or flushing. Although regulatory controls on WTE emissions have substantially reduced atmospheric releases of dioxins and PAHs in recent decades, legacy contamination from ash storage and historical deposition persists in many urban and rural water bodies. The hydrophobicity, trophic transfer potential, and chronic ecological potency of these compounds underscore their relevance in screening-level ecological risk potential assessments.

Inorganic Nutrients (e.g., nitrate, ammonia, phosphorus)

Inorganic nutrients, including nitrate (NO_3^-), ammonium (NH_4^+), and phosphorus (PO_4^{3-}), are released from MSW infrastructure through the decomposition of organics, biosolid handling, and landfill leachate generation. While essential to biogeochemical cycling, excess inputs disrupt aquatic ecosystem structure and function, particularly in nutrient-sensitive systems common to Minnesota. The environmental fate of these compounds is shaped by their solubility and redox behavior. Nitrate is highly soluble and prone to leaching through coarse-textured soils, such as those in glacial outwash regions. Ammonium may

adsorb to soils under oxygenated conditions but is readily transformed to nitrate through microbial nitrification, increasing its mobility. Phosphorus, though often immobilized in oxygenated soils, can be released under anoxic conditions, especially in saturated landfill cells and wetland sediments (78). These dynamics establish persistent exposure pathways to surface and groundwater. Transport occurs via leachate infiltration, surface runoff from composting and landfill surfaces, and lateral groundwater movement into wetlands and streams. The MPCA's Closed Landfill Program has documented elevated nitrate and ammonia in downgradient wells and surface waters (39,42). Monitoring confirms complete exposure pathways across multiple facility types.

Ecological effects of inorganic nutrient vary by nutrient type and structure. Un-ionized ammonia (NH_3) is directly toxic to fish, amphibians, and invertebrates, causing gill damage, reduced growth, and reproductive impairment at concentrations found in leachate-affected waters (79). Nitrate contributes indirectly by fueling eutrophication and has been linked to endocrine disruption and altered oxygen transport in vertebrates (80). Phosphorus enrichment drives algal blooms, oxygen depletion, and shifts in community structure, with pronounced impacts in low-flushing ecosystems such as prairie pothole wetlands, seepage lakes, and groundwater-fed streams (81). These effects are compounded under multiple stressors, e.g., high temperatures, low dissolved oxygen, conditions increasingly common in shallow or confined systems. Chloride, often co-released with nutrients in leachate, can exacerbate stress by reducing survival and reproduction in zooplankton and benthic invertebrates at concentrations lower than those associated with road salt impacts (82).

Inorganic nutrients from MSW and associated facilities represent a complete and high-priority exposure pathway. They pose negative ecological effects both through direct toxicity (e.g., ammonia) and indirect ecosystem-level effects (eutrophication, hypoxia, altered community dynamics). Minnesota's wetlands, headwater streams, and closed-basin lakes are especially vulnerable due to their limited dilution capacity, reinforcing the need to integrate nutrient pathways into ecological risk potential screening.

Polymers and Microplastics

Polymers and microplastics are emerging contaminants of concern within Minnesota's MSW infrastructure, particularly in landfills, MRFs, and, to a lesser extent, composting and mixed-waste processing sites. These substances derive from the breakdown of packaging, textiles, containers, and other plastic-laden consumer goods. Microplastics may enter the environment directly as primary particles (e.g., resin pellets, synthetic fibers) or as secondary fragments formed through abrasion, UV weathering, and microbial degradation (83). Their environmental behavior is shaped by polymer type, particle size, and interactions with natural surfaces. Common plastics such as polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyethylene terephthalate (PET) are buoyant and chemically inert in freshwater but can undergo density shifts after sorbing metals or hydrophobic organics, altering their transport and fate (84). Surface runoff from uncovered waste handling operations, stormwater outfalls near MRFs, and leachate discharge from landfills represent the most likely transport routes. While vertical migration into aquifers is less well characterized, detections of microplastics in landfill leachate and downstream waters confirm plausible exposure pathways in hydrologically connected systems (85).

In aquatic environments, microplastics exert ecological effects through both physical and chemical mechanisms. Ingestion by invertebrates, fish, and amphibians has been linked to gut obstruction, reduced feeding efficiency, and impaired growth or reproduction. Benthic taxa such as amphipods, chironomids, and mollusks are especially vulnerable due to their feeding strategies and sediment contact. Ingested plastics also act as vectors, concentrating sorbed contaminants such as PAHs, flame retardants, and metals, thereby facilitating their entry into food webs (58). Biofilms and periphyton mats can further trap fine microplastics, altering microbial communities and primary production.

Plastic additives, particularly phthalates such as di(2-ethylhexyl) phthalate (DEHP), are co-released from MSW sources and amplify ecological risk potential. These hydrophobic plasticizers leach from flexible PVC, packaging materials, and degraded consumer plastics, entering surface waters and leachate streams. Phthalates are endocrine disruptors that interfere with hormone signaling in aquatic life, with effects including altered reproductive behavior, delayed development, and reduced fertility documented at environmentally relevant concentrations (86,87). Their frequent co-occurrence with microplastic particles strengthens the plausibility of combined stressor effects. Minnesota's small wetlands, drainage ditches, and shallow headwater streams are particularly susceptible to plastic-associated stress due to low dilution capacity and their proximity to waste handling sites. Sediment accumulation zones near MRF stormwater outfalls or landfill runoff channels provide plausible hotspots for exposure. Although monitoring data in Minnesota remain limited, national studies and field surveys in temperate regions suggest that microplastics and phthalates are already entering receiving waters adjacent to MSW facilities.

Polymers and microplastics, together with their associated chemical additives, represent a persistent and multifaceted stressor in Minnesota's aquatic systems. Their physical presence, role as contaminant vectors, and endocrine-disrupting additives establish complete and plausible exposure pathways, particularly in benthic and low-flow environments near MSW infrastructure. Their inclusion in ecological risk potential assessments is warranted given their persistence, trophic transfer potential, and cumulative contribution to aquatic ecosystem stress.

Ecological Risk Potential Characterization

Framing and Objectives

This ecological risk potential characterization applies a screening-level, spatially explicit framework to evaluate relative ecological effects associated with Minnesota's MSW system under two diversion scenarios (90% with WTE facilities & 90% without WTE facilities). The analysis integrates projected waste flows, facility locations, and ecological sensitivity indicators to identify where MSW infrastructure may contribute to elevated exposure potential for ecological receptors.

Consistent with U.S. EPA ecological risk potential assessment principles (1,2), the model emphasizes comparative, precautionary evaluation rather than absolute risk quantification. Results should therefore be interpreted as relative patterns of potential concern, designed to highlight priority regions, facility types, and ecological receptors for further monitoring or site-level evaluation.

Model Integration: Pressure x Exposure x Vulnerability (P x E x V)

The ecological risk potential index was derived from the integration of three dimensions described in Section 2: Pressure (P), Exposure (E), and Vulnerability (V). All sublayers were normalized to a 0–1 scale to enable comparability across heterogeneous datasets, following best practices in multicriteria ecological risk indicator screening (16,88)

The composite index was calculated as:

$$\text{Risk Potential Index (Ecological Concern)} = P \times E \times V$$

This multiplicative formulation reflects the principle that ecological risk potential is greatest when waste-handling intensity, plausible contaminant transport pathways, and ecologically sensitive receptors co-occur (88). Conversely, risk potential diminishes when one or more dimensions are absent, for example, a high-throughput facility in a landscape that is isolated from sensitive ecosystems. The multiplicative structure avoids overestimation of risk that can occur in additive models, where high values in a single dimension may mask the absence of others (15).

Risk potential scores were assigned at the facility level and aggregated by region and facility type to evaluate both current conditions and 90% diversion scenarios. This allows for identification of relative areas of ecological concern and assessment of how statewide patterns of ecological concern may shift under alternative waste management trajectories.

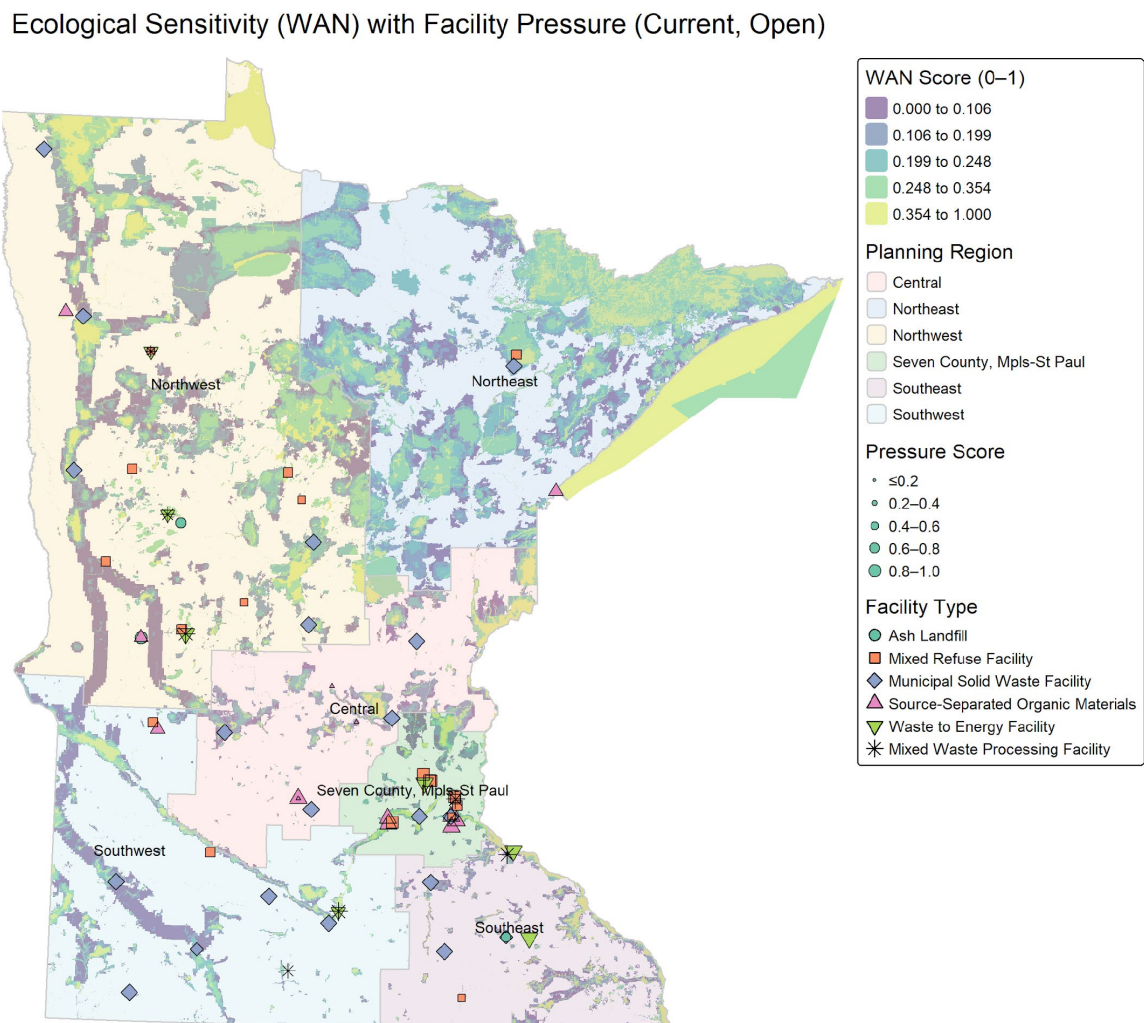
Statewide and Regional Patterns (Current Conditions)

Screening results under current conditions establish a comparative baseline for ecological concern across Minnesota's solid waste system. Results highlight how ecological concern emerges not only from facility density and throughput but also from the interaction of those pressures with hydrologically and biologically sensitive landscapes. This baseline provides the reference point against which diversion scenarios are later evaluated.

State Pattern

Figure 56 provides a statewide perspective by overlaying current MSW facilities on the Wildlife Action Network (WAN) ecological sensitivity surface. Darker shading reflects landscapes of higher biodiversity sensitivity (0–1), while facility symbols are scaled by throughput and differentiated by type. The map reveals distinct zones of elevated concern where high-throughput facilities coincide with sensitive ecological settings. Two regions stand out most clearly: the Southeast, where large landfills intersect karst terrain and shallow aquifers, and the TCMA, where WTE facilities and landfills are embedded within dense wetland and surface water networks. In contrast, facilities in the Central and Northwest are more often located in lower-sensitivity landscapes, suggesting comparatively reduced potential for ecological interaction.

Figure 56. Ecological sensitivity (WAN) with current open solid waste facilities



Regional Contracts

Disaggregating results by planning region (Table 50) highlights how ecological concern reflects the interaction of facility type, throughput, and landscape sensitivity. The Southeast emerges with the highest median ecological concern (0.53), a result of large MSW and ash landfills situated within karst terrain and groundwater-dependent ecosystems. Here, elevated pollution sensitivity (0.91 within 500 m) and MCBS vulnerability indices (0.60) amplify the risk potentials associated with leachate and contaminant transport through highly permeable hydrogeology. The TCMA follows with a median of 0.37 across 19 facilities. In this region, ecological concern is less about geology than about density: numerous facilities coincide with dense wetland and surface water networks (exposure median 0.73), creating an aggregate footprint where cumulative impacts are likely.

The Northeast, while home to only three facilities, records a comparatively high vulnerability index (0.75) due to the prevalence of MCBS-designated biodiversity landscapes, demonstrating how limited infrastructure can still yield elevated concern when placed in sensitive ecological contexts. The Northwest shows a moderate median score (0.31), but here concern is disproportionately shaped by the persistence of WTE and ash facilities embedded in otherwise less sensitive landscapes. These facilities contribute elevated concern scores despite the broader regional setting being comparatively less vulnerable.

By contrast, the Central region reports the lowest median ecological concern (0.25), with MSW and MRF facilities located in areas that overlap less frequently with sensitive ecological features. The Southwest presents an intermediate case, with a median of 0.32 driven by mixed facility types intersecting prairie pothole wetlands and surface waters.

These contrasts demonstrate that ecological concern at the regional scale is not simply a function of facility density, but rather the convergence of three potential regional drivers: vulnerable geology, as in the Southeast; cumulative facility density, as in the Metro; and persistent facility-specific pathways, as in the Northwest. This regional lens underscores how different mechanisms can elevate ecological concern.

Table 50. Regional summary of ecological concern drivers for current operations

Region	Facility count	Exposure driver	Exposure median	Vulnerability driver	Vulnerability median
Seven County Mpls-St Paul (TCMA)	18	poll_sens_exposure_500m	0.72	mcbs_vuln_combined	0.5
Northeast	3	whaf_exposure_3km	0.79	mcbs_vuln_combined	0.75
Southeast	9	poll_sens_exposure_3km	0.76	mcbs_vuln_combined	0.57
Northwest	22	poll_sens_exposure_500m	0.57	mcbs_vuln_combined	0.44
Central	8	whaf_exposure_3km	0.39	mcbs_vuln_combined	0.4
Southwest	11	poll_sens_exposure_500m	0.44	mcbs_vuln_combined	0.48

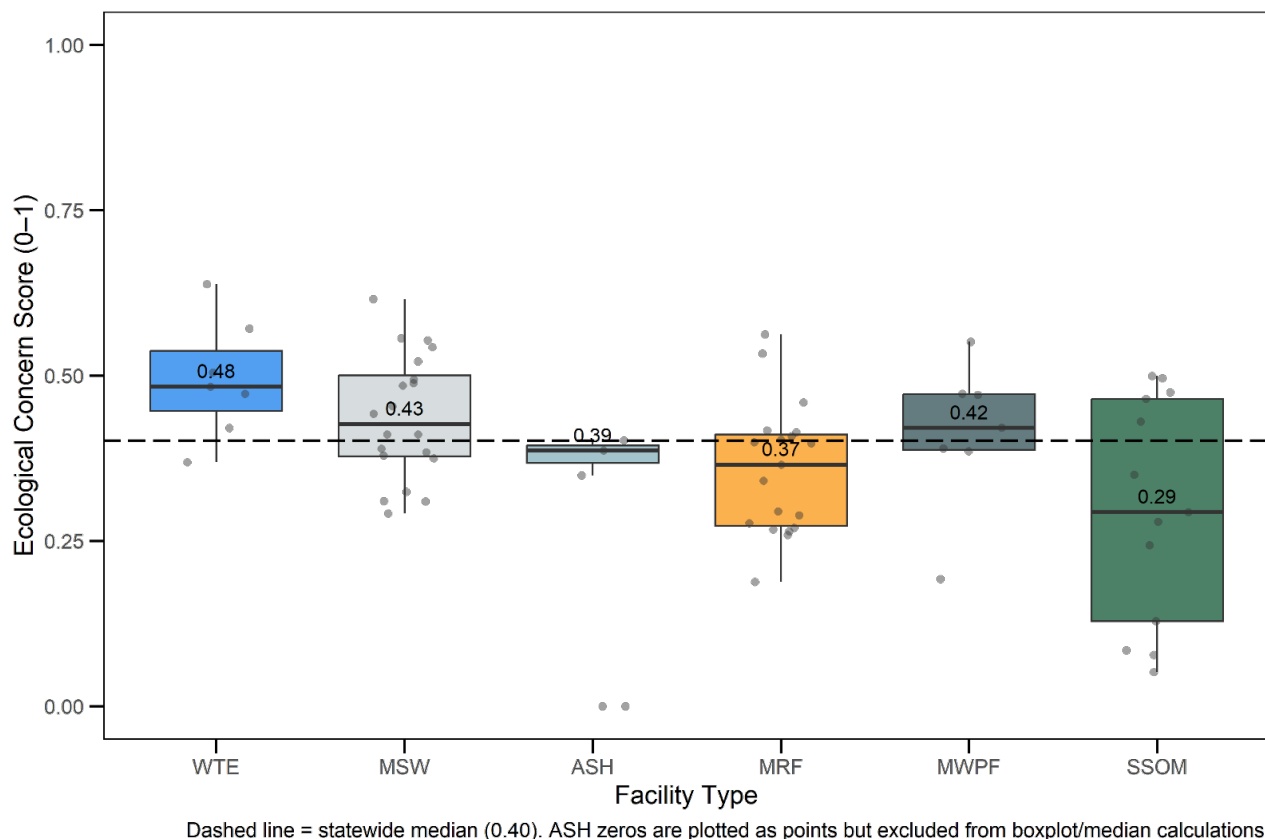
Facility Distribution

The boxplots of ecological concern scores by facility type (Figure 57) illustrate systematic differences in how facility classes interact with ecological sensitivity across Minnesota’s MSW infrastructure. Waste-to-energy facilities exhibit the highest median ecological concern (0.48) and a relatively narrow interquartile range, indicating consistently elevated scores across sites. This pattern suggests that WTE facilities tend to be associated with higher screening-level ecological concern irrespective of local siting variability, reflecting broadly distributed exposure potential interacting with regional ecological sensitivity rather than isolated site conditions.

Municipal solid waste landfills and mixed waste processing facilities (MWPF) occupy an intermediate tier, with median scores of 0.43 and 0.42, respectively. These facility types display greater variability than WTE facilities, indicating stronger dependence on site-specific context, including proximity to sensitive surface waters, wetlands, and groundwater-dependent ecosystems. Ash landfills cluster somewhat lower overall (median 0.38), with a compressed distribution reflecting fewer facilities and limited dispersion in ecological concern scores.

Material recovery facilities show a lower median ecological concern (0.37) but a wide range of values, indicating substantial heterogeneity across sites. This spread suggests that ecological concern for MRFs is highly context-dependent and driven more by surrounding landscape sensitivity than by facility type alone. Source separated organics management (SSO) facilities exhibit the lowest median concern (0.29), though with pronounced variability, reinforcing their generally lower screening-level interaction potential while highlighting isolated cases of elevated concern where facilities intersect sensitive ecological features.

Figure 57. Ecological concern scores by facility type for open facilities in Minnesota



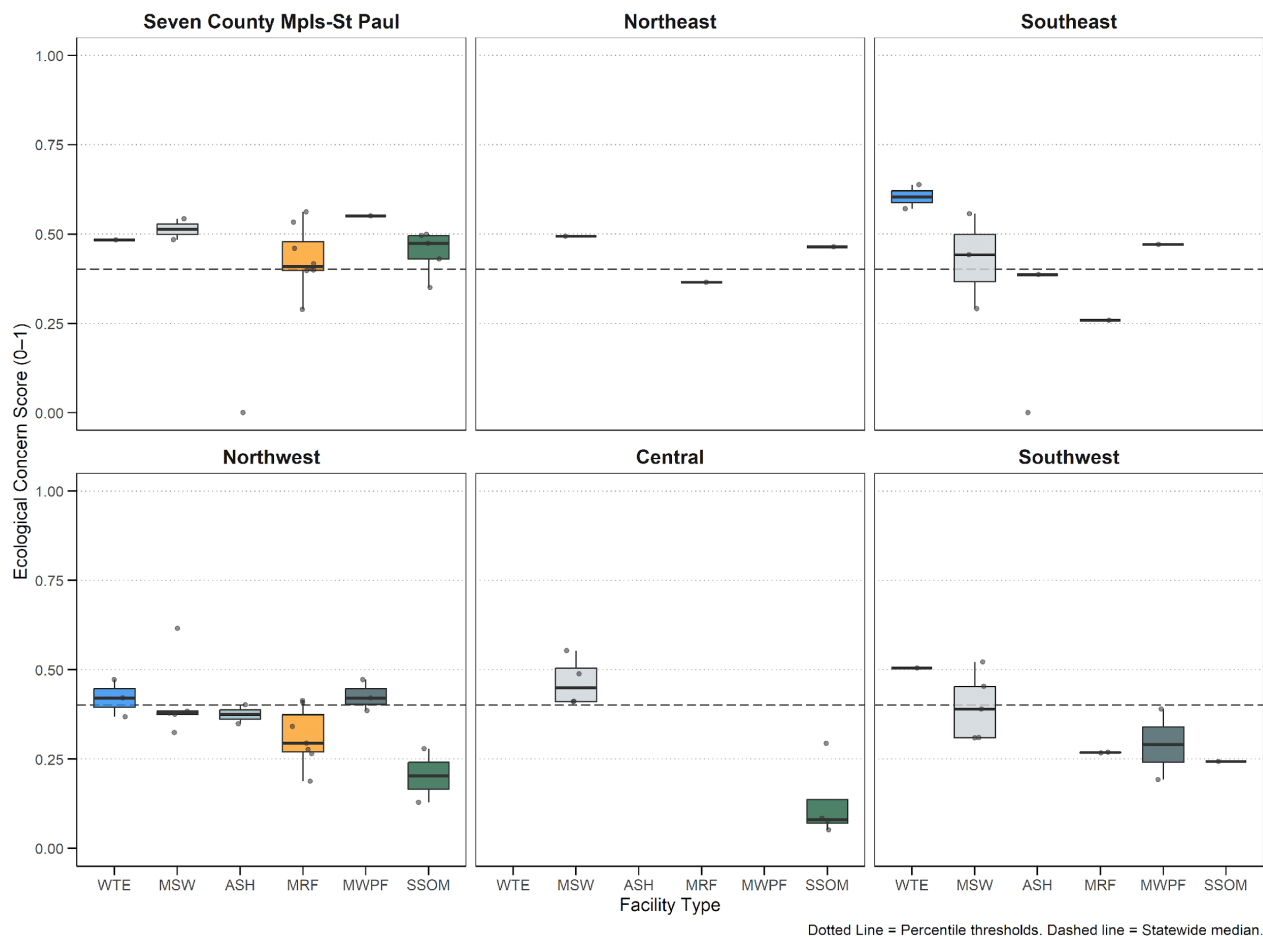
Boxplots show medians, interquartile ranges, and individual facility-level values.

Overall, these distributions indicate that facility type influences ecological concern but does not determine it in isolation. Combustion-related and landfill facilities tend to anchor the upper range of screening-level concern, while processing and materials management facilities display broader dependence on siting context. This pattern underscores the importance of integrating facility characteristics with spatial exposure and vulnerability metrics in statewide ecological screening.

Ecological concern scores by planning region (Figure 58) show how statewide facility-type patterns are moderated by regional landscape context. In the Southeast, MSW landfills consistently plot above the statewide median, with WTE and ash facilities also trending higher than in other regions, reflecting regional amplification of concern across multiple facility types. In the TCMA, facility types that are lower or more variable statewide, particularly MRF and SSO facilities, shift upward relative to the statewide median, highlighting the influence of cumulative facility density within dense surface water and wetland networks.

By contrast, facilities in the Southwest generally plot at or below the statewide median across most facility types, indicating weaker regional amplification of concern. The Northwest provides a distinct contrast, where WTE facilities remain consistently elevated relative to other facility types and the statewide median, suggesting that certain facility-specific exposure characteristics can sustain elevated concern even in regions with comparatively moderate background vulnerability.

Figure 58. Ecological concern scores by facility type and planning region



Scores range from 0 to 1. Dashed line denotes the statewide median. Single points indicate categories with only one facility in a region.

Table 51 highlights representative facilities that contribute most strongly to elevated ecological concern within each planning region under current diversion conditions. Facility-level scores presented here represent comparative indicators of ecological risk potential based on modeled pressure, exposure, and vulnerability conditions, rather than site-specific ecological risk determinations or evaluations of facility performance. Across regions, the highest concern scores are consistently associated with MSW landfills and WTE facilities, though the drivers of concern vary by regional context. In the Southeast and Metro regions, large MSW landfills and WTE facilities coincide with elevated exposure connectivity and sensitive surface water or wetland networks. In the Northwest, multiple WTE facilities exhibit elevated concern despite more moderate regional vulnerability, indicating the persistence of facility-specific exposure characteristics. In the Northeast, Central, and Southwest regions, facilities with more moderate operational profiles nonetheless register elevated concern where they intersect biodiversity-sensitive MCBS landscapes or hydrologically connected aquifer systems.

Table 51. High-risk potential facilities by region under current waste diversion conditions

Facility	Facility type	Ecological concern score (0–1)
Southeast		
Xcel Energy - Red Wing Generating Plant	WTE	0.66
Olmsted Waste-to-Energy Facility	WTE	0.54
Olmsted County - Kalmar Landfill	MSW	0.53
TCMA		
Pine Bend MSW Landfill	MSW	0.59
Burnsville MSW Landfill	MSW	0.54
Covanta Hennepin Energy Resource Co LP	WTE	0.52
Northeast		
Saint Louis County Regional Landfill	MSW	0.45
St Louis County Recycling Processing Facility	MRF	0.33
Western Lake Superior Sanitary District	SSO	0.21
Southwest		
Ponderosa MSW Landfill	MSW	0.46
Xcel Energy - Wilmarth Generating Plant	WTE	0.38
Redwood/Renville Counties MRF/Transfer Station	MRF	0.33
Northwest		
Crow Wing County Landfill	MSW	0.5
Pope/Douglas Solid Waste Management	WTE	0.44
Perham Resource Recovery Facility	WTE	0.44
Central		
East Central Solid Waste Commission	MSW	0.52
Elk River Landfill	MSW	0.5
Kandiyohi County MSW Landfill	MSW	0.37

Taken together, these results reinforce that ecological concern arises from the interaction between baseline facility risk potential and regional ecological context. Combustion and landfill facilities consistently anchor the upper range of concern, while processing and organics facilities generally remain lower but can contribute meaningfully where clustered within sensitive landscapes. This interaction is central to identifying cumulative screening-level hotspots where facility concentration and ecological sensitivity converge.

Cumulative Areas of Elevated Concern

Although the Risk Potential Index (Ecological Concern) evaluates facilities individually, cumulative ecological concern emerges where multiple facilities coincide with ecologically sensitive landscapes. This pattern is most evident in the TCMA, where MSW landfills, WTE facilities, and MRF's overlap with dense networks of wetlands and surface waters. In these settings, multiple exposure pathways, including leachate, stormwater runoff, and atmospheric deposition, co-occur within the same landscapes, increasing the potential for additive ecological stress.

In the Southeast, cumulative concern is driven by the placement of large MSW landfills within landscapes characterized by high hydrological connectivity and sensitive receptors, including shallow aquifers, trout streams, and groundwater-dependent ecosystems. These conditions increase

vulnerability by facilitating rapid contaminant transport and limiting natural attenuation. The Northwest represents a different cumulative pattern, where overall facility density is lower, but the persistence of WTE facilities results in localized areas of elevated concern associated with facility-specific exposure pathways.

Across the state, cumulative ecological concern reflects the interaction of three primary drivers: (1) landscape vulnerability, including karst aquifers and biodiversity-significant habitats identified by MCBS and related layers; (2) hydrological exposure pathways, such as streams, wetlands, and surface water networks that enhance contaminant transport; and (3) facility-specific contaminant profiles and release mechanisms. Where these drivers converge, ecological concern may exceed that expected from individual facilities considered in isolation, consistent with watershed-scale screening assessments that emphasize additive and interacting stressors (88).

As a screening-level analysis, cumulative impacts are interpreted qualitatively rather than quantified explicitly. Nonetheless, identifying areas of overlapping facility pressure and ecological sensitivity provides an important planning lens, highlighting regions where ecological monitoring, management, or mitigation may warrant prioritization. Waste to energy facilities emerge as a consistent contributor to elevated concern across multiple regions, reinforcing their relevance for MPCA's regulatory and planning considerations. This statewide baseline establishes a defensible reference for evaluating future conditions. Section 3.4 builds on this foundation by examining how alternative diversion scenarios redistribute ecological concern and modify interactions with sensitive ecological features.

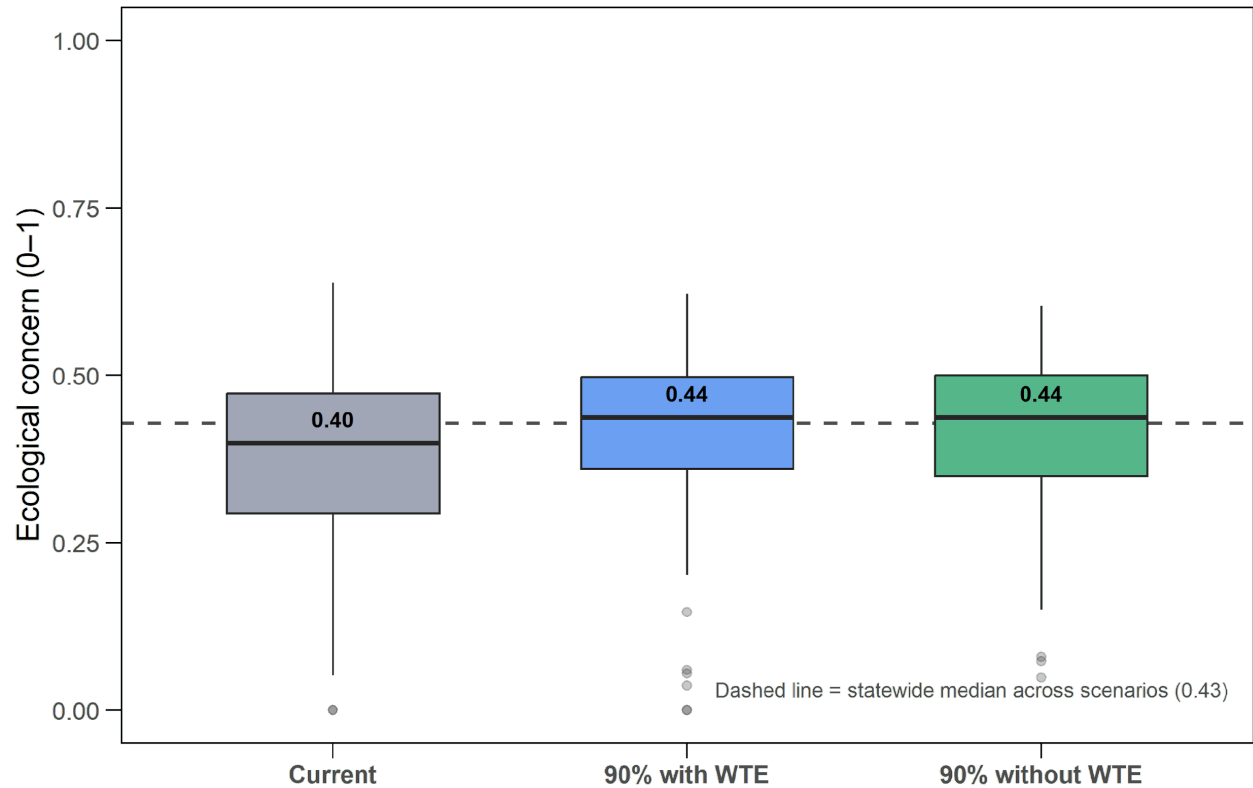
Scenario-Based Shifts (90% with WTE and 90% without WTE Diversion Futures)

Diversion scenarios provide a lens for understanding how Minnesota's solid waste system might reshape, not eliminate, ecological concern. Using the Risk Potential Index (Ecological Concern), which integrates facility pressure, hydrological exposure, and ecological vulnerability into a normalized score (0–1), we compared Current, 90% with waste to energy facilities, and 90% without waste to energy facilities diversion futures. The intent is not to quantify absolute ecological risk, but to provide a precautionary, comparative view of how system-wide changes in waste allocation alter the geography and composition of ecological concerns.

Shifts in Statewide Profile

Distributional patterns (Figure 59) indicate that statewide ecological concern remains broadly consistent across diversion scenarios, with only modest shifts. Median ecological concern increases slightly from 0.40 under current conditions to 0.44 under both 90% diversion scenarios, regardless of whether WTE capacity is retained. Summary statistics (Table 52) show limited changes in quartiles and overall range, with a modest increase in the proportion of facilities exceeding the statewide median under diversion scenarios. Collectively, these patterns indicate that diversion does not substantially reduce the overall magnitude of ecological concern at the statewide scale but instead redistributes and modestly intensifies concern across a larger set of facilities.

Figure 59. Ecological concern score distributions under current and modeled diversion scenarios



Includes current conditions, 90% diversion with WTE, and 90% diversion without WTE scenarios. Median values remain relatively stable, highlighting that statewide ecological concern is redistributed and moderately intensified statewide. Statewide median equates to 0.43.

Table 52. Summary statistics for facility-level ecological concern scores under diversion scenarios

Scenario	Count	Min	Q1	Median	Mean	Q3	Max	Percentage of facilities above state ecological concern median (%)
Current	71	0.00	0.29	0.40	0.38	0.47	0.64	36.62
90% with WTE	94	0.00	0.36	0.44	0.41	0.50	0.62	56.38
90% without WTE	89	0.05	0.35	0.44	0.42	0.50	0.60	53.93

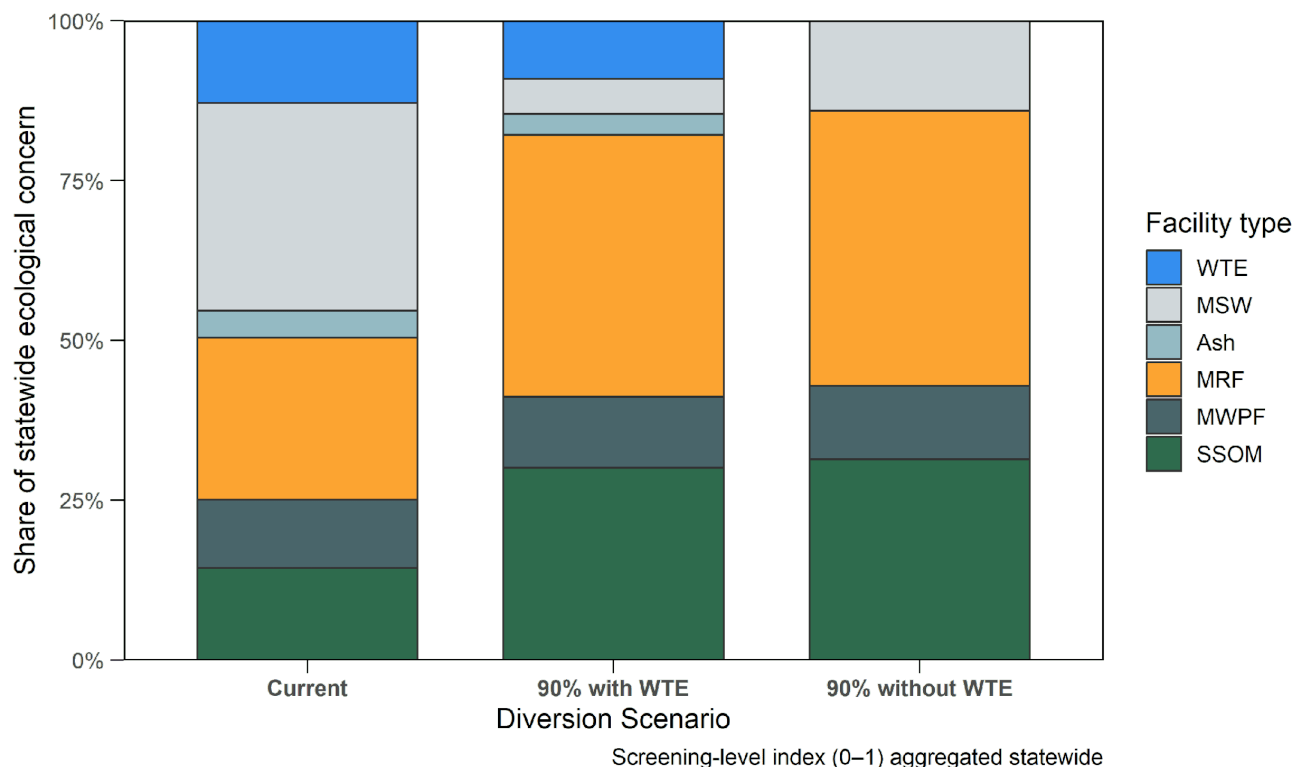
The similarity between the 90% diversion scenarios, with and without WTE, further suggests that changes in ecological concern are driven less by the presence or absence of specific facility classes and more by how waste volumes are reallocated across the system. As throughput is redistributed, ecological concern becomes more evenly shared among facilities, resulting in reduced variance and fewer extreme low-concern sites rather than a downward shift in statewide risk.

These shifts in statewide distributions are accompanied by a redistribution in the composition of ecological concern across facility types. As diversion intensifies, the relative contribution of WTE facilities to statewide ecological concern declines, while the share associated with MSW landfills and SSO facilities increases (Figure 60). This pattern reflects changes in throughput allocation rather than a uniform reduction in ecological interaction potential.

Landfills remain persistent contributors to ecological concern under all scenarios, particularly where facilities are situated in karst or shallow aquifer settings. In these contexts, leachate-related exposure pathways, including PFAS, nutrients, metals, and other mobile contaminants, interact with hydrologically connected systems, increasing the potential for transport to groundwater-dependent ecosystems, springs, fens, and trout streams (40, 41, 42). As diversion increases landfill reliance, these pathways account for a larger share of the statewide ecological concern profile.

Source separated organic waste and MRFs, while generally exhibiting lower concern on a per-facility basis, also contribute incrementally under higher diversion scenarios. Their relative influence increases as processing volumes expand and clustering of facilities, with ecological outcomes strongly mediated by siting, stormwater controls, and operational management. Screening-level concern at these facilities is primarily associated with nutrient-rich runoff, localized sediment and dust mobilization, and proximity to wetlands or surface waters. Poorly managed SSO facilities, in particular, have been associated with localized eutrophication and oxygen depletion in adjacent wetlands (89).

Figure 60. Statewide ecological concern by facility type under current and modeled diversion scenarios



Includes current conditions, 90% diversion with WTE, and 90% diversion without WTE scenarios.

Diversion reduces the prominence of WTE pathways while increasing the contribution of landfill- and SSO-linked risk.

Taken together, Figure 59 and Figure 60 indicate that diversion scenarios do not substantially reduce the statewide magnitude of ecological concern but instead reallocate concern across facility types and exposure pathways. Combustion-related contributions decline, while waterborne and nutrient-mediated pathways become more prominent. From a screening-level perspective, diversion therefore represents a rebalancing of Minnesota’s ecological risk potential profile rather than a net reduction, with implications for which ecosystems are most likely to experience elevated concern under future waste management configurations.

Regional Redistribution of Concern

Statewide summary metrics mask important regional variation in how ecological concern responds to diversion. The regional maps illustrate how the two 90% diversion scenarios redistribute ecological concern across Minnesota’s ecological landscapes relative to current conditions. Although statewide medians remain similar across scenarios, these maps reveal pronounced shifts in where concern is expressed.

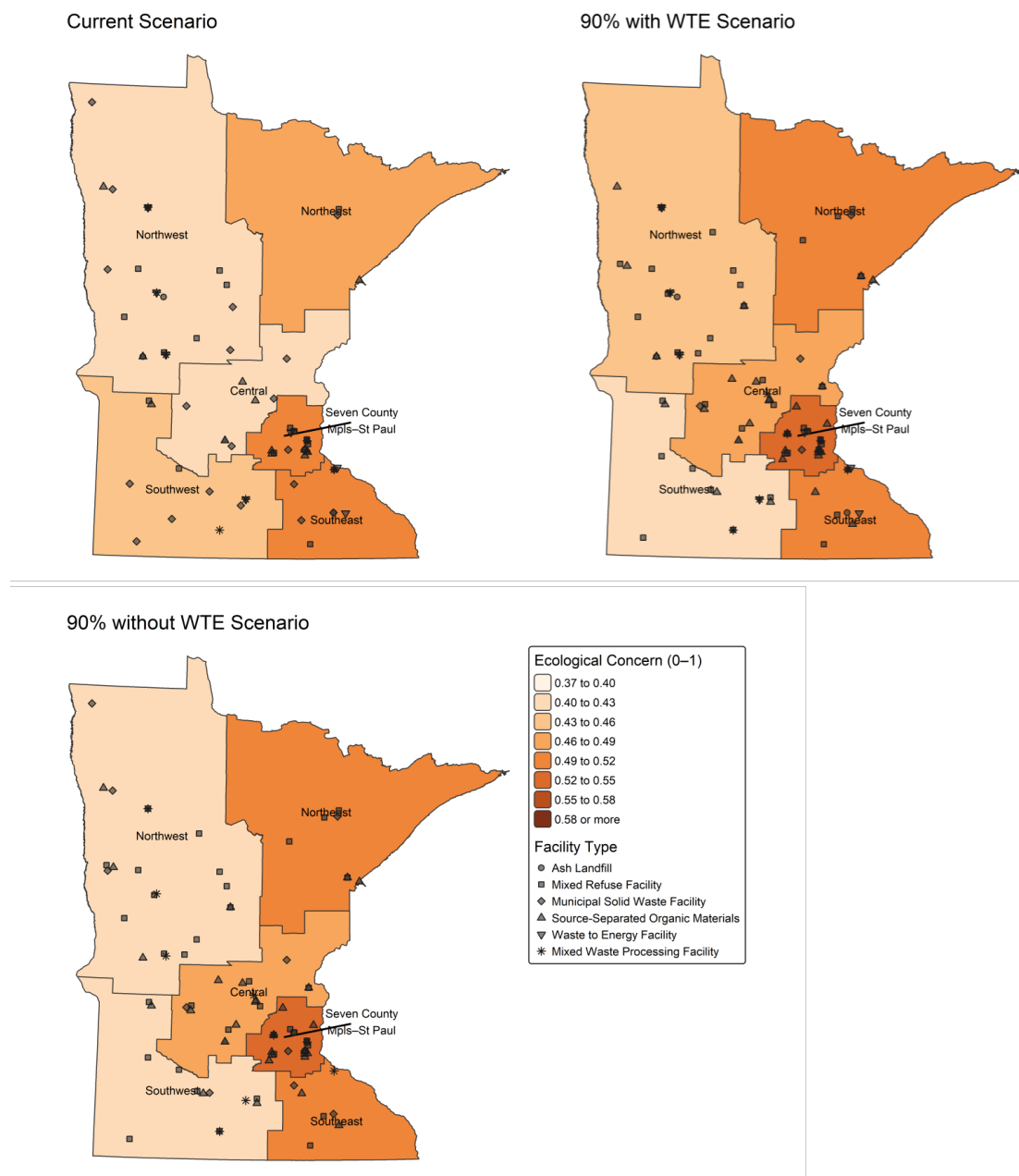
Under the 90% diversion with WTE scenario, ecological concern does not uniformly moderate ecological concern relative to current conditions. Instead, the scenario shows persistence or intensification of concern in several regions, reflecting the continued influence of redistributed waste flows. The Southeast remains among the highest concern regions, indicating that reduced landfill throughput alone does not offset the effects of regional hydrologic connectivity and ecological vulnerability when WTE-related exposures persist. Ecological concern also increases in the TCMA, where high facility density and overlapping exposure pathways amplify cumulative effects despite diversion. The Northeast exhibits a

similar upward shift, suggesting that redistribution of waste flows into ecologically sensitive landscapes can elevate concern even in the absence of high facility density. In contrast, changes in the Northwest and Southwest are more modest, with concern remaining broadly similar to current conditions. Overall, the 90% diversion with WTE scenario reflects a compounding and reallocation of exposure pathways rather than a reduction in regional ecological concern.

The 90% diversion without WTE scenario produces a distinct, but not uniformly lower, regional pattern. While combustion-related pathways are removed, Figure 61 shows that ecological concern remains elevated in several regions as waste flows are redistributed into remaining facility types and locations. The Southeast continues to exhibit high concern, indicating that removal of WTE alone does not offset the influence of hydrologic connectivity, groundwater vulnerability, and continued reliance on landfills and processing facilities. Ecological concern also increases in the TCMA, where waste flows become concentrated among MSW landfills, MRFs, and SSO facilities within a highly connected landscape. A similar intensification is evident in the Northeast, where redistributed throughput intersects biodiversity-sensitive landscapes. As in the with-WTE scenario, changes in the Northwest and Southwest are comparatively modest.

These patterns demonstrate that diversion alters the spatial distribution and dominant exposure pathways of ecological concern rather than reducing total pressure outright. As diversion increases, ecological concern becomes progressively less controlled by facility type alone and more strongly governed by regional landscape vulnerability and facility clustering, particularly in hydrologically connected and biodiversity-sensitive settings. Under 90% diversion with WTE, combustion- and landfill-related pathways continue to operate in parallel, redistributing concern between regions sensitive to different exposure mechanisms. Under 90% diversion without WTE, concern is increasingly concentrated within dense clusters of MSW, MRF, and SSO facilities, where cumulative pressures emerge despite lower individual facility risk profiles.

Figure 61. Ecological concern index by planning region under current and modeled diversion scenarios



Maps show spatial redistribution of relative ecological concern, with deeper orange colors indicating higher ecological concern values. Includes current conditions, 90% diversion with WTE, and 90% diversion without WTE scenarios.

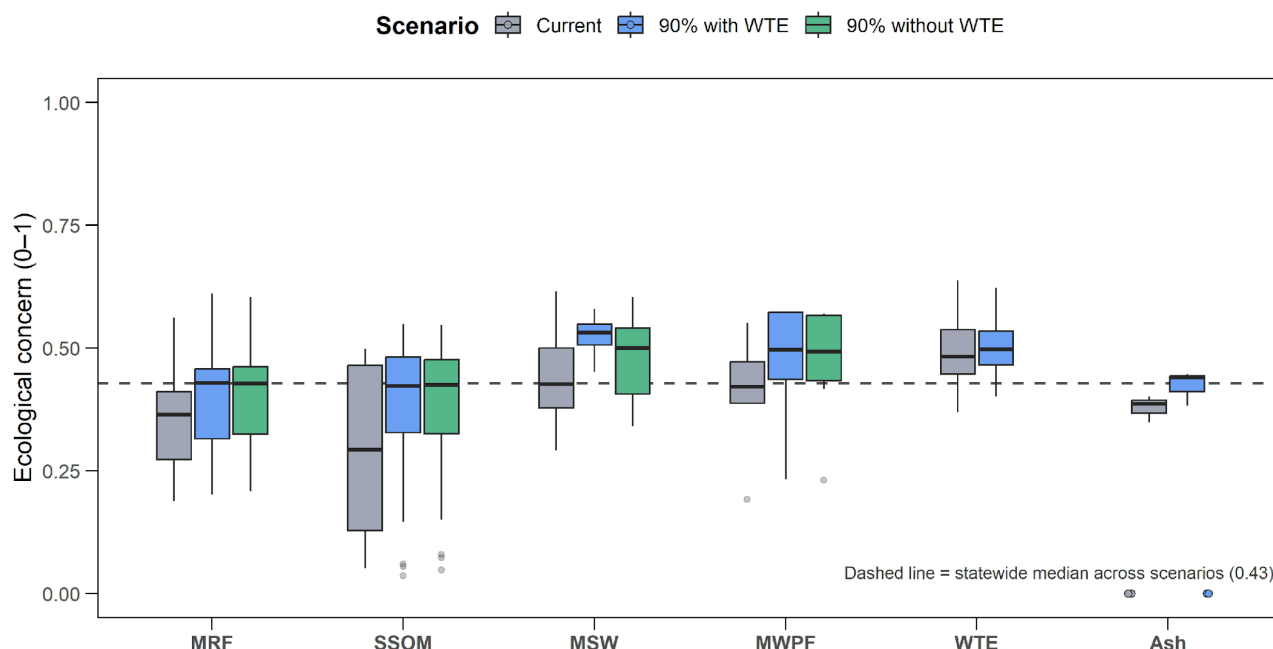
Facility Class Dynamics

Facility-type patterns (Figure 62) show that diversion primarily reshapes which facility classes drive ecological concern, rather than reducing concern uniformly. Where they remain active, WTE facilities consistently anchor the upper range of ecological concern with little variability, indicating that elevated screening-level concern is intrinsic to combustion-related pathways and largely insensitive to diversion intensity.

Under both 90% diversion scenarios, MSW landfills exhibit higher median concern (≈ 0.50), reflecting the concentration of waste flows at fewer sites. This pattern indicates that diversion can intensify site-level ecological concern even as total waste volumes decline, particularly where remaining landfills intersect hydrologically connected or ecologically sensitive landscapes. Mixed waste processing facilities show a similar upward shift. Material recovery facilities remain near the statewide median across scenarios but display increasing variability, indicating that ecological concern is driven more by siting context than by facility type alone. Source separated organics management facilities show the largest proportional increase from current conditions, though absolute concern remains lower than for landfills or WTE facilities. Their wide distributions highlight the importance of operational controls and local hydrologic setting, consistent with nutrient-driven pathways documented for organics facilities (90).

Overall, diversion reallocates ecological concern across facility classes rather than eliminating it. As combustion pathways decline, concern becomes increasingly concentrated in landfills, processing, and organics facilities, where cumulative effects and landscape sensitivity play a greater role.

Figure 62. Ecological concerns distributed across facility type



Illustrates how ecological concern is redistributed across facility types under diversion scenarios. Boxes show interquartile range with median (line); whiskers indicate data spread; circles mark outliers; diamonds denote mean values. Dashed line indicated statewide median (0.43)

Interpretation and Synthesis

Taken together, the results support two central interpretive conclusions. First, diversion meaningfully alters *where* and *how* ecological concern is expressed, particularly in hydrologically sensitive regions, but does not uniformly reduce concern at the statewide scale. In regions such as the Southeast, where karst systems and surface–groundwater connectivity amplify exposure, reductions in landfill throughput under diversion scenarios modify dominant pathways of concern. However, these changes do not consistently translate to lower regional concern across all futures, underscoring the strong role of landscape vulnerability in mediating ecological outcomes.

Second, diversion does not eliminate ecological concern but redistributes it across facility classes and exposure pathways. Under the 90% diversion with WTE scenario, combustion-related pathways persist and continue to shape regional patterns, particularly in regions influenced by diffuse atmospheric deposition and cumulative facility density. Under the 90% diversion without WTE scenario, combustion-linked stressors are removed, but ecological concern remains through increased reliance on MSW landfills, MRF's, and SSO facilities. Although these facility classes generally exhibit lower individual concern, their increased prominence introduces greater dependence on site-specific performance, siting, and cumulative effects, particularly in densely developed and hydrologically connected landscapes such as the TCMA.

It is important to emphasize that these findings are derived from a screening-level assessment. The ecological concern score integrates pressure, exposure, and vulnerability to highlight relative patterns rather than predict site-specific impacts. While alternative weighting schemes or finer-resolution data could influence absolute magnitudes, the overall signal is consistent: diversion reconfigures dominant exposure pathways and redistributes ecological concern spatially. Across all scenarios, exposure-related factors contribute the largest share of modeled concern, reflecting the ubiquity of hydrologic transport pathways. Vulnerability layers remain essential for distinguishing where exposure translates into heightened ecological concern.

Priority Ecological Concerns

Minnesota's ecological vulnerabilities are driven not by waste volumes alone, but by the interaction between facility pressure, persistent contaminant pathways, sensitive ecological receptors, and facility density. Across scenarios, exposure-related factors account for the largest share of modeled concern, reflecting the widespread presence of hydrologic transport pathways and biodiversity-linked landscape features. However, increased waste volumes and facility throughput consistently heighten ecological concern where exposure pathways and vulnerable receptors are present.

These intersections give rise to cumulative hotspots where elevated facility pressure and facility density converge with multiple exposure pathways and sensitive receptors. In regions with clustered facilities, repeated and overlapping sources increase the frequency and spatial coincidence of exposure, amplifying ecological concern even when individual facilities exhibit moderate risk profiles. Rather than dispersing ecological pressure, increased waste handling and facility clustering within these landscapes reinforces vulnerability through additive and interacting stressors. Identifying these priority concern areas is therefore central to understanding how changes in waste management translate into ecological risk potential at the screening level.

Groundwater-dependent ecosystems (GDE's) and Karst landscapes

The Southeast consistently emerges as the most critical zone of ecological concern. While diversion reduces overall landfill throughput in this region, the hydrogeological properties of karst terrain and shallow aquifers maintain exceptionally high vulnerability to contaminant transport (38). Karst systems are characterized by fractured bedrock and rapid subsurface flow, providing little natural attenuation capacity. As a result, even relatively modest contaminant inputs can propagate rapidly into groundwater-dependent ecosystems such as springs, fens, and coldwater streams.

Landfills in karst settings therefore remain persistent sources of ecological concern, particularly through leachate carrying PFAS, VOCs, ammonia, and nutrients (39,42). These pollutants are problematic at low concentrations due to chronic toxicity and their potential to drive eutrophication and bioaccumulation. Even under 90% diversion, residual concern is non-trivial, underscoring that diversion is a partial mitigation measure rather than a substitute for targeted groundwater protection, monitoring, and engineering safeguards.

Coldwater streams and surface water networks

Coldwater streams and connected headwater networks, concentrated in southeastern and central Minnesota, represent another ecological receptor of elevated concern. These systems depend on sustained groundwater inflows for thermal regulation and dissolved oxygen, making them sensitive to both groundwater-mediated contaminant transport and surface water inputs. Where waste management facilities intersect surface water corridors, ecological concern is amplified by the efficient downstream transport of contaminants through hydrologically connected networks.

Under diversion scenarios where WTE facilities remain active, atmospheric deposition of metals (e.g., mercury, cadmium) and combustion byproducts (dioxins/furans) continues to contribute diffuse stress to coldwater systems, particularly through watershed-scale deposition and subsequent runoff into streams and wetlands. In scenarios without WTE, these combustion-linked pathways are reduced; however, localized concern persists where MSW landfills, MRFs, and SSO facilities coincide with surface water corridors, especially in regions with high facility density such as the TCMA.

Because surface waters function as integrative transport pathways for both point-source and diffuse inputs, even modest pollutant contributions can propagate downstream, affecting sensitive fish assemblages and aquatic invertebrate communities (90). This interaction between groundwater support, surface water connectivity, and facility proximity reinforces coldwater stream habitats as cumulative ecological hotspots, where multiple waste-related stressors converge under both current and future waste management configurations.

Wetlands, prairie potholes, and nutrient-accumulating systems

Wetlands, including prairie potholes, riparian systems, floodplain marshes, and peatlands, emerge as receptors of increasing importance under diversion futures. As waste tonnage shifts toward SSO and MRF facilities, ecological concern is increasingly shaped by stormwater-mediated transport and nutrient enrichment pathways rather than by combustion-related inputs. These systems are particularly sensitive because they function as natural sinks for nutrients and organic matter, allowing even incremental inputs to accumulate over time.

The wide distribution of ecological concern scores associated with SSO facilities indicates that outcomes are strongly conditioned by siting and operational management. Poorly managed SSO facilities have been linked to elevated nitrogen, phosphorus, and organic matter loading to adjacent wetlands, contributing to eutrophication, hypoxia, and altered community structure (89). These effects can propagate beyond individual wetlands, influencing amphibians, waterfowl, and downstream aquatic ecosystems through hydrologic connectivity. Unlike flowing systems, wetlands and prairie potholes retain water and sediments for extended periods, increasing the likelihood that repeated low-level inputs translate into measurable ecological change. Because nutrient accumulation and organic loading operate over longer time horizons, ecological responses in wetlands may lag behind changes in facility throughput, reinforcing the importance of sustained management and monitoring under diversion-intensive futures. In regions where multiple SSO and MRF facilities are clustered, these nutrient-driven pathways contribute to cumulative ecological concern, particularly where wetlands are hydrologically connected to downstream waters.

By contrast, well-sited and well-managed SSO and MRF facilities exhibit relatively low screening-level concern, highlighting the importance of management controls in moderating negative ecological outcomes. Under diversion-intensive scenarios, wetlands and prairie potholes therefore function as management-dependent sensitivity zones, where ecological concern is driven less by facility type alone than by the interaction between nutrient pathways, hydrologic connectivity, and local site practices.

Persistent facility-class pathways

Diversion reshapes the geographic distribution of ecological concern but does not eliminate the contaminant pathways inherent to major municipal solid waste facility classes. Across scenarios, both WTE facilities and MSW landfills continue to contribute to ecological risk potential through distinct exposure mechanisms linked to emissions, residual management, and long-term contaminant mobility. Atmospheric deposition from combustion processes represents one pathway through which WTE facilities may influence regional exposure patterns, particularly for metals and combustion byproducts capable of bioaccumulation. However, modeled diversion scenarios also indicate that absolute throughput and associated pressure at WTE facilities may decline as overall residual waste volumes decrease.

MSW landfills similarly remain persistent drivers of ecological concern due to long-term leachate generation, groundwater plume migration, and legacy waste mass that continues to influence subsurface contaminant transport well beyond operational timeframes. These pathways are strongly mediated by hydrogeologic context and proximity to sensitive ecological receptors. Under diversion scenarios that retain WTE capacity, ash landfills may increase in relative prominence as combustion residuals require continued disposal. These residual streams can concentrate metals, PAHs, and other combustion byproducts, reinforcing the ecological importance of ash management alongside primary waste handling activities (39). Other facility classes, including source-separated organics management facilities and materials recovery or transfer sites, may also contribute to localized ecological exposure through stormwater runoff, particulate dispersion, or handling of residual waste streams. While these pathways are generally more episodic and spatially constrained, they represent an important component of cumulative infrastructure-related pressures within certain diversion scenarios.

Together, these patterns indicate that diversion shifts waste flows and redistributes dominant exposure pathways rather than eliminating facility-class-specific mechanisms that operate over long temporal scales. Effective ecological risk reduction therefore depends not only on diversion targets, but also on facility siting, long-term containment performance, residuals management, and the cumulative interaction of infrastructure with sensitive hydrological and biodiversity landscapes.

Implications

These findings indicate that Minnesota's priority ecological concerns arise where sensitive ecosystems intersect with persistent or redistributed contaminant pathways. Across diversion scenarios, statewide ecological concern does not decline substantially; instead, concern is reallocated across regions and facility classes. Diversion therefore alters the expression of ecological risk potential rather than eliminating it.

Model results show that diversion modifies dominant stressors, but localized vulnerabilities remain acute for several receptor types:

- Groundwater-dependent ecosystems and karst aquifers, where rapid subsurface transport and limited attenuation capacity sustain high vulnerability even as landfill throughput is reduced.
- Coldwater streams, where hydrologic connectivity concentrates both groundwater-mediated inputs and, in scenarios with active WTE facilities, diffuse atmospheric deposition.
- Wetlands and prairie potholes, where increasing reliance on SSO and MRF facilities elevates the importance of nutrient and organic enrichment pathways that are highly sensitive to siting and operational performance.

These receptors define the ecological sensitivity zones of Minnesota's waste management system, landscapes where redistribution of waste flows and facility activity can intensify concern even as other

pathways diminish. In this context, diversion should not be interpreted as a universal ecological risk-reduction strategy. Rather, it functions as a rebalancing mechanism that shifts concern from combustion-dominated pathways toward groundwater- and surface-water-mediated pathways, and from fewer high-intensity facilities toward broader clusters of lower-risk but higher-density operations.

By interpreting these receptor sensitivities alongside the mapped regional patterns and facility clustering observed in the scenario results, these findings provide a planning-relevant synthesis that links exposure pathways, ecological sensitivity, and diversion outcomes. This perspective highlights the importance of coupling diversion targets with strategic siting, residuals management, and cumulative-impact awareness to avoid unintentionally concentrating ecological pressure within Minnesota's most sensitive landscapes.

Uncertainty and Limitations

The findings presented in this assessment should be understood within the inherent uncertainties of screening-level ecological risk potential modeling. The assessment model integrates facility-level waste processing pressure, hydrological exposure, and ecological vulnerability into a normalized composite score, providing a consistent framework for comparing scenarios. As a result, the model is more likely to conservatively flag areas of potential ecological interaction than to underestimate risk, particularly in hydrologically connected landscapes. While these limitations affect absolute magnitudes, they do not alter the relative patterns observed across regions, facility classes, or diversion scenarios.

First, the model relies on a simplified representation of ecological processes. By adopting a multiplicative Pressure $\times$ Exposure $\times$ Vulnerability structure, the three dimensions are treated as equally weighted contributors to ecological concern. In practice, contaminant transport and ecological response are non-linear and may be dominated by a single factor under certain conditions. Normalization of inputs to a 0–1 scale further assumes comparability between fundamentally different indicators, such as waste throughput, groundwater sensitivity, and biodiversity value. These assumptions facilitate comparability but inevitably reduce ecological nuance. In practice, this weighting can bias risk potential toward exposure metrics, since hydrologic features such as streams, lakes, and rivers occur broadly across the state and intersect with many facilities, whereas vulnerability indicators are more spatially discrete and occur less consistently across regions.

Second, the assessment is limited by the resolution and completeness of available data. Facility throughput values are drawn from MPCA reporting data and represent the most complete and recent year available yet may not fully capture operational variability or future trends. Similarly, WTE emissions were filtered to exclude pollutants deemed non-ecologically relevant. Exposure surfaces, including WHAF hydrology, pollution sensitivity indices, and proximity to streams and lakes function as proxies for transport but do not directly model contaminant fate at the facility scale. Vulnerability datasets, including the Minnesota County Biological Survey (MCBS), MNWAP Wildlife Action Network and designated ecological features (e.g., trout streams, calcareous fens), emphasize documented receptors and may underrepresent smaller or less-studied ecosystems.

Third, the analysis is static and comparative, rather than predictive. Seasonal hydrology, long-term climate variability, and future land use change are not incorporated, nor are potential facility-specific improvements in engineering or operations. Diversion scenarios assume proportional redistribution of tonnage based on facility capacity caps, which simplifies the complex siting decisions, cross-jurisdictional waste flows, and technological changes that may shape future system trajectories. As such, the modeled 90% with WTE and 90% without WTE diversion scenarios should be interpreted as stylized futures rather than forecasts.

Finally, it is important to emphasize that results identify relative ecological risk potential, not absolute ecological risk. The persistence of elevated values for waste-to-energy facilities and landfills reflects known contaminant pathways, air deposition of metals and dioxins/furans, leachate and PFAS/VOC loading, but does not substitute for site-level contaminant monitoring or receptor-specific ecological assessment. Cumulative impacts arising from overlapping facilities, shared watersheds, and interactions with other land uses are not fully quantified within this framework, though they are qualitatively examined through regional and facility distribution analyses. For these reasons, model outputs are best interpreted as indicators of relative concern that support screening, prioritization, and planning rather than definitive determinations of ecological risk. Consistent with EPA guidance for screening-level ecological risk assessments, these results are intended to inform prioritization and guide more detailed evaluation where warranted. A qualitative summary of key data sources and associated uncertainties is provided in the Appendix B - Human Health and Cumulative Risks to support transparency and interpretation of screening-level results.

Synthesis and Planning Relevance

The results of this screening-level ecological risk potential assessment demonstrate that ecological pressures within Minnesota's waste management system are neither evenly distributed nor readily eliminated through diversion alone. Instead, the findings indicate that certain facility classes exert persistent ecological influence across scenarios, while specific regions remain consistently vulnerable due to their hydrogeological and biodiversity context. This distinction carries direct implications for MPCA's planning, monitoring, and policy development.

Waste-to-energy facilities emerge as structurally persistent contributors to ecological concern. Where combustion remains part of the system, atmospheric deposition pathways operate largely independent of diversion rate, sustaining elevated concern across futures. Municipal solid waste landfills similarly remain central to the ecological risk potential profile, driven by long-term leachate generation and PFAS and VOC transport pathways (39). Under diversion-intensive scenarios with active combustion, ash landfills gain increased prominence as repositories of combustion residuals that concentrate metals, PAHs, and other byproducts, reinforcing the ecological importance of residuals management (39). By contrast, MRFs and SSO facilities generally exhibit lower statewide concern but display substantial variability. Ecological outcomes for these facility types are highly contingent on siting and operational practices; poorly managed SSO facilities, in particular, can elevate nutrient and organic loading to wetlands and prairie potholes (89). This variability underscores that risk potential for these classes is context-dependent rather than intrinsic.

The Southeast consistently emerges as the most ecologically consequential region, where large MSW landfills intersect karst terrain and groundwater-dependent ecosystems, sustaining elevated concern even under high diversion. The TCMA similarly exhibits persistent concern, driven by facility density and extensive surface water and wetland networks that amplify cumulative exposure pathways.

By contrast, patterns in the Northwest and Northeast reflect more localized and pathway-specific drivers. In the Northwest, ecological concern is proportionately influenced by the presence of WTE facilities, with atmospheric deposition pathways sustaining elevated concern at specific sites despite more moderate regional vulnerability. The Northeast and Central regions generally exhibit lower overall ecological concern at the regional scale due to limited facility density and reduced cumulative pressure. However, in the Northeast, high underlying ecological vulnerability means that individual facilities can register elevated concern where they intersect MCBS-designated biodiversity sites or hydrologically sensitive features.

Diversion futures highlight both the promise and the limits of waste system transformation. While diversion alters dominant contaminant pathways, reducing reliance on combustion in some scenarios and shifting pressure toward landfills, MRFs, and SSO facilities, it does not substantially reduce statewide ecological concern in aggregate. Instead, diversion redistributes risk potential across regions and facility classes, concentrating pressure at fewer landfills, increasing the ecological relevance of ash management where WTE remains active (39), and elevating the importance of nutrient- and stormwater-mediated pathways associated with SSO and materials processing (89). Diversion should therefore be interpreted not as a universal ecological risk-reduction strategy, but as a mechanism that rebalances ecological concern across pathways and landscapes.

For MPCA, these findings provide a clear basis for prioritization. The assessment indicates that WTE facilities, MSW landfills, and ash landfills represent persistent high-concern facility classes where sustained monitoring, technological controls, and residuals management are warranted (39). It also identifies ecological sensitivity zones, karst aquifers, groundwater-dependent ecosystems, coldwater streams, wetlands, and prairie potholes, where relatively modest contaminant inputs may generate disproportionate ecological responses due to hydrologic connectivity and biological vulnerability (38). While diversion can modify system-wide pressures, its ecological benefits are most effective when paired with safeguards that directly address these structurally embedded pathways.

From a planning perspective, diversion strategies should be treated as complementary measures rather than stand-alone solutions. Their ecological value is maximized when combined with geographically targeted monitoring, stringent siting controls in vulnerable landscapes, advanced PFAS and leachate management at landfills (39), emissions controls where WTE facilities remain active, and consistent operational standards for SSO facilities. Taken together, these actions support a risk-informed framework that directs resources toward the intersections of highest facility pressure and ecological sensitivity.

Ultimately, the central planning challenge for MPCA is therefore not simply to divert waste, but to actively manage where and how ecological pressures are expressed. By focusing interventions on landscapes and facility classes where vulnerability and exposure converge, MPCA can reduce current areas of concern while strengthening the long-term resilience of Minnesota's groundwater, surface waters, and biodiversity.

Stakeholder Engagement

The Minnesota Pollution Control Agency (MPCA) designed a robust stakeholder engagement process to ensure that recommendations to the Legislature on the future of solid waste and materials management reflect the lived experiences, challenges, and priorities of Minnesotans. The process sought to capture the perspectives of residents, businesses, local governments, Tribal government representatives, advocacy organizations, and industry stakeholders on the current challenges, opportunities, and priorities for the state's solid waste and materials management system.

Through a combination of methods and audience-specific engagement strategies, the project team compiled a broad and representative picture of how waste diversion policies and practices are experienced across Minnesota. These insights helped shape the strategic recommendations presented in the Resource Management Report (RMR).

Methodology

The engagement effort was designed to be inclusive, transparent, and accessible. Key activities included:

- **statewide materials management survey:** an online survey gathered input from 488 respondents including residents and various stakeholders; topics ranged from recycling, composting, service gaps, and education needs; provided vital quantitative data and highlighted key trends
- **virtual stakeholder interviews:** 70 virtual interviews conducted with representatives of counties, cities, Tribal governments, haulers, recyclers, processors, environmental organizations, and advocacy groups; conversations provide more nuanced insights into infrastructure, policy barriers, and community priorities/needs
 - **public meetings and presentations:** four meetings and presentations were convened; one with Tribal governments, focusing on infrastructure challenges, sovereignty, and coordination needs; two with environmental justice organizations, centering equity, health impacts, pollution and waste reduction; a presentation to industry stakeholders at the Recycling Association of Minnesota/Solid Waste Association of North America (RAM/SWANA) conference

Figure 63. Social media graphic for stakeholder survey



Voluntary Public Comments: RRS and MPCA also received letters and emails from advocacy coalitions and individuals, including the Minnesota Zero Waste Coalition and Coalition for Plastic Reduction, which provided additional feedback and presented ideas for further improving the recommendations made in the Resource Management Report.

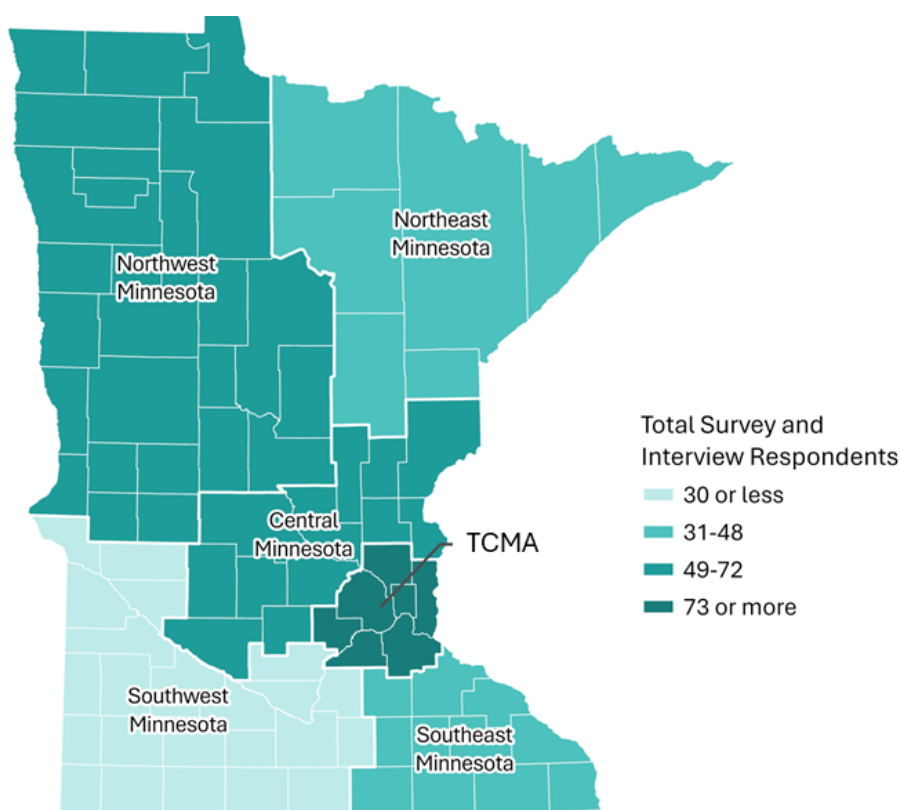
This multi-pronged approach ensured that diverse perspectives were included, while also creating multiple opportunities for stakeholders with varying resource capacities and interest levels to participate.

Audiences Engaged

Engagement reached across the state and across sectors. Figure 64 shows the distribution of survey and interview respondents across Minnesota. Lighter shaded regions indicate fewer participants (30 or less), while progressively darker shades highlight areas with higher levels of response, with the TCMA, Northwest Minnesota, and Central Minnesota reporting the greatest concentrations.

- **local governments:** county solid waste administrators, city staff, and elected officials shared perspectives on funding, mandates, and service delivery
- **tribal governments:** representatives highlighted challenges in infrastructure, cross-jurisdictional coordination, and staff capacity, as well as opportunities for partnership
- **industry stakeholders:** haulers, processors, composters, and industry associations participated through interviews, the survey, and at the RAM/SWANA Conference
- **community organizations:** nonprofits and grassroots groups passionately brought forward equity concerns, cultural perspectives, and frontline community experiences
- **residents:** hundreds of residents responded to the survey, offering feedback on their household experiences with materials management
- **advocacy coalitions:** written submissions underscored systemic policy needs, including stronger upstream waste reduction and producer accountability

Figure 64. Density of survey and interview respondents by region

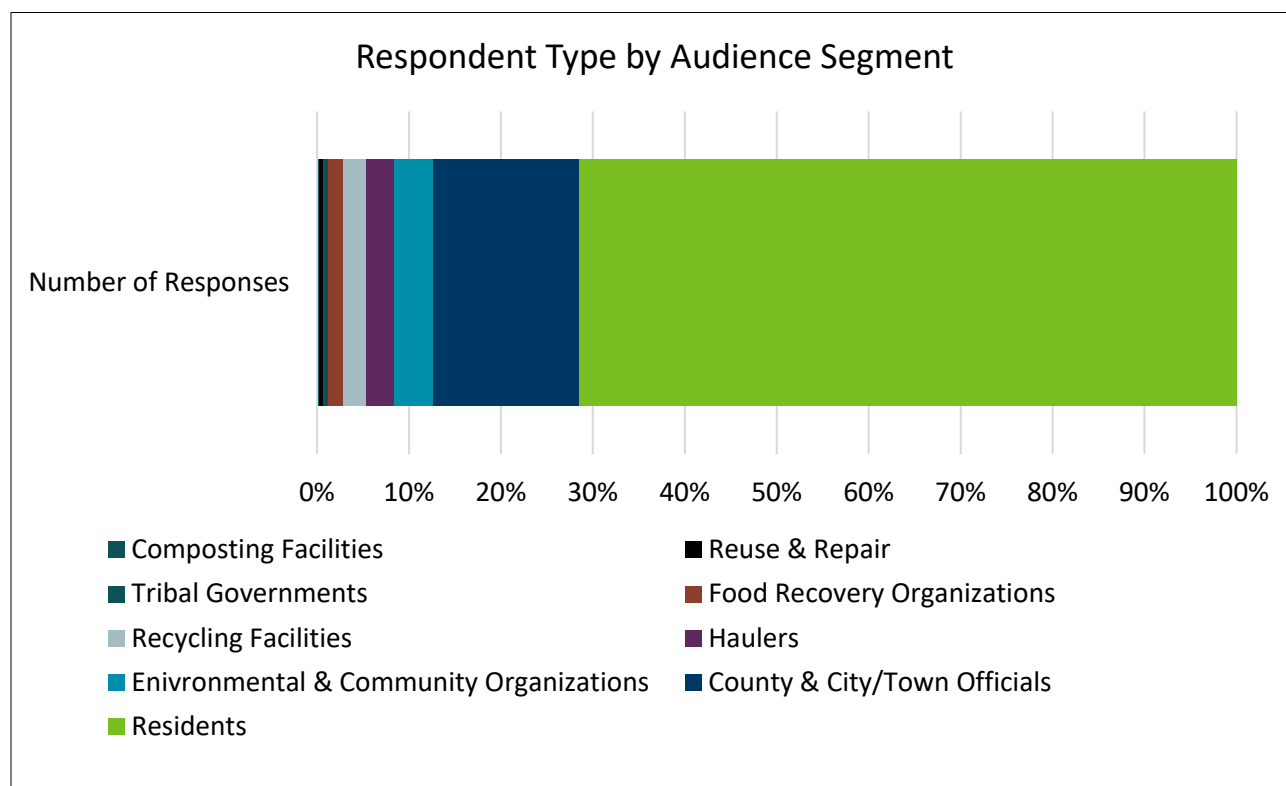


Survey respondent breakdown

The Statewide Materials Management Survey was open for a three-month period from April through July 2025. During this time:

- **participation:** 639 surveys were started, with 488 fully completed, resulting in a 76% completion rate
- **geographic representation:** respondents represented all five MPCA districts (Metro, Northeast, Northwest, Southeast, Southwest)
- **regional distribution:** the TCMA accounted for the largest share (53%), with additional participation from rural and Greater Minnesota communities

Figure 65. Distribution of survey respondent type by audience segment



In addition to residents (349 responses), the survey reached local government staff (77 responses), community organizations (21 responses), haulers (15 responses), recycling facilities (12 responses), food recovery organizations (8 responses), Tribal governments (3 responses), reuse and repair businesses (2 responses), and one composting facility. No responses were received from AD facilities. Figure 65 shows the distribution of survey respondents by audience segment.

Interview participant breakdown

Between July and August 2025, the project team reached out to more than 185 entities statewide with a request to interview them. The stakeholders were invited by RRS staff to complete a 30-minute interview via Zoom. Stakeholders were contacted up to three times (via phone and email) to ensure that if they were interested in scheduling interviews, they would have the opportunity to. In total, 70 virtual interviews were completed – a 38% success rate. Entities being interviewed represented all state regions, with the largest share in the TCMA (37 interviews). Table 53 summarizes outreach and interview participation by stakeholder type. County and city/town representatives accounted for the

largest number of contacts and interviews, followed by environmental or community-based organizations. Table 54 shows the outreach and interview participation broken down by state region.

Table 53. Interviews by stakeholder type

Stakeholder type	Contacted	Interviewed	Not interviewed
County or city/town representative	58	37	21
Tribal government representative	27	2	25
Waste hauler representative	22	4	18
Recycling facility representative	13	6	7
Composting facility representative	4	1	3
AD facility representative	5	0	5
Reuse and/or repair retail representative	9	2	7
Food recovery organization representative	6	1	5
Environmental or community-based organization representative	36	13	23
Resident (submitted online)	5	4	1

Table 54. Interviews by state region

State region	Contacted	Interviewed	Not interviewed
Central Minnesota	19	3	16
Northeast Minnesota	18	7	11
Northwest Minnesota	19	8	11
Seven County Region (TCMA)	84	37	47
Southeast Minnesota	8	2	6
Southwest Minnesota	12	4	8
Statewide	25	9	16

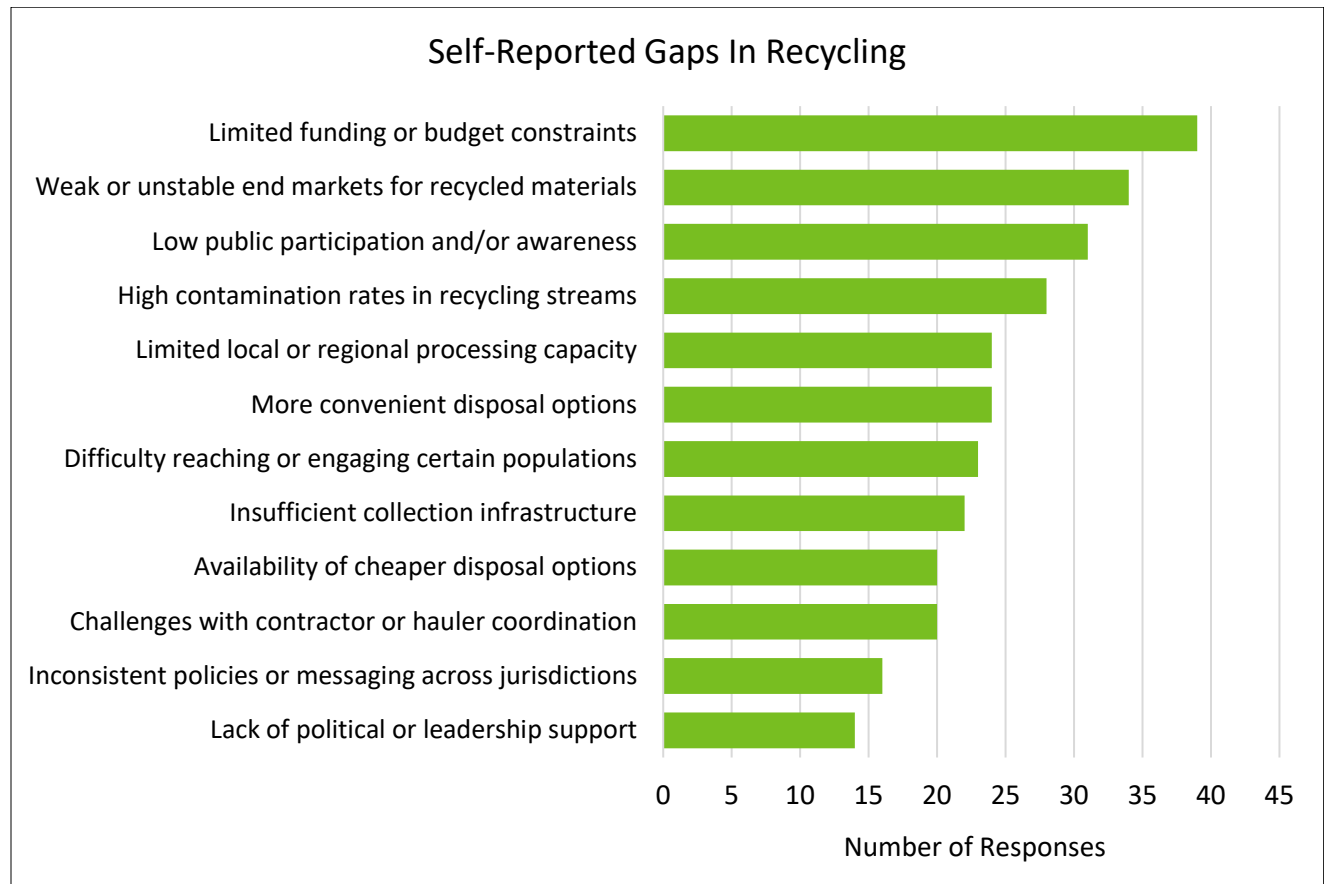
Key Takeaways

Local governments

There were 77 survey respondents who identified as a county or city/town representative. Of those respondents, there were 46 different counties selected in the sample, mainly Hennepin County (11 respondents), Washington County (9 respondents), and Dakota County (4 respondents). Most of the respondents noted that they represent a county (65%) while 35% were municipal respondents representing a city or town. Respondents in Central Minnesota and Northwest Minnesota were more likely to report major gaps in recycling access, while most respondents in the TCMA reported little to no gaps.

Local governments consistently underscored the strain of limited capacity and funding, particularly in smaller counties and rural areas, where long hauling distances and low population density make recycling and composting costly. Respondents emphasized that the most useful support for county and municipal recycling operations would be increased and more flexible funding, particularly through expanded SCORE allocations and state grants, noting that financial constraints and limited staffing remain the most significant barriers. Figure 66 summarizes self-reported gaps in Minnesota's recycling system.

Figure 66. Self-reported recycling gaps



Many local officials also pointed to end-market development as a critical missing piece. Without reliable buyers for materials like textiles, plastic film, and organics, local programs remain limited in which materials they can divert. Stakeholders highlighted the need for better end-market development and transparency, especially for hard-to-recycle materials and rural areas where collection is not economically viable. Cities such as Minneapolis, St. Louis Park, and West St. Paul emphasized the importance of expanding organics diversion, while others requested more flexibility and assistance from MPCA in permitting new composting facilities.

Education and outreach support, including state-led campaigns, resources, and training, were identified as critical for improving public participation and reducing contamination. Education was viewed as inconsistent across jurisdictions, with staff repeatedly asking for statewide standardization of recycling lists, messaging, and hauler reporting requirements. Metro-area cities highlighted persistent challenges with multi-family housing and language access, noting that existing programs and outreach efforts struggle to reach renters and non-English-speaking populations. The next question asked how respondents would use additional funding, specifically for recycling education and outreach. Survey respondents were asked to rank individual activities based on impact on their jurisdiction. Expanding school-based waste reduction and recycling education programs were ranked as having the most potential impact for respondents, and launching targeted campaigns to reduce contamination in recycling followed closely.

Local government officials also spoke about the importance of policy and regulatory action, including stronger enforcement of existing requirements, extended producer responsibility, and investment in composting and alternative recycling infrastructure. Cities such as Minneapolis, St. Louis Park, and West

St. Paul emphasized the importance of expanding organics diversion, while others requested more flexibility and assistance from MPCA in permitting new composting facilities. Table 55 shows the most reported gap in recycling by region.

Table 55. Most reported recycling gaps by region

County	Most reported gap
Central Minnesota	High contamination rates in recycling streams
Northeast Minnesota	Limited local or regional processing capacity
Northwest Minnesota	Limited funding or budget constraints
Southeast Minnesota	Weak or unstable end markets for recycled materials
Southwest Minnesota	Weak or unstable end markets for recycled materials
TCMA	Difficulty reaching or engaging certain populations (e.g., non-English speakers, renters)

Tribal Governments

There were three survey responses and two virtual interviews completed with representatives of Tribal Nations. In addition, a virtual meeting was held for Tribal Government leaders. A total of eight people registered for the event, but only two attendees were present at the meeting. Tribal representatives highlighted unique challenges like those faced by rural counties, but often with added complexity because of geographical, funding limitations, and jurisdictional overlap. Recycling is limited primarily to drop-off sites, with minimal curbside service, and programs often rely on short-term grant funding that is difficult to sustain over time. Staffing shortages were described as one of the most pressing barriers – small departments are tasked with covering wide service areas, which makes even basic operations like running recycling trailers or tracking data a heavy burden. Landfill capacity was also raised as a major concern, with some Tribal owned C&D landfills nearing closure and limited alternatives available without hauling long distances.

Organics management remains largely absent, with most disposal occurring through backyard composting or informal practices. While some Tribes collaborate with neighboring counties for access to WTE facilities or E-waste programs, they stressed the need for more reliable regional infrastructure designed to meet Tribal needs. Perspectives on WTE varied: some view nearby facilities as a necessary part of the system in the near term, while others raised concerns about air quality and long-term reliance on incineration.

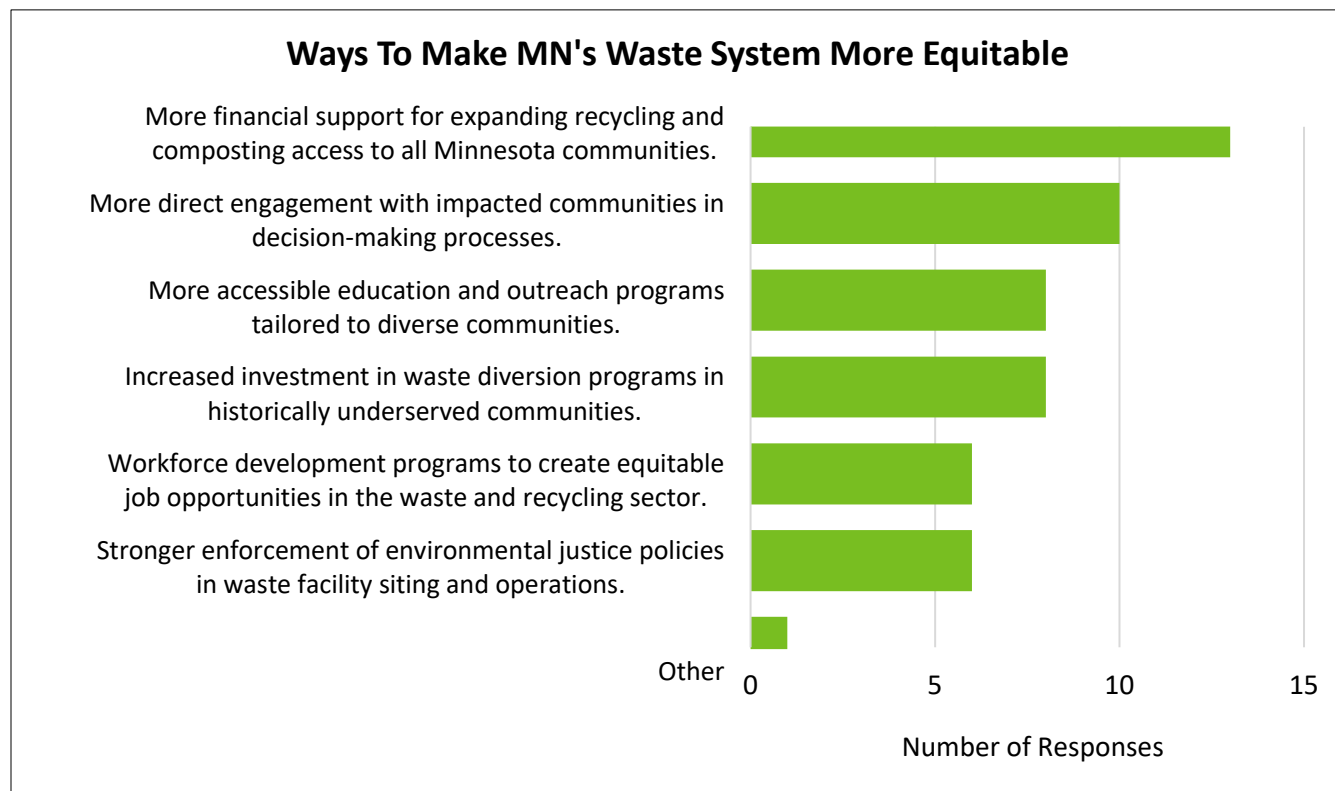
Tribes expressed interest in collaborating with counties and MPCA but emphasized the need for sustained flexible funding, technical support, and meaningful inclusion in statewide planning. Limited public awareness or participation in waste management programs was a common theme among the Tribal nation representatives. Costs, paired with limited participation and limited access, can lead to illegal dumping, which was noted as a concern by these groups.

Environmental and Community-based Organizations

There were 21 complete survey responses from environmental and community-based organizations, representing the third-highest response rate after residents and local government officials. In addition, 13 virtual interviews were conducted with representatives from these groups, the second highest total after local governments. Environmental and community-based groups emphasized that environmental justice and equity must be central to Minnesota's waste and materials management system. They repeatedly stressed that waste facilities, landfills, WTE facilities, and transfer stations, are

disproportionately sited in low-income communities and communities of color, where residents face both environmental and health impacts but often have little voice in decision-making.

Figure 67. Ideas to improve equity in Minnesota's waste system



Groups called for earlier and more accessible engagement in project planning, with longer public comment windows, culturally relevant outreach, and support services such as translation, childcare, and stipends for participation. Figure 67 shows respondents' most emphasized ideas for making the state's waste system more equitable.

A common thread was the call for upstream solutions, with stakeholders urging the state to focus less on end-of-life approaches like recycling and incineration and more on waste prevention, reuse, and repair systems. Many participants opposed framing WTE as a renewable resource, arguing that it prolongs dependence on short-lived plastics and undermines Minnesota's climate goals. While some acknowledged that incineration may currently play a role in managing residuals, there was strong agreement that the long-term strategy must be to phase out incineration and reduce reliance on landfills.

Groups also pressed for systemic policy changes, noting that voluntary programs alone cannot achieve the scale of change required. Specific ideas included product bans, reuse and refill requirements, bottle-deposit legislation, stronger toxics-in-packaging laws, and disposal bans on organics. Education was seen as critical, but participants cautioned that it must be coupled with structural reforms to ensure residents are not left carrying the burden while producers avoid accountability.

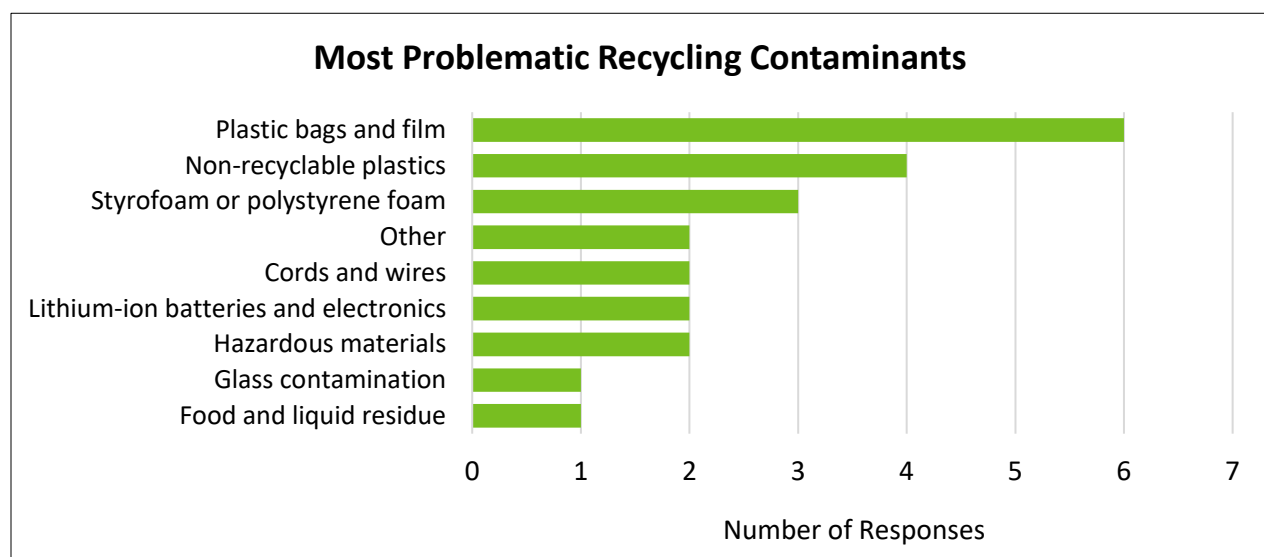
Another major theme was data transparency and accountability. Community groups requested that stakeholder feedback and survey results be made public, and that decision-makers be more present in community spaces to listen rather than present pre-determined solutions. Participants pointed to grassroots examples, both in Minnesota and internationally, where decentralized composting, reuse networks, and neighborhood-driven initiatives have succeeded when adequately supported.

Industry Stakeholders

Industry stakeholders, including facility operators, waste haulers, reuse and repair organizations, and food recovery groups, play a pivotal role in Minnesota’s solid waste system. They provide the infrastructure and services that enable collection, processing, reuse, and recovery, making them essential partners in planning for the future of materials management. Although participation was lower than anticipated, 14 interviews completed out of 59 entities contacted and 38 survey responses from 488 distributed, the input received offers important insights into both day-to-day operations and broader system needs.

Facility operators pointed first to the persistent problem of contamination, which undermines both recycling and organics systems. Recycling facilities described batteries, plastic film, and hazardous materials as particularly dangerous contaminants, with lithium-ion batteries causing repeated fires and safety risks. Compost facilities raised concerns about supposedly “compostable” products that fail to meet certification standards, creating confusion for residents, additional labor costs, and skepticism about the integrity of composting programs. Operators stressed that clear statewide standards for labeling and accepted materials are urgently needed to restore trust and reduce contamination. Figure 68 highlights the most reported contaminants in recycling facilities.

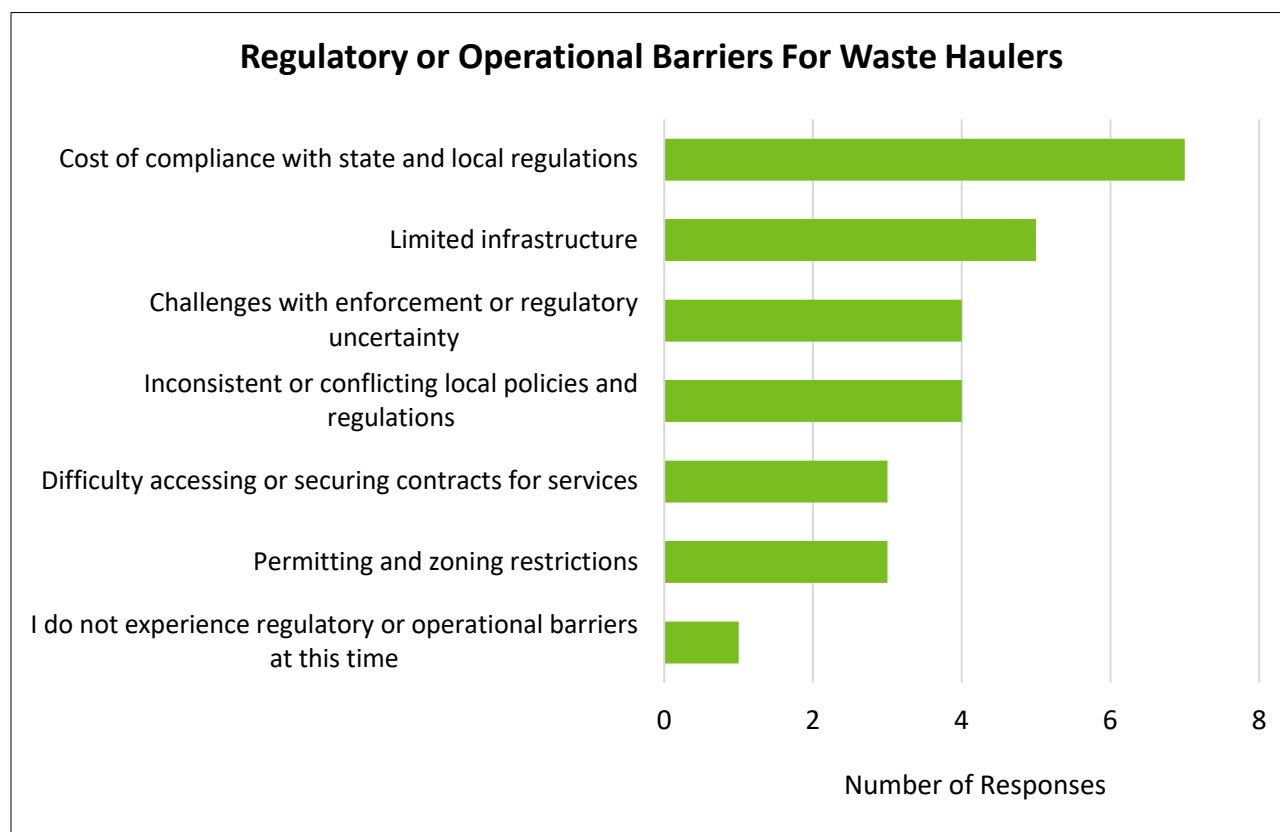
Figure 68. Most problematic contaminants in recycling facilities



In addition, operators noted that the instability of recycling markets remains one of their top challenges. Unpredictable pricing, coupled with a lack of demand for certain commodities, undermines long-term planning and investment. Stakeholders stressed that Minnesota must prioritize market development and demand creation to ensure materials diverted from disposal can consistently find end markets.

Waste haulers echoed these concerns, noting that batteries continue to pose significant safety and cost challenges across the sector. They also voiced frustration with the patchwork of local regulations, which create inefficiencies and added costs when hauling across multiple jurisdictions. Several emphasized that statewide standardization of rules, education, and reporting requirements would make operations more efficient while also reducing confusion for residents and businesses. Smaller haulers noted that compliance with complex regulations can be a disproportionate burden, particularly when serving rural or Tribal communities where resources are limited. Figure 69 lists the self-reported regulatory or operational barriers for waste haulers.

Figure 69. Self-reported regulatory or operational barriers for waste haulers



Reuse and repair organizations highlighted the significant diversion potential of their work, with one interviewee serving up to 120,000 customers annually across its three locations. At the same time, they reported that rising rents and operating costs present barriers to expansion. Food recovery organizations described success in achieving high diversion rates – up to 95% of donated food – yet noted that their efforts rely on short-term or inconsistent funding. They also face logistical challenges in managing supply and distribution as volunteer participation shifts.

Residents

Residents represented the most survey responses with 349 completed surveys compared to 139 from all other stakeholder groups combined. Although the survey was made available in Spanish and Hmong, no responses were submitted in those languages. Most residents reported being highly engaged in waste issues, which may skew our data in favor of those who were willing to take the time to take the survey. Nearly half said they frequently consider the environmental impact of their purchases, and the most common waste reduction actions included donating or selling used items, using reusable bags and containers, and participating in recycling programs. Recycling access was widespread, with 97% reporting either curbside or drop-off access. However, this level of engagement may also skew perspectives toward more sustainability-minded households, meaning the results may not fully represent the broader public.

When asked about future changes, nearly half said they would fully support curbside food-scrap collection, with another third supporting it if convenient and well-explained. Fewer than one in ten said they would oppose such a program. Residents also voiced concerns about limited opportunities to influence decision-making, with one-third saying they do not feel included. Many noted frustrations with overflowing recycling carts, limited bulky-item options, and confusion caused by inconsistent recycling

rules. Common requests included expanded organics programs, more consistent statewide guidance, and better access to drop-off and reuse opportunities.

Common Themes Across Stakeholders



Contamination: Batteries, plastic film, cords, uncertified compostables, and hazardous materials were cited as major and costly problems in both recycling and organics systems.



Market Volatility: Market instability and lack of demand for certain commodities remain top challenges, making long-term planning and diversion program expansion difficult.



Staffing and Capacity: Local governments, Tribes, nonprofits, and facility operators all reported a need for additional staff and limited capacity as barriers to expanding programs.



Equity and Access: Waste facilities often impact low-income and BIPOC communities; service gaps were noted in multi-family housing, rural areas, and non-English speaking communities.



Organics Management: There is strong support for food-scrap diversion, but infrastructure, permitting, and education challenges limit access and expansion.



Consistency and Standardization: Conflicting recycling lists, regulations, and outreach materials cause confusion and added costs; stakeholders called for clearer statewide guidance.



Education and Outreach: Stakeholders voiced a desire for clearer, multilingual, and more consistent education; misinformation about recycling (especially plastics) undermines trust.



Infrastructure and Funding: Infrastructure gaps exist across composting, reuse systems, and rural recycling, with emphasis on the need for stable, ongoing funding beyond short-term grants.

Recommendations

Based on the findings of this report and input from stakeholders, the following recommendations outline a pathway to achieve Minnesota's 90% diversion goal. Minnesota should reassess these recommendations every five years to evaluate progress, measure effectiveness, and adjust strategies as needed. These recommendations are intended to be implemented in combination; no single policy or program change will achieve high diversion outcomes on its own.

The following recommendations are presented as an integrated policy framework. Achieving high diversion outcomes will require coordinated implementation across multiple strategies. Prioritization, sequencing, and timelines should be determined through collaborative planning with state agencies, local governments, Tribal governments, private-sector partners, nonprofits, and community stakeholders.

Implementation, education, and system support

- **implementation capacity:** establish sustainable funding to support local governments, Tribal governments, nonprofits, private-sector partners, and community-based organizations; reduce reliance on one-time grants and expand access to ongoing operational support
- **model tools and technical assistance:** provide model ordinances, toolkits, and contract language to support deconstruction and C&D diversion, expanded organics access (including multi-family housing), and organized collection systems
- **local policy flexibility:** revise Minn. Stat. § 471.9998 to allow local governments to enact plastic bag ordinances
- **statewide education and outreach:** develop a coordinated public education campaign with adaptable materials for local use; expand K–12 curricula to include waste reduction, recycling, litter prevention, wasted food prevention, and organics management
- **system standardization:** align accepted materials lists, education messaging, and hauler reporting requirements statewide; prioritize outreach to improve capture of high-value recyclables such as aluminum, steel, and cardboard
- **community-based engagement:** support education and outreach through trusted community organizations; increase public trust by communicating economic and environmental benefits; ensure multilingual and accessible materials
- **contamination reduction:** implement targeted campaigns focused on specific regions and problem materials to improve recycling and organics stream quality

Access, equity, and local implementation

- **universal access:** expand recycling and organics services beyond single-family households to include multi-family housing and the CII sector
- **statutory updates (metro and statewide):** revise Minn. Stat. § 115A.151 to expand recycling requirements beyond large generators (e.g., requiring more commercial properties and multifamily buildings to provide recycling access); update Minn. Stat. § 115A.552 to strengthen recycling access in Greater Minnesota (e.g., expanding curbside recycling and organics collection beyond current population thresholds through phased implementation)
- **nonresidential requirements:** revise statutory language to require, rather than encourage, recycling services for commercial, industrial, and institutional generators
- **alternative collection systems:** invest in drop-off and special collection programs for materials not suited for curbside systems, including bulky items and tires

- **environmental justice integration:** embed equity into all decision-making; ensure inclusive engagement with stipends, translation, childcare, and accountability measures; engage communities early in facility planning and siting

Policy, infrastructure, and market development

- **coordinated policy action:** advance high-impact policies such as landfill bans, deposit return systems, and expanded EPR; prioritize materials with high disposal impact and environmental footprint (e.g., wasted food, electronics, mattresses)
- **organics diversion:** expand and enforce requirements for large generators using models from states such as Massachusetts and New York; pair requirements with education and enforcement
- **EPR implementation:** support rollout of packaging EPR and expansion to additional material streams
- **upstream investment:** fund reuse hubs, repair programs, refill systems, and right-to-repair initiatives to reduce waste generation
- **infrastructure investment:** provide strategic funding for MRF upgrades, organics processing, and transfer infrastructure to improve system performance
- **market development:** establish a coordinated approach to end-market development, such as a market development center or innovation hub; ensure local end markets exist to sustain diversion efforts

Accountability and system performance

- **clear goals and metrics:** establish enforceable targets and expand beyond weight-based metrics to include per capita disposal, climate impacts, and system performance indicators
- **continuous evaluation:** regularly assess policies and programs to ensure effectiveness and alignment with diversion goals
- **MWP as a last resort:** ensure mixed waste processing is appropriately sized and used only for residual recovery; recognize higher costs and lower material quality relative to source-separated systems

Appendix A

Appendix A.1 MSW Disposal by County

Table 56. MSW disposed by county (tons, 2021)

County	Landfill	WTE	Total	County	Landfill	WTE	Total
Aitkin	11,245	-	11,245	McLeod	15,273	-	15,273
Anoka	187,350	18,508	205,858	Meeker	11,423	-	11,423
Becker	9,900	10,998	20,898	Mille Lacs	11,989	-	11,989
Beltrami	11,368	7,749	19,117	Morrison	24,705	-	24,705
Benton	10,698	7,626	18,324	Mower	23,936	-	23,936
Big Stone	4,809	-	4,809	Murray	4,772	-	4,772
Blue Earth	23,223	18,464	41,687	Nicollet	36,021	15,939	51,960
Brown	30,637	580	31,217	Nobles	10,615	-	10,615
Carlton	17,530	-	17,530	Norman	738	2,916	3,654
Carver	56,150	6	56,156	Olmsted	3,551	92,994	96,545
Cass	18,613	-	18,613	Otter Tail	11,184	26,576	37,759
Chippewa	11,425	-	11,425	Pennington	9,560	-	9,560
Chisago	38,922	-	38,922	Pine	21,682	-	21,682
Clay	40,557	8,425	48,982	Pipestone	5,812	-	5,812
Clearwater	7,951	3,133	11,084	Polk	11,774	19,337	31,111
Cook	3,188	-	3,188	Pope			
Cottonwood	10,191	-	10,191	Douglas	232	27,401	27,633
Crow Wing	46,095	-	46,095	Ramsey	81,696	236,012	317,708
Dakota	226,796	10,013	236,810	Red Lake	1,774	-	1,774
Dodge	774	9,217	9,991	Redwood			
Faribault	1,167	6,150	7,318	Renville	14,392	-	14,392
Fillmore	6,948	1,223	8,171	Rice	44,695	988	45,683
Freeborn	21,956	-	21,956	Rock	4,164	-	4,164
Goodhue	337	23,813	24,150	Roseau	10,347	-	10,347
Grant	0	2,744	2,744	Scott	77,768	1	77,769
Hennepin	442,189	355,436	797,625	Sherburne	38,751	4,084	42,835
Houston	1,466	6,183	7,649	Sibley	5,826	740	6,566
Hubbard	11,995	5,096	17,091	St. Louis - partial	53,952	-	53,952
Isanti	29,908	-	29,908	Stearns	42,077	29,991	72,068
Itasca	30,286	-	30,286	Steele	38,386	-	38,386
Jackson	4,410	5	4,415	Stevens	4,032	2,345	6,377
Kanabec	10,357	-	10,357	Swift	6,141	-	6,141
Kandiyohi	33,515	-	33,515	Todd	5,706	7,039	12,745
				Traverse	1,018	-	1,018
				Wabasha	158	5,338	5,496

County	Landfill	WTE	Total	County	Landfill	WTE	Total
Kittson	1,605	-	1,605	Wadena	1,356	4,983	6,340
Koochiching	8,657	-	8,657	Waseca	6,157	-	6,157
Lac qui Parle	4,533	-	4,533	Washington	30,216	87,292	117,508
Lake	5,943	-	5,943	Watonwan	2,762	-	2,762
Lake of the Woods	3,270	-	3,270	Wilkin	2,561	-	2,561
Le Sueur	11,961	4,173	16,134	Winona	25,602	1,386	26,988
Lincoln	2,810	-	2,810	RESOURCE RENEW	51,177	-	51,177
Lyon	20,851	-	20,851	Wright	106,486	-	106,486
Mahnomen	10	1,687	1,697	Yellow Medicine	4,725	-	4,725
Marshall	4,612	-	4,612	Total	2,293,084	1,075,440	3,368,524
Martin	1,680	8,851	10,531				

Appendix A.2 MSW Characterization Methodology

MSW for the state of Minnesota was characterized using a desktop waste characterization analysis. The results of selected waste characterization studies were categorized into universal categories by specific material type (e.g. glass bottles and jars, aluminum cans, mixed paper) and waste stream (single-family, multi-family, and ICI). The collected waste characterization studies were Burnsville MSW Landfill (2019), Polk County Solid Waste Resource Recovery Facility (2024), Pope/Douglas Solid Waste Management (2024), Wisconsin (2021), and Iowa (2022). The categorized results from each study were averaged, and the mean composition of each waste category was applied to the tonnage of MSW from Minnesota in the baseline year of 2021 to estimate tons of waste generated, landfilled, and sent to WTE. Further estimates of tons of data generated by waste stream (single-family, multi-family, and ICI) were calculated using the average percentage of waste composition by stream (Pennsylvania Department of Environmental Protection 2022, Illinois Recycling Association 2015, U S Environmental Protection Agency Office of Resource Conservation and Recovery 2013) to estimate residential versus commercial MSW generation. Residential waste generation was then divided by the percentage composition of single-family and multi-family households using county-level census data (U.S. Census Bureau, 2020). Possible diversion strategies were assigned to each specific material category for analysis. For example, corrugated cardboard is able to be sorted at a MRF and is thus MRF-compatible, while plastic film is generally not sortable at MRFs and instead is likely to be collected through drop-off or special collection programs, and wasted food through organics recycling.

Table 57. Detailed desktop waste characterization for Minnesota

General category	Specific category	Management of material	Single-family	Multi-family	ICI
Glass	Glass Non-Container	Drop-off/Special Collection	19,516	5,292	20,738
Glass	Glass Bottles and Jars	MRF-compatible	7,848	2,128	13,019
Metal	Aluminum Cans	MRF-compatible	13,643	3,699	16,016
Metal	Steel Cans	MRF-compatible	10,127	2,746	12,231
Metal	Ferrous Scrap	Drop-off/Special Collection	23,314	6,321	43,914

General category	Specific category	Management of material	Single-family	Multi-family	ICI
Metal	Non-ferrous Scrap	Drop-off/Special Collection	10,367	2,811	12,191
Organics	Wasted Food	SSO	257,442	69,805	341,695
Organics	Other Recyclable Wood	Drop-off/Special Collection	36,987	10,029	121,996
Organics	Leaves and Grass	SSO	36,149	9,802	25,402
Organics	Other Organics	SSO	112,668	30,550	129,797
Paper	Corrugated Cardboard	MRF-compatible	41,558	11,268	124,948
Paper	Paperboard Boxboard	MRF-compatible	20,214	5,481	24,430
Paper	Newspaper (ONP)	MRF-compatible	8,563	2,322	8,859
Paper	Magazines	MRF-compatible	15,358	4,164	19,658
Paper	White Office	MRF-compatible	13,183	3,575	19,364
Paper	Mixed Paper	MRF-compatible	61,984	16,807	86,251
Paper	Gable-top and Aseptic Cartons Combined	MRF-compatible	5,883	1,595	13,452
Organics	Compostable Paper	SSO	71,650	19,428	104,357
Plastic	Plastic PET #1 Bottles	MRF-compatible	16,109	4,368	21,452
Plastic	Plastic PET #1 Non-Bottle	MRF-compatible	7,048	1,911	7,822
Plastic	Plastic HDPE #2 Bottle & Non-Bottle colored and natural combined	MRF-compatible	13,612	3,691	18,629
Plastic	Plastic PS #6 Expanded Polystyrene	Drop-off/Special Collection	8,159	2,212	9,758
Plastic	Plastic PP#5	MRF-compatible	17,431	4,726	20,295
Plastic	Plastic Mixed Plastics Rigid #3-#7	MRF-compatible	19,107	5,181	27,769
Plastic	Plastic Film	Drop-off/Special Collection	93,119	25,249	143,700
Plastic	Plastic Other Plastic	Drop-off/Special Collection	34,517	9,359	48,947
Textiles	Textiles	Drop-off/Special Collection	81,929	22,215	93,556
Other	Electronics	Drop-off/Special Collection	15,963	4,328	21,699
Other	Construction and Demolition Other Construction and Demolition	Drop-off/Special Collection	22,751	6,169	49,466
Other	HHW	Drop-off/Special Collection	8,327	2,258	14,677
Other	Bulky Waste Mattresses	Drop-off/Special Collection	2,443	662	1,621
Other	Bulky Waste Carpet	Drop-off/Special Collection	11,906	3,228	25,652

General category	Specific category	Management of material	Single-family	Multi-family	ICI
Other	Bulky Waste Other Bulky Waste	Drop-off/Special Collection	7,760	2,104	15,034
Other	Tires	Drop-off/Special Collection	0	0	1,992
Other	Residue	Non-Recyclable	127,845	34,665	91,947
Paper	Paper Non-Recoverable	Non-Recyclable	8,240	2,234	11,090
Total			1,262,719	342,383	1,763,422

Appendix A.3 Prevention and Reuse Industries

The scope for defining reuse centers was focused on identifying organizations engaged in the repair, reuse, or rental of items that would otherwise end up in municipal waste streams. A review of the full list of six-digit NAICS codes was conducted, with the following criteria applied to define reuse centers:

- **inclusion criteria:** organizations associated with codes that mention terms such as “recycle,” “salvage,” “repair,” “rental,” or “used” in their descriptions; companies whose primary operations involve the sale and/or use of secondary goods, repair or rental or items that would otherwise contribute to MSW streams
- **exclusion criteria:** organizations dealing with materials not commonly found in standard MSW streams (e.g., automotive parts, tires, boats); companies where repair services are not the primary focus of the business (e.g., jewelry stores that may offer repairs but primarily sell new jewelry); manufacturers who create products from other materials (e.g., textile and steel mills)

The application of these criteria resulted in the identification of 9 NAICS codes relevant to reuse centers, outlined below.

- All Other Consumer Goods Rental (532289)
- Appliance Repair and Maintenance (811412)
- Community Food Services (624210)
- Consumer Electronics and Appliances Rental (532210)
- Electronic and Precision Equipment Repair and Maintenance (811210)
- Footwear and Leather Goods Repair (811430)
- Formal Wear and Costume Rental (532281)
- General Rental Centers (532310)
- Home and Garden Equipment Repair and Maintenance (811411)
- Home Health Equipment (532283)
- Office Machinery and Equipment Rental and Leasing (532420)
- Other Personal and Household Goods Repair and Maintenance (811490)
- Recreational Goods Rental (532284)
- Recyclable Material Merchant Wholesalers (423930)
- Reupholstery and Furniture Repair (811420)
- Used Merchandise Retailers (459510)
- Video Tape and Disc Rental (532282)

RRS used these NAICS codes to search for corresponding businesses in Minnesota using the Data Axle platform. This enabled us to generate a list of businesses for each NAICS code we defined as a reuse center.

Appendix A.4 Prevention and Reuse Case Studies

Achieving the modeled 90% diversion scenario requires substantial increases in waste prevention and reuse, particularly within Minnesota's CII sector. The modeling indicates that more than half of additional diversion must come from CII sources, where material generation volumes are highest and operational decisions strongly influence waste outcomes. The following case studies, drawn from Minnesota and national examples, illustrate how prevention and reuse strategies can reduce material generation before it enters recycling or disposal systems. These examples demonstrate practical pathways for scaling upstream solutions statewide.

Prevention

Packaging Reduction Through Minnesota Technical Assistance Program (MnTAP)

MnTAP, housed at the University of Minnesota, provides technical assistance to businesses seeking to reduce waste, improve material efficiency, and lower operating costs. Through confidential on-site consultations, MnTAP has helped manufacturers and food processors identify opportunities to reduce packaging materials, minimize production scrap, and redesign processes to prevent waste before it is generated.

For example, MnTAP has assisted companies in transitioning to lighter-weight packaging, optimizing material use during production runs, and reducing off-spec product waste. These improvements not only decrease landfill disposal and hauling costs but also reduce raw material purchasing expenses and energy use associated with manufacturing. By focusing on source reduction rather than downstream diversion, MnTAP demonstrates how prevention strategies can simultaneously improve environmental performance and business profitability.

Wasted Food Prevention in Minnesota Grocery and Food Service Operations

Food waste prevention efforts in Minnesota have increasingly focused on upstream strategies within grocery stores, food manufacturers, and institutional kitchens. Many Minnesota retailers partner with food rescue organizations such as Second Harvest Heartland to redirect surplus edible food to hunger relief organizations rather than disposal.

In addition to donation, grocery chains and institutional kitchens have implemented improved inventory management systems, revised ordering practices, and staff training programs to reduce spoilage and shrink. Hospitals and universities across Minnesota have adopted operational changes such as trayless dining, batch cooking, and improved forecasting to reduce plate waste. These operational adjustments reduce wasted food at the source, lower purchasing costs, and decrease the volume of material requiring composting or disposal.

These examples illustrate that prevention in the CII sector can significantly reduce organics generation before materials enter the waste management system.

Plastic Bag Reduction Policies in Minnesota Cities

Although Minnesota law currently preempts most local regulation of merchant bags under Minn. Stat. § 471.9998, several cities adopted policies prior to the preemption law or structured ordinances within

allowable pricing authority. Cities such as Minneapolis and St. Louis Park implemented ordinances that require retailers to charge for single-use paper bags and restrict certain plastic bags.

These policies are designed to reduce single-use bag consumption and encourage reusable bag use. Local experience demonstrates that pricing mechanisms and public education can shift consumer behavior toward reusable alternatives. While policy design details influence effectiveness, these examples show how local governments can use economic signals and education to prevent waste generation upstream.

General Mills – Manufacturing Food Waste Reduction (Minnesota Operations)

General Mills, headquartered in Golden Valley, Minnesota, has implemented food waste prevention strategies across its manufacturing operations, including facilities in Minnesota. Through improved production forecasting, enhanced quality control, employee engagement, and operational efficiency measures, the company has reduced food waste generated during manufacturing.

As part of its public sustainability report, General Mills has documented reductions in food waste across its global manufacturing network, reporting measurable decreases in production-related food loss over time. These efforts include redesigning production processes to minimize off-spec products, improving storage and handling practices, and diverting unavoidable residuals to higher-value uses such as animal feed rather than disposal.

Manufacturing-level food waste prevention represents a high-impact strategy within the CII sector. Even modest percentage reductions in production loss can translate into substantial tonnage reductions due to the scale of food manufacturing operations. By preventing food waste before it enters the waste management system, manufacturers reduce disposal costs, conserve embedded resources such as water and energy, and lower greenhouse gas emissions associated with wasted food.

This example demonstrates how upstream prevention in large-scale food manufacturing can contribute meaningfully to statewide diversion goals, particularly given that more than half of modeled additional diversion must come from the CII sector.

Reduced Mylar Waste in Alameda County, California

The StopWaste Partnership is a public agency in Alameda County, California that provides technical assistance to residents, businesses, and schools for waste prevention efforts. One initiative provided a grant through the Business Waste Prevention Fund to a local family-owned business in Oakland, Peerless Coffee & Tea. As a small business, Peerless Coffee & Tea was previously unable to invest in new capital projects for waste prevention. StopWaste's analysis found that besides coffee-roasting byproducts, the most significant source of waste was Mylar scrap from coffee packaging, which was not practical to recycle. Peerless' packaging process used machines that needed to be manually recalibrated each time the packaging for one product size was changed to packaging another. Mylar packaging continued to flow through the machinery during the calibration process, producing excess non-recyclable waste. A \$100,000 grant helped Peerless Coffee & Tea purchase upgraded, computerized coffee packaging equipment that increased efficiency in the packaging process. The new computerized packaging equipment can be calibrated electronically, which reduced Mylar waste by 95% and saved \$100,000 annually in reduced packaging supply costs. This project ultimately reduced Peerless Coffee & Tea's waste stream by 85% (StopWaste 2025).

Wasted Food Reduction Through The Pacific Coast Waste Commitment

The Pacific Coast Food Waste Commitment (PCFWC) is a collaborative public-private partnership with the goal of preventing and reducing wasted food. As part of this effort, the PCFWC has initiated

employee engagement projects to reduce wasted food at consumer-packaged goods manufacturing facilities on the Pacific Coast. Starting in March 2024, Fresh Del Monte began an initiative to identify and implement wasted food mitigation strategies at a manufacturing plant in North Portland, Oregon. The project began with providing foundational awareness about wasted food with a bilingual training video for employees. Then, employees were encouraged to submit “quick win” ideas to prevent wasted food that are simple to implement but yield significant savings. The chosen wasted food reduction opportunity developed a new process for inspecting fresh produce that recovered and incorporated edible food into finished products. A pilot study of the new procedure measured recovery of between 47-64% of fruit that would have been wasted in the previous process. This equated to 4,620 additional units of finished product that the facility could have produced over the five-week trial period (Pacific Coast Food Waste Commitment 2024b). Previous employee engagement projects with Land O’Lakes reduced wasted food of one product by 74%, projected to save the company \$3,500 annually, and Bob’s Red Mill achieved an average reduction in wasted food by over 70% on manufacturing lines where the change was implemented (Pacific Coast Food Waste Commitment 2024a; Pacific Coast Food Waste Commitment 2022). These projects leverage employee knowledge of production processes to achieve low-cost, yet effective prevention of wasted food.

Plastic Bag Bans and Fees Across 12 States

While the legislature enacted a law in 2017 that prohibits local jurisdictions from implementing ordinances to prohibit or restrict the use of plastic bags regulations prohibiting the sale of single-use plastic bags have been effective in preventing waste. Plastic bags cause a disproportionate number of deaths in wildlife than other kinds of plastic and are one of the most common causes of damage to recycling equipment. As of March 2025, twelve US states have banned single-use plastic bags: California, Colorado, Connecticut, Delaware, Hawaii, Maine, New Jersey, Oregon, New York, Rhode Island, Vermont, and Washington. Half of these states have mandatory fees for reusable or paper bags, ranging from five to ten cents (Retail Compliance Center 2025). Reviews of studies on plastic bag bans indicate that such policies can eliminate an average of nearly 300 single-use plastic bags per person per year, reducing plastic bag litter by at least one-third. Studies on single-use bag bans in California found that customers were much more likely to use reusable bags or use no bags after the policy was implemented. However, key aspects of the policy design of single-use bag bans have been found to impact their effectiveness in preventing waste. Jurisdictions that allow more durable “reusable” plastic bags for a fee saw increases in the total weight of plastic waste, as these thicker, heavier plastic bags are often only used once by customers. Additionally, jurisdictions that do not implement fees for paper bags at checkout see increased consumption of paper bags; while paper bags are widely recyclable, they are also environmentally intensive to produce. Policy that encourages the use of reusable bags are the most effective in preventing overall waste. Statewide bag bans in New Jersey and Vermont are estimated to eliminate the use of 5.51 billion and 191 million bags per year, respectively. Estimates of the impact of city-level bag bans have reduced annual plastic bag use by 200 million in Philadelphia, 100 million in Portland, Oregon, and nearly 45 million in Santa Barbara, California (Environment America, US PIRG Education Fund 2024).

Reuse

Hennepin County Fix-It Clinics

Hennepin County operates Fix-It Clinics that provides residents with free assistance from volunteer repair experts to repair household goods such as electronics, small appliances, clothing, and bicycles. Since the program’s inception, thousands of items have been repaired, diverting usable materials from disposal and extending product life.

The clinics reduce waste generation, save residents money, and build community repair skills. By lowering barriers to repair and normalizing product maintenance, the program supports waste prevention while strengthening local capacity for reuse.

Bridging – Furniture Reuse and Social Impact

Bridging is a Minnesota-based nonprofit organization that redistributes donated furniture and household goods to families transitioning out of homelessness and poverty. By collecting gently used furniture from households and businesses and redistributing it to families in need, Bridging diverts usable materials from disposal while providing essential household items at no cost to recipients.

This model demonstrates how reuse systems can deliver both environmental and social benefits. Furniture reuse reduces landfill tonnage, avoids the environmental impacts of new product manufacturing, and supports housing stability and equity outcomes.

Minnesota Digital Fair Repair Act

In 2023, Minnesota enacted the Digital Fair Repair Act, which requires manufacturers of certain electronic equipment to make parts, tools, and repair information available to consumers and independent repair providers. By reducing barriers to product repair, the law supports longer product lifespans and reduces premature disposal of electronics.

Electronic waste represents a relatively small percentage of total waste by weight but contains valuable materials and potentially hazardous components. By enabling repair and maintenance, Minnesota's Right to Repair law supports waste prevention, reduces e-waste generation, and strengthens local repair economies.

Reusable Containers in Boulder Valley School District, Colorado

The Boulder Valley School District in Colorado is comprised of 56 schools and serves over 30,000 students across 12 communities in the Front Range. In the 2014-2015 school year, the district continued its sustainability efforts by replacing corrugated cardboard used in the delivery of food for reusable containers. In previous years, the school district had also replaced disposable trays, silverware, and cups for reusable ones. The pilot program for reusable containers was funded by a StopWaste grant, which provided reusable plastic containers for the delivery of apples and hamburger patties. Suppliers package food directly into reusable containers, which are then washed at schools and picked up when new shipments are delivered. This change resulted in an annual savings of over \$4,500 in packaging costs and a reduction in over 4,500 pounds of cardboard from entering the waste stream, as well as a reduction in labor for breaking down cardboard boxes (RPA Reusable Packaging Association 2015).

Reusable Cup Program at Portland Sports Events

In order to address excessive use of single-use plastic from concessions at event and sports venues, the Portland Trail Blazers NBA team, concessionaire Levy Restaurants, and Bold Reuse created the Rip City Reuse program at the Moda Center in Portland, Oregon. Rip City Reuse is a stadium-wide, reusable cup program for alcoholic beverages. After use, cups are returned to reuse bins and then transported to an off-site facility to be washed and sanitized. Since implementation, this program has an average return rate of 82%, eliminating the use of nearly one million single-use cups and keeping over 30,000 pounds of waste out of landfills (BOLD Reuse 2025). A life-cycle analysis of reusable and single-use cups by the University of St. Thomas quantified the environmental benefits of introducing reuse systems for cups at sports and entertainment venues like the Moda Center. The study concluded that reusable polypropylene and stainless-steel cups are the most sustainable, outperforming single-use cups in all environmental metrics, including the transportation and washing of reusable cups. If the average

stadium replaced single-use cups with reusable cups, it would divert over 60 tons of plastic from landfill annually (REUSE 2025).

Right to Repair in California

In 2023, California passed the Right to Repair Act, which requires that manufacturers of electronic equipment and appliances provide service, information and functional parts for the maintenance and repair of their products. Similar laws have been passed in other states and countries around the world to lower barriers for consumers to maintain and repair consumer electronics, household appliances, and vehicles. While electronic waste only accounts for 2-3% of global waste, many electronic components contain toxic materials that are hazardous if not managed correctly, and less than 20% of e-waste is recycled (Earth.org 2023). The average US household generates about 115 pounds of e-waste annually and spends nearly \$2,000 annually purchasing new electronic products (U.S. PIRG Education Fund 2023). Right to repair laws have the potential to decrease overall e-waste by significantly extending the lifespan of products; electronics that previously would have been landfilled due to one faulty component can be repaired and reused, in turn reducing the purchase of replacement products.

Reuse/Refill Infrastructure and Programs:

Cities of all sizes have installed water bottle refill stations that can reduce the use of single use plastic water bottles. For Example, the City of Jacksonville, Onslow County, NC Cooperative Extension – Onslow County, Onslow County Schools, and Sturgeon City are collaborating in a “Reuse It Refill It” initiative which aims to increase the number of water bottle refill stations in public buildings and schools. As of 2019 more than a dozen stations had been installed through the initiative. Similarly, New York City is planning to install 500 water fountains and water bottle refill stations between 2015 and 2025.

Higher Education Campus Move-In/Move-Out Programs:

Student move-outs present a major opportunity for waste diversion, as students leave behind reusable items that often end up in landfills. Many universities have successfully implemented donation and reuse programs to tackle this issue. Home goods and clothing often are collected at move out, stored over the summer and made available to students when they return in the fall for sale. Alternatively, universities can partner with charities so that donatable items are set aside for charities at move-out.

In 2024, the University of Michigan diverted 10.6 tons of items through its Move-Out Donation Program. At Michigan State University, the Surplus Store and Recycling Center collected 500,000 pounds of materials during move-out, including 115,000 pounds that were directly diverted from landfills. According to the District of Columbia’s 2023 Reuse Report, Move-In/Move Out Programs had the following results at universities in Washington, DC: American University Collected 4.7 tons of clothing for donation and 4.5 tons of home goods, which were distributed during move-in fall 2023. Catholic University Diverted approximately 3,500 pounds of clothing and dorm room essentials, much of which was used to restock the Cardinal Closet (on-campus thrift store) and Cardinal Cupboard (on-campus food pantry) or distributed to students during move-out. Georgetown University Partnered with 17 non-profits to collect and donate more than 35,000 pounds of clothing, furniture, and household goods valued at \$340,000.

Appendix A.5 Infrastructure Modeling Methodology

Infrastructure data was assessed using multiple data sources, including:

- data received from MPCA in December of 2024 and January of 2025
 - permitted facilities from 2019-2023

- waste origin and destination data
 - landfill design capacity and estimated end of life
- 2020, 2021, and 2022 MPCA score reports
 - tons each county sent to WTE
 - tons each county sent to landfills
 - tons each county diverted through organics and recycling processes
- MPCA GIS portal
 - all solid waste facility site identifiers
- RRS database
 - solid waste facility site data
 - sorting facility tonnage information

Active and permitted facilities were compared to the RRS database of landfills, sorting facilities, WTE, and organics processing facilities across the state. Then, the RRS database was matched to the MPCA permitted site data, so that all available facility information was joined together. The site type description created by MPCA was used to determine the category each facility was identified as, along with the RRS database facility type.

The flow of MSW bound for disposal through WTE or landfills was analyzed from both the MPCA Score Reports, and the waste activity and counties served datasets provided by MPCA. RRS identified the tons of waste flowing from each county to WTE from 2020-2022, creating a 3-year average. RRS used this average as the baseline in determining how WTE closures would impact landfills.

The MSW landfills used by each county from 2020 to 2023 were identified from the counties served dataset provided by MPCA. Data gaps for certain counties were found in this dataset. Landfill design capacity and end of life was analyzed from the 2023 land disposal activity dataset, which provided an updated outlook on the status of each landfill in the state.

To create an estimated impact of closing each WTE facility, RRS started by looking at the flow of MSW from each county to each MSW landfill. However, there are data gaps and inconsistencies when summarizing data as compared to the MPCA score report, likely due to differences in reporting from transfer facilities and out-of-state facilities. RRS defaulted to using the tonnages by county found in the MPCA score report when needed.

To provide an estimated impact of closing WTE facilities, RRS assumed the following:

- 2020-2022 tons per county to WTE from the MPCA Score Reports was accurate
- counties served dataset of county-to-landfill MSW data was accurate
- no additional diversion would take place in any county using WTE facilities
- each county using WTE facilities would continue using the same landfills that they used from 2020-2023.
- each of the selected landfills would receive an equal proportion of the MSW the county is currently sending to WTE

RRS analyzed the impacts by taking a proportionate amount of waste currently being sent to WTE to each landfill that a county has used from 2020-2023. RRS assumed that counties may be utilizing certain landfills due to geographic access, competitive pricing, prior agreements with the landfill, and other reasons. Due to data limitations, RRS decided to project the impacts of closures by sending an equal proportion of MSW currently being sent to WTE to each landfill used by the county. For example, if a county was using three different landfills in the counties served dataset and sent 21k tons to WTE

annually on average from the MPCA score report, those specific three landfills they are already using would receive an additional seven tons of waste annually.

Additional data that would assist RRS in creating alternative landfill impact projections would be:

- clarity on discrepancies between the annual tons of MSW landfills between the counties served and waste activity datasets
- how counties utilizing MSW landfills that are near end-of-life plan to re-direct MSW
- clarity on counties missing an MSW landfill in the counties served dataset
- which counties are sending MSW out of state through transfer, and how many tons are being sent
- which landfills may have plans for future expansion in design capacity

Appendix A.6 Additional Facility Specifications

The modeled additional facilities needed to reach the low and high diversion scenarios are based on some basic facility specifications outlined in the tables below.

Table 58. Additional MRF facility sizes and specifications

Facility size	Tons per hour	Shifts/day	Hours/shift	Days/week	Uptime	Hours/year	Tons/year
Small	10	1	8	5	90%	1,872	19,000
Medium	15	2	8	5	90%	3,744	56,000
Large	50	2	8	5	90%	3,744	187,000

Appendix A.7 Methods of Managing Organics Waste

Windrow Composting

Windrow composting is the oldest and most widely adopted form of industrial composting, with origins in agricultural practices dating back centuries and formalized as a municipal strategy in the mid-20th century. Its simplicity, reliance on low-cost equipment, and suitability for large volumes of yard trimmings and agricultural residues made it the dominant method in early municipal organics programs. In most cases, windrows are constructed in long, narrow piles (6-8 feet high) that are turned regularly to maintain aerobic conditions. Today, windrow systems remain the most common form of large-scale composting worldwide, particularly in regions with ample land and favorable climates. However, concerns about odor control, slower processing times, and pathogen reduction have limited its adoption in densely populated or highly regulated areas. They were often built in response to the widespread encouragement of yard waste collection through landfill bans and the desire to improve recovery rates overall. The overall decomposition and stabilization processes can take between 6 and 12 months, making windrow processing comparatively inefficient from a land use perspective. Integration of food waste or other source-separated organic streams is often difficult to manage and is not typically recommended in quantities that exceed 10% of the entire volume of material.

Static Pile Composting

Static pile composting emerged as a low-tech alternative to windrows, designed for situations where frequent turning and high labor inputs were impractical. By relying on bulking agents and passive aeration, static piles offer a simple and inexpensive method for small- to medium-scale operations, particularly in rural or agricultural contexts. Passively aerated systems use bulking agents such as chipped wood and smaller pile sizes than windrow composting. Despite its accessibility, this method has

never reached the same scale of adoption as windrow composting, largely because its slower, less uniform decomposition and greater variability in material quality. Its current penetration is modest, typically confined to farms, local governments, and private operators who value minimal infrastructure investment over throughput or regulatory precision. Integration of food waste or other source-separated organic streams is often difficult to manage and is not typically recommended in quantities that exceed 10% of the entire volume of material. Static pile composting has fewer maintenance costs than windrow but longer process times and larger space needs.

Aerated State Pile (ASP) Composting

ASP composting was developed in the 1970s as a technological solution to address odor, space, and regulatory problems that were beginning to limit the deployment of windrow composting. By using blowers and controlled airflow, ASP systems achieve higher process control, shorter composting times, and better pathogen reduction, making them attractive for urban or peri-urban facilities handling food waste, biosolids, and mixed organics. Forced aeration eliminates the need for turning of the piles during the most active portion of the process. While more capital-intensive than windrows, ASP has gained significant market penetration in North America, Europe, and parts of Asia, where regulations require stricter environmental and product quality standards. It now represents a substantial share of the commercial composting sector, especially in programs tied to municipal food waste diversion. The technology is also well suited to more volatile feedstocks like food waste, other source separated organic streams and manures. Enhanced process control enables aerobic breakdown to occur more quickly than windrow composting, often requiring only 4 to 6 months.

In-Vessel Composting

In-vessel composting is the most technologically advanced and capital-intensive option, developed in the late 20th century to process challenging waste streams such as food scraps, biosolids, and animal byproducts in a fully enclosed, controlled environment. These systems offer rapid decomposition, active odor management, and consistently high product quality when accompanied by uncontaminated input streams. They are well-suited for urban areas, institutional settings, and jurisdictions with stringent air quality, health, and environmental standards. High costs and complex operations limit widespread adoption. In-vessel systems represent a relatively small but strategically important segment of the composting market, often deployed where space constraints, odor control, or regulatory compliance make lower-tech methods infeasible. Because of process controls and precise aeration, they can produce compost more quickly (primary composting - 21 days and curing - 30 – 60 days) than most other means. They are also capable of high throughputs, with some operations exceeding 50 -tons per day.

Anaerobic Digestion (AD)

AD is a biological process that breaks down organic material in the absence of oxygen, producing biogas (a mixture of methane and carbon dioxide) and a nutrient-rich digestate. First deployed at wastewater treatment plants in the early 20th century, AD gained momentum in Europe during the 1970s energy crises as both a renewable energy strategy and a waste management solution. In the past two decades, AD has expanded beyond wastewater to include food waste, manure, and other organics, driven by renewable energy incentives, landfill diversion policies, and carbon reduction goals. Today, AD systems are well established in Europe, particularly in Germany, the UK, and Scandinavia, where supportive policy frameworks and energy markets have enabled thousands of installations. Penetration in North America has been slower but is increasing as municipalities and private operators seek solutions for food waste diversion and renewable natural gas production. While AD requires high capital investment and skilled operation, it produces multiple revenue streams, energy, tipping fees, and digestate for soil amendment, positioning it as an increasingly important technology in integrated organics management systems.

AD presents some challenges as an organics management approach. Many systems, especially those categorized as “wet-AD” are designed in order to enable the organic material to be pumped, requiring very high moisture content. While this enhances overall gas production, it also creates high quantities of liquid as well as solid digestate. Both of these streams need to be managed, often at substantial cost. A typical end state for liquid digestion is treatment at a wastewater treatment plant where typically fees are assessed by gallon. Solid digestate, after dewatering, also requires further stabilization which can often mean composting. Each of these terminal steps can require substantial capital investment and/or operating cost expenditure. Recently, some developers have started to consider pyrolysis of the solid digestate, especially because it has complementary benefits like PFAS stabilization and carbon sequestration benefits.

Composting and AD represent two complementary but distinct strategies for managing organic waste, differing primarily in their outputs, infrastructure requirements, and market positioning. Composting is an aerobic process that stabilizes organic material into a soil amendment, emphasizing nutrient recycling and soil health benefits; it is generally lower cost, less technologically complex, and widely deployed where land is available and product markets exist. By contrast, AD is an anaerobic process that prioritizes energy recovery through the generation of biogas while also producing a digestate that can be used as a fertilizer or soil amendment, though often requiring post-treatment. AD facilities are typically more capital- and operations-intensive, requiring advanced engineering and stable energy markets to be financially viable. As a result, composting dominates in jurisdictions prioritizing soil enrichment and low-cost diversion of yard and food wastes, whereas AD has gained stronger traction in regions with robust renewable energy incentives, landfill bans, or carbon reduction mandates. Together, the two technologies offer complementary roles: composting supports solid health and carbon sequestration, while AD produces renewable energy generation and recovers value from organic waste.

Appendix A.8 Mixed Waste Processing (MWP) Technology

Examples of MWP Facilities

R&E Center (Newport, MN)

The R&E Center in Newport, Minnesota, was purchased by Ramsey and Washington Counties in 2015. In 2024, the facility processed approximately 450,000 tons of municipal MSW. The system begins with the removal of bulky and hazardous items before MSW is loaded onto the infeed conveyor. Material first passes through a shredder, after which an overhead magnet removes ferrous metals for recycling. Disc screens then separate material by size, with a 2-inch minus screen allowing organics-rich material to fall through. In the future, these organics are planned to be directed to AD, producing biogas, digestate, and biochar.

Remaining material is further sorted by two-dimensional versus three-dimensional characteristics. Three-dimensional items are separated using a combination of optical sorters and robotic systems. Optical sorters target #1 and #2 plastics for recovery, while robotics help remove contamination from the plastic streams. Finally, aluminum is recovered using an eddy current separator.

Project Juno (Toledo, OR)

Project Juno is a demonstration-scale (capacity of 80,000 TPY) facility co-located at a Georgia Pacific containerboard mill. The project began in February 2022 and primarily runs on MSW generated in Lincoln County, Oregon. The demonstration facility includes a basic automated MWP facility with integrated hydrolysis and pulping for fiber. The fiber pulp is sent directly to the co-located containerboard mill. After a manual pre-sorting process to remove bulky items like furniture, material

undergoes a wet separation process where liquid food and pulp are separated from solids like plastics, metals, glass, textiles, and other materials. The liquid fraction is then sent to an 8-step process where fibers are aggregated, cleaned, and pumped to a wet AD system to produce biogas. The solid fraction of the stream goes through a process which separates grit, rigid plastics, non-ferrous metals, and ferrous metals. The remaining residue may be landfilled, converted into fuel, or sold to cement kilns. The demonstration site reported a diversion rate of 46%, with capture rates of 90% for organics, paper, rigid plastic, and glass, and 85% of metals.

Athens Services (Sun Valley, CA)

This facility was renovated in 2017 and is designed to process 330,000 TPY. First, the facility pre-processes material using bag breaker screens and a drum separator to separate recyclables and organics from non-recyclable materials. Recyclable materials run through an automated MWP facility with screens that separate cardboard and containers. The container line also includes an eddy current separator, optical sorters, and an AI quality control robot. Organic materials go through an Organic Separation Press (OSP) which presses out liquids for AD. The estimated capture rates for this system are 60% of organics (primarily liquids), 85% of metals, and 55% of cardboard and plastics. It is not expected to capture mixed paper or glass, and 25-50% of paper products are anticipated to be too saturated for recovery and move through the organics stream.

CleanLane Resource Recovery Facility (Goshen, OR)

CleanLane Resource Recovery Facility is under development and set to open in 2026. The facility incorporates best practices from other facilities designed by Bulk Handling Systems. The facility is sized to process MSW generated in Lane County and is expected to process 80,000 TPY. MWP begins with bagged waste and a manual pre-sort to remove bulky items. Material is loaded into shredders to further reduce any remaining bulky items. Recyclables are separated from organics using disc screens, and organic materials are sent to an on-site anaerobic digester to produce biogas, which is upgraded to renewable natural gas. The remaining fraction moves through an advanced MRF which employs artificial intelligence, optical sorters, robotics, eddy currents, magnets, and an autonomous container loop to capture metals, plastics, and cardboard. The facility is estimated to divert up to 55% of MSW, including 85% of metals, 80% of organics, and 55% of cardboard and plastics.

RDS Virginia – AMP ONE (Portsmouth, VA)

This MWP system was built alongside an existing MRF and compost facility and began operating in 2023. The system is designed for co-location at landfills and can be scaled up to 750,000 TPY. The system separates bagged MSW into organics, recyclables, and residue. The only sortation technology employed is fully automated AI enabled optical jet sorters that target different materials and can be continually optimized. Material can be circulated continuously to maximize capture of target materials. Organics are currently managed through the co-located composting site, with AD and biochar production planned for future development. The system can divert more than 60% of MSW, including over 80% of recyclables such as rigid plastics, plastic film, and cardboard.

Placer County Waste Recycling Compound – FCC (Lincoln, CA)

Originally built in 1995, this MWP facility continues to operate while a new facility is built that can meet the state's organics diversion target of 75%. The new facility is designed to process 110 tons per hour (250,000-300,000 TPY) of MSW and 60 tons per hour of C&D waste. The new facility will include a highly automated sorting process using shredders and auger screens to separate organics and recyclables. Recyclable materials run through the MRF system for recovery, which includes trommels, optical sorters, AI-powered quality control robotic sorters, density separators, magnets, and eddy currents. A paper

dryer prepares cardboard and paper for baling and marketing. The organic fraction is sent to a covered ASP composting system. This new system is expected to recover about 60% of materials from incoming streams.

WM Sun Valley Recycling Park – Rialto Biodigester (Sun Valley/Rialto, CA)

WM's Sun Valley Recycling Park includes a transfer station with a system for diverting organic materials from MSW, which is transported about 65 miles to the Rialto Bioenergy Facility for digestion. The sorting system uses a series of shredders, disc screens, and magnets to separate organic and heavy materials from the rest of the stream. This material moves through a press that squeezes out food and other organic material, which is digested and converted into renewable natural gas and fertilizer. This system can process 50 tons per hour of organic material but does not recover recyclable materials

Appendix A.9 Biochar

Biochar is a carbon-rich byproduct generated through pyrolysis, a thermal process that heats organic materials such as yard trimmings, SSO, wasted food, and other biodegradable inputs in a low-oxygen environment. During this process, volatile gases are released, leaving behind a porous, stable form of carbon. Because the carbon in biochar is resistant to decomposition, it offers long-term sequestration benefits and may qualify for carbon offset credits.

Under Minnesota's waste hierarchy, biochar production from SSO or other organics extracted through mixed waste processing may qualify as a recycling strategy—but only if certain conditions are met. The quality of the resulting material and its end use are key. For example:

- use of biochar as alternative daily cover (ADC) at a landfill would not count as recycling, as landfilling precludes further beneficial use
- use of biochar as a soil amendment, in manufactured products, or as a carbon-negative additive in construction materials would likely meet recycling criteria

As with all thermal conversion technologies, siting and emissions must be managed equitably to avoid placing additional burdens on already-impacted communities. Unlike traditional incineration, pyrolysis with thermal oxidation does not combust material in an oxygen-rich environment, thereby reducing the formation of harmful emissions such as dioxins and furans.

Standards and Definitions Needed

To ensure consistency, Minnesota will ultimately need to establish:

- **a formal definition of biochar** under state law
- **testing standards and classifications for use**, similar to compost (e.g., Class I compost for unrestricted use; Class II compost with restrictions and distribution plans)
- **material quality benchmarks**, particularly important when feedstocks are derived from mixed waste processing, where the composition and potential contaminants of the final product remain uncertain. In addition, outputs must be tested for hazardous additives, including PFAS and brominated flame retardants, to ensure that recycling pathways do not reintroduce these chemicals into new products. Biochar derived from contaminated feedstocks should only count as recycling if testing verifies it meets health-protective standards for unrestricted or restricted uses

Applications and Benefits

- **soil health**: enhances moisture retention, nutrient availability, and microbial activity

- **process enhancement:** can accelerate composting and increase biogas yields in anaerobic digestion (AD)
- **pollution control:** effective for odor, pollutant, and nutrient capture
- **construction materials:** a carbon-negative additive for the built environment
- **digestate management:** offers stabilization benefits for AD digestate, a material increasingly challenged by contamination

PFAS Mitigation Potential

Concerns about PFAS in food scraps, packaging, and organic residuals limit the safe reuse of compost and digestate. Conventional options such as incineration for energy or landfilling as ADC fail to recover nutrient value and do not count toward Minnesota’s diversion goals.

Pyrolysis, followed by thermal oxidation of the syngas produced, offers a promising pathway for PFAS destruction. The U.S. EPA, working with BioForce Tech and PYREG, has tested rotary biodryers paired with modular pyrolysis units. Pilot projects, including one at Silicon Valley Clean Water, demonstrate high PFAS removal rates while still producing a usable biochar byproduct.

Implementation Considerations

- **energy balance:** after startup, pyrolysis is generally self-sustaining, but feedstocks must be dried to ~15% moisture
- **current deployment:** most U.S. applications are at wastewater treatment plants for sludge management
- **emerging opportunities:** expansion to mixed waste processing is gaining attention, especially where PFAS mitigation and carbon reduction are priorities

Appendix A.10 Economic Impact Assessment Methodology

Table 59 lists the NAICS codes included in the IMPLAN economic contribution and impact analyses, which evaluate the current economic output of recycling, reuse, and remanufacturing industries, as well as the economic impacts associated with increasing diversion to 90 percent.

Table 59. Recycling, reuse, and manufacturing NAICS codes

2022 NAICS US code	Material	2022 NAICS US title	Type category
321920	Wood	Wood Container and Pallet Manufacturing	Manufacturing
322110	Fiber	Pulp Mills	Manufacturing
322120	Fiber	Paper Mills	Manufacturing
322130	Fiber	Paperboard Mills	Manufacturing
325315	Organics	Compost Manufacturing	Material Processing
325991	Plastic	Custom Compounding of Purchased Resins	Manufacturing
327212	Glass	Other Pressed and Blown Glass and Glassware Manufacturing	Manufacturing
327213	Glass	Glass Container Manufacturing	Manufacturing
327993	Glass	Mineral Wool Manufacturing	Manufacturing
331110	Metal	Iron and Steel Mills and Ferroalloy Manufacturing	Manufacturing
331314	Metal	Secondary Smelting and Alloying of Aluminum	Manufacturing

2022 NAICS US code	Material	2022 NAICS US title	Type category
331492	Metal	Secondary Smelting, Refining, and Alloying of Nonferrous Metal (except Copper and Aluminum)	Manufacturing
331511	Metal	Iron Foundries	Manufacturing
331512	Metal	Steel Investment Foundries	Manufacturing
331513	Metal	Steel Foundries (except Investment)	Manufacturing
331524	Metal	Aluminum Foundries (except Die-Casting)	Manufacturing
331529	Metal	Other Nonferrous Metal Foundries (except Die-Casting)	Manufacturing
423930	Reuse	Recyclable Material Merchant Wholesalers	Reuse
459510	Reuse	Used Merchandise Retailers	Reuse
532210	Rental	Consumer Electronics and Appliances Rental	Rental
532281	Rental	Formal Wear and Costume Rental	Rental
532282	Rental	Video Tape and Disc Rental	Rental
532283	Rental	Home Health Equipment Rental	Rental
532284	Rental	Recreational Goods Rental	Rental
532289	Rental	All Other Consumer Goods Rental	Rental
532310	Rental	General Rental Centers	Rental
532420	Rental	Office Machinery and Equipment Rental and Leasing	Rental
541620	Support Services	Environmental Consulting Services	Support Services
561110	Support Services	Office Administrative Services	Support Services
562111	Recycling Collection	Solid Waste Collection	Recycling Collection
562920	Material Processing	Materials Recovery Facilities	Material Processing
811210	Repair	Electronic and Precision Equipment Repair and Maintenance	Repair
811411	Repair	Home and Garden Equipment Repair and Maintenance	Repair
811412	Repair	Appliance Repair and Maintenance	Repair
811420	Repair	Reupholstery and Furniture Repair	Repair
811430	Repair	Footwear and Leather Goods Repair	Repair
811490	Repair	Other Personal and Household Goods Repair and Maintenance	Repair
322211	Fiber	Corrugated and Solid Fiber Box Manufacturing	Manufacturing
322212	Fiber	Folding Paperboard Box Manufacturing	Manufacturing
322219	Fiber	Other Paperboard Container Manufacturing	Manufacturing
322220	Fiber	Paper Bag and Coated and Treated Paper Manufacturing	Manufacturing
322230	Fiber	Stationery Product Manufacturing	Manufacturing
322291	Fiber	Sanitary Paper Product Manufacturing	Manufacturing

2022 NAICS US code	Material	2022 NAICS US title	Type category
322299	Fiber	All Other Converted Paper Product Manufacturing	Manufacturing
326111	Plastic	Plastics Bag and Pouch Manufacturing	Manufacturing
326112	Plastic	Plastics Packaging Film and Sheet (including Laminated) Manufacturing	Manufacturing
326113	Plastic	Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing	Manufacturing
326121	Plastic	Unlaminated Plastics Profile Shape Manufacturing	Manufacturing
326122	Plastic	Plastics Pipe and Pipe Fitting Manufacturing	Manufacturing
326130	Plastic	Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing	Manufacturing
326140	Plastic	Polystyrene Foam Product Manufacturing	Manufacturing
326150	Plastic	Urethane and Other Foam Product (except Polystyrene) Manufacturing	Manufacturing
326160	Plastic	Plastics Bottle Manufacturing	Manufacturing
326191	Plastic	Plastics Plumbing Fixture Manufacturing	Manufacturing
326199	Plastic	All Other Plastics Product Manufacturing	Manufacturing
327215	Glass	Glass Product Manufacturing Made of Purchased Glass	Manufacturing
331210	Metal	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	Manufacturing
331221	Metal	Rolled Steel Shape Manufacturing	Manufacturing
331222	Metal	Steel Wire Drawing	Manufacturing
331315	Metal	Aluminum Sheet, Plate, and Foil Manufacturing	Manufacturing
331318	Metal	Other Aluminum Rolling, Drawing, and Extruding	Manufacturing
331420	Metal	Copper Rolling, Drawing, Extruding, and Alloying	Manufacturing
331523	Metal	Nonferrous Metal Die-Casting Foundries	Manufacturing

Appendix A.11 Technical Summary of Ash Management and Metal Recovery in Minnesota

Overview of Ash Generation

Municipal solid waste (MSW) combusted at waste-to-energy (WTE) facilities generates residual ash, which typically represents approximately 20–30% of incoming MSW by weight (commonly estimated at ~25% on average).

Ash is more homogeneous than raw MSW and may allow for additional material recovery after combustion, depending on facility design and processing practices.

Post-Combustion Metal Recovery Practices

Post-combustion recovery practices vary by facility and are not directly comparable due to differences in:

- pre-combustion material recovery

- ash processing equipment
- ash composition
- whether legacy ash mining is included
- mixing of fines or other residual materials

Pope/Douglas Solid Waste Management (PDSWM)

- processes mixed ash to recover ferrous and non-ferrous metals
- reported recovery from mixed ash is generally in the range of 7–9% by weight
- assuming ash represents ~25% of incoming MSW by weight, this equates to approximately 1.75–2.25% relative to original MSW tonnage

Note: PDSWM has also conducted recovery from previously disposed ash, which may not directly reflect annual system performance.

Polk County

- screens combustor ash for use in road construction under a Controlled Storage Beneficial Use Determination (CSBUD)
- removes ferrous metals via magnetic separation during screening.
- primary metals recovery occurs pre-combustion through the county’s MRF and pre-sort operations
- post-combustion metal recovery is minimal relative to total ash or incoming MSW tonnage

Polk’s ash landfill has, in some years, experienced a net reduction in ash volume due to ongoing beneficial use activities.

SKB Environmental / HERC Ash

- metals recovery is conducted in partnership with private-sector operators
- recovery methods are proprietary
- reported recovery levels are understood to be in a similar general range as other facilities performing post-combustion processing, though site-specific comparisons are limited

Pre-Combustion Metal Recovery Context

At facilities with integrated MRFs or pre-sort operations, a significant portion of metals may be removed before combustion. For example:

- pre-combustion metal recovery at certain facilities may represent approximately 1–2% of incoming MSW
- when metals are removed prior to combustion, post-combustion recovery rates may appear lower, but overall system recovery may be higher

Because facilities differ in where recovery occurs (pre- vs post-combustion), simple percentage comparisons can be misleading.

Residual Management and Beneficial Use

Even after recovery activities, remaining ash must be managed in engineered facilities. Ash landfills in Minnesota are regulated under state solid waste rules and incorporate environmental protections such as:

- liner systems
- leachate collection and management

- groundwater monitoring
- operational controls appropriate for ash material properties

In addition to landfill disposal, some facilities utilize ash under state-approved CSBUD authorizations for road construction and other projects. This beneficial use reduces the volume requiring disposal, subject to regulatory conditions.

Appendix B - Human Health and Cumulative Risks

Pollutants of Concern

Combustion Byproducts: PCDDs, pcdfs, pcbs, pm2.5, PM10

Combustion byproducts have been known to cause a large array of human health problems and are most often the byproducts of waste incineration. Dioxins (PCDDs), furans (PCDFs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and particulate matter (PM), including PM_{2.5} and PM₁₀, are contaminants of concern in MSW facilities. These byproducts are of particular concern for WTE facilities and other facilities that create fuel for WTE facilities through direct dump incineration, pyrolysis of feedstock, and gasification; the associated waste ash landfills; and landfill fires. Research is not available to quantify the exposure of these byproducts from specific WTE processes, such as pyrolysis of feedstock, gasification, and traditional incineration, but because the processes can result in the formation of these byproducts, it can be inferred the processes have an associated risk to human health if not managed and operated properly.

Dioxins, Furans, & PCBs

Dioxins, or polychlorinated dibenzo-p-dioxins (PCDDs), furans, or polychlorinated dibenzofurans (PCDFs), and certain PCBs are a group of persistent organic pollutants (POPs), generalized as dioxins, that are highly toxic and have significant health impacts (EPA, 2025). PCDDs, PCDFs, and PCBs are formed during the combustion process of waste incineration, as well as the burning of fuels, resulting in dioxins detected in the air, and dispersed amongst water bodies, soil, and vegetation. Additionally, 90% of exposure to dioxins and furans is through food, including meat, dairy products, fish, and shellfish with bioaccumulation a factor, therefore the protection of the food supply chain is critical (EPA, 2025). The potential route of exposure to dioxins can be through inhalation, ingestion, and direct dermal contact.

Because of the toxicity of dioxins, the health impacts, and the long half-life, dioxins are referred to as one of the “Dirty Dozen” which is group of POPs identified that have a significant adverse effect on human health (WHO, 2023). Dioxins are considered carcinogens and teratogens, thus have been found to cause cancer, reproductive and developmental problems, hormone interference, and damage to the immune system (ATSDR, 2009). Other health effects that have been documented include diabetes, ischemic heart disease, and chloracne. (NIEHS, 2025) The most well studied dioxin, 2,3,7,8-TCDD (TCDD), known as a component in Agent Orange, has long been used to investigate the health impacts of dioxins. The EPA’s National Primary Drinking Water Regulations (NPDWR) has a MCL of 0.00000003 milligrams/liter (mg/L) for 2,3,7,8-TCDD, which is the highest allowable amount in drinking water. The EPA also has a reference dose (RfD) value, or the daily oral exposure to a substance that is unlikely to cause non-carcinogenic effects, for 2,3,7,8-TCDD of 7×10^{-10} mg/kg-day. Additionally, the EPA’s NPDWR has an MCL for PCBs set at 0.0005 mg/L.

Dioxins are associated with an increase in all-cancer mortality, with significant increase in incidence, mortality, and morbidity for esophagus cancer, larynx cancer, kidney cancer, soft-tissue sarcoma, non-Hodgkin’s lymphoma, lung cancer, and myeloma (Ranzi et al., 2013; Frederico et al, 2010). Evidence also supports that workers who are occupationally exposed to increased levels of dioxin have an increased risk of all-cancer mortality (Yamamoto et al., 2015).

Dioxins, furans, and PCBs are of particular concern at WTE facilities and other waste incinerators, as they are byproducts formed during the combustion of waste. PCBs have historically been used in industrial applications and were banned in 1979, but products containing PCBs are still present in various waste

streams. Risk of cancer, through both inhalation and ingestion of dioxins, has been quantified through slope factors by the State of California Office of Health Hazard Assessment and are used to estimate the risk of cancer per unit dose, found in Table 60.

Table 60. Cancer slope factors for selected dioxins, furans, and dioxin-like PCBs (OEHHA)

DIOXIN / FURAN / PCB	Compound Abbreviation	Inhalation Slope Factor (mg/kg-day) ⁻¹	Oral Slope Factor (mg/kg-day) ⁻¹
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1,2,3,4,6,7,8-HpCDD	1.3 E+3	1.3 E+3
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,4,7,8-HxCDD	1.3 E+4	1.3 E+4
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-HxCDD	1.3 E+4	1.3 E+4
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	1,2,3,7,8,9-HxCDD	1.3 E+4	1.3 E+4
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	1,2,3,4,6,7,8,9-OCDD	3.9 E+1	3.9 E+1
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1,2,3,7,8-PeCDD	1.3 E+5	1.3 E+5
2,3,7,8-Tetrachlorodibenzo-p-dioxin and related compounds	2,3,7,8 TCDD	1.3 E+5	1.3 E+5
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1,2,3,4,6,7,8-HpCDF	1.3 E+3	1.3 E+3
1,2,3,4,7,8,9-Heptachlorodibenzofuran	1,2,3,4,7,8,9-HpCDF	1.3 E+3	1.3 E+3
1,2,3,4,7,8-Hexachlorodibenzofuran	1,2,3,4,7,8-HxCDF	1.3 E+4	1.3 E+4
1,2,3,6,7,8-Hexachlorodibenzofuran	1,2,3,6,7,8-HxCDF	1.3 E+4	1.3 E+4
1,2,3,7,8,9-Hexachlorodibenzofuran	1,2,3,7,8,9-HxCDF	1.3 E+4	1.3 E+4
2,3,4,6,7,8-Hexachlorodibenzofuran	2,3,4,6,7,8-HxCDF	1.3 E+4	1.3 E+4
1,2,3,4,6,7,8,9-Octachlorodibenzofuran	1,2,3,4,6,7,8,9-OCDF	3.9 E+1	3.9 E+1
1,2,3,7,8-Pentachlorodibenzofuran	1,2,3,7,8-PeCDF	3.9 E+3	3.9 E+3
2,3,4,7,8-Pentachlorodibenzofuran	2,3,4,7,8-PeCDF	3.9 E+4	3.9 E+4
2,3,7,8-Tetrachlorodibenzofuran	2,3,7,8-TCDF	1.3 E+4	1.3 E+4
2,3,3',4,4',5,5'-Heptachlorobiphenyl	2,3,3',4,4',5,5'-HpCB	3.9 E+0	3.9 E+0
2,3',4,4',5,5'-Hexachlorobiphenyl	2,3',4,4',5,5'-HxCB	3.9 E+0	3.9 E+0
2,3,3',4,4',5'-Hexachlorobiphenyl	2,3,3',4,4',5'-HxCB	3.9 E+0	3.9 E+0
2,3,3',4,4',5-Hexachlorobiphenyl	2,3,3',4,4',5-HxCB	3.9 E+0	3.9 E+0
3,3',4,4',5,5'-Hexachlorobiphenyl	3,3',4,4',5,5'-HxCB	3.9 E+3	3.9 E+3
2',3,4,4',5-Pentachlorobiphenyl	2',3,4,4',5-PeCB	3.9 E+0	3.9 E+0
2,3',4,4',5-Pentachlorobiphenyl	2,3',4,4',5-PeCB	3.9 E+0	3.9 E+0
2,3,3',4,4'-Pentachlorobiphenyl	2,3,3',4,4'-PeCB	3.9 E+0	3.9 E+0
2,3,4,4',5-Pentachlorobiphenyl	2,3,4,4',5-PeCB	3.9 E+0	3.9 E+0
3,3',4,4',5-Pentachlorobiphenyl	3,3',4,4',5-PeCB	1.3 E+4	1.3 E+4
3,3',4,4'-Tetrachlorobiphenyl	3,3',4,4'-TCB	1.3 E+1	1.3 E+1
3,4,4'5-Tetrachlorobiphenyl	3,4,4'5-TCB	3.9 E+1	3.9 E+1

**All values were provided by the State of California Office of Environmental Health Hazard Assessment Chemical Database*

The EPA has different slope factors for specific PCDDs, PCDFs, and PCBs, as well as RfD values, or the daily oral exposure to a substance that is unlikely to cause non-carcinogenic effects. Hexachlorodibenzo-p-dioxin (HxCDD), which is a mixture of 1,2,3,6,7,8-HxCDD and 1,2,3,7,8,9-HxCDD has an oral slope factor of 6.2×10^3 per mg/kg-day and an inhalation unit risk for cancer (similar to slope factor) of $1.3 \mu\text{g}/\text{m}^3$. 2,3,7,8-Tetrachlorodibenzo-p-dioxin has an RfD of 7.10×10^{-10} mg/kg-day (EPA IRIS).

Toxic equivalency factors (TEFs), or the relative toxicity value of a compound compared to the most toxic of similar compounds. For PCDDs, PCDFs, and PCBs, the TEF compares each dioxin, furan, or dioxin-like compound to the most toxic dioxins, 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD) and 1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PeCDD) (van den Burg, 2005). The TEFs set by the World Health Organization (WHO) for certain PCDDs, PCDFs, and PCBs can be found in Table 61.

Table 61. Toxic equivalency factors (TEFs) for applicable PCDDs, PCDFs, and PCBs

PCDD / PCDF / PCB Abbreviation	TEF
2,3,7,8 TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
1,2,3,4,6,7,8,9-OCDD	0.003
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
1,2,3,4,6,7,8,9-OCDF	0.0003
3,3',4,4'-TCB	0.0001
3,4,4',5'-TCB	0.0003
3,3',4,4',5'-PeCB	0.1
3,3',4,4',5,5'-HxCB	0.03
2,3,3',4,4'-PeCB	0.00003
2,3,4,4',5'-PeCB	0.00003
2,3',4,4',5'-PeCB	0.00003
2',3,4,4',5'-PeCB	0.00003
2,3,3',4,4', 5 -HxCB	0.00003
2,3,3',4,4',5'-HxCB	0.00003
2,3',4,4',5,5'-HxCB	0.00003
2,3,3',4,4',5,5'-HpCB	0.00003

*All values were provided by WHO's Reevaluation of TEFs

The presence of increased dioxins and furans in the blood can result in an increased risk of cancer, congenital malformations, reproduction and development problems, and heart diseases for populations living near waste incinerators. Older incinerators, operating prior to approximately 2000, have been found to increase concentrations of dioxins in breast milk and blood (Reis et al., 2007; Chen, Su, Lee, 2006). Serum dioxin levels and an increase in hypertension have been observed for those living near

incinerators (Chen et al., 2006). The presence of congenital malformations, such as facial clefts, renal dysplasia, and obstructed uropathies, were also associated with dioxins produced by incinerators (Cordier et al., 2010; Cordier et al., 2004).

Specific cancers that have been associated with incinerator-produced dioxins include non-Hodgkin's lymphoma and soft tissue sarcoma. Research has shown an increase in likelihood of non-Hodgkin's lymphoma by 2.3 when consistently exposed to dioxin levels greater than 0.0004 pg/m³ (Floret et al., 2003). An increase in soft tissue sarcoma was also found when exposed to dioxin levels greater than 6 fg/m³ for populations living near incinerators (Zambon et al., 2007). Elevated blood lipids and liver problems have also been associated with PCBs due to MSW incineration (Ruokojärvi et al., 2004). However, these studies, like a majority of available research, were for older incineration facilities operating between 1971-1986.

Dioxins are a particular concern for the ash byproduct of WTE facilities, because bottom ash and fly ash are known to have elevated concentrations of dioxins (Passarini et al., 2014). Occupational workers transporting the ash to designated landfills are likely to have a higher risk of exposure to dioxins and other contaminants found within the ash, with and without personal protective equipment (PPE). Ash landfills, and transportation of ash, create a higher risk for dioxin exposure when near water bodies and agriculture areas. This may create potential for dioxin contamination of drinking water, vegetation, and animals.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a class of organic compounds produced during incomplete combustion of waste, coal, oil, gas, wood, and tobacco, as well as high temperatures cooking (ATSDR, 2013). PAHs have the ability to bind to particles, such as PM_{2.5} and PM₁₀, thus making them able to expose human populations through inhalation, as well as ingestion from deposited particles in waterways and soil that contaminate groundwater, vegetation, aquatic life, and livestock. PAHs also have some potential of exposure through dermal contact. The high lipophilicity of PAHs allows easy deposition in internal organs and adipose tissue, remaining in the body long after exposure (Abdel-Shafy & Mansour, 2016).

Certain PAHs are considered carcinogens, mutagens, and teratogens, and pose a danger to human health. Evidence supports the correlation between exposure to certain PAHs and cardiovascular disease, atherosclerosis, thrombosis, myocardial infarction, and hypertension (Holme et al., 2019).

Benz(a)pyrene, a well-studied PAH, is known to increase the risk of cancer, as well as cause reproductive difficulties. The EPA's NPDWR MCL is established at 0.0002 mg/L for PAHs. Exposure to PAHs has been shown to increase risk of multiple cancers, such as cancer of the skin, lungs, pancreas, esophagus, bladder, colon, and breast (Kim et al., 2013; Rajpara et al., 2017). Research is ongoing to definitively classify individual PAH compounds, their carcinogenic effect, and the respective dose for health impacts. There are various PAHs, such as benzo[a]pyrene, that have been classified by the International Agency for Research on Cancer (IARC), which can be found in Table 62. A select few of these PAHs also have RfD values and can be found in Table 63.

Table 62. IARC classification for common PAHs found in environmental exposure

PAH	IARC group classification	Classification explanation
Acenaphthene	3	Not classifiable as to its carcinogenicity to humans
Anthracene	2B	Possibly carcinogenic to humans
Benz[a]anthracene	2B	Possibly carcinogenic to humans
Benzo[a]anthracene	2B	Possibly carcinogenic to humans
Benzo[a]pyrene (BaP)	1	Carcinogenic to humans

PAH	IARC group classification	Classification explanation
Benzo[b]fluoranthene	2B	Possibly carcinogenic to humans
Benzo[c]phenanthrene	2B	Possibly carcinogenic to humans
Benzo[g,h,i]perylene	3	Not classifiable as to its carcinogenicity to humans
Benzo[j]fluoranthene	2B	Possibly carcinogenic to humans
Benzo[k]fluoranthene	2B	Possibly carcinogenic to humans
Chrysene	2B	Possibly carcinogenic to humans
Dibenzo[a,h]anthracene	2A	Probably carcinogenic to humans
Dibenzo[a,h]anthracene	2A	Probably carcinogenic to humans
Dibenzo[a,l]pyrene	2A	Probably carcinogenic to humans
Fluoranthene	3	Not classifiable as to its carcinogenicity to humans
Fluorene	3	Not classifiable as to its carcinogenicity to humans
Indeno[1,2,3-cd]pyrene	2B	Possibly carcinogenic to humans
Phenanthrene	3	Not classifiable as to its carcinogenicity to humans
Pyrene	3	Not classifiable as to its carcinogenicity to humans

**All values were provided by the IARC carcinogenic database*

Table 63. California OEHHA PEFs and cancer slope factors for common PAHs found in environmental exposure

PAH	PEF	Inhalation unit risk (µg/m3)-1	Inhalation slope factor (mg/kg-day)-1	Oral slope factor (mg/kg-day)-1	No significant risk level (NSRL) – oral (µg/day)
Acenaphthene	0	N/A	N/A	N/A	N/A
Acenaphthylene	0	N/A	N/A	N/A	N/A
Anthracene	0	N/A	N/A	N/A	N/A
Benz[a]anthracene	0.1	1.1 E-4	3.9 E-1	1.2 E+0	0.033
Benzo[a]pyrene	1	1.1 E-3	3.9 E+0	2.9 E+0	0.06
Benzo[b]fluoranthene	0.1	1.1 E-4	3.9 E-1	1.2 E+0	0.096
Benzo[g,h,i]perylene	0	N/A	N/A	N/A	N/A
Benzo[k]fluoranthene	0.1	1.1 E-4	3.9 E-1	1.2 E+0	None
Chrysene	0.01	1.1 E-5	3.9 E-2	1.2 E-1	0.35
Dibenzo[a,h]anthracene	1	1.2 E-3	4.1 E+0	4.1 E+0	0.2
Fluoranthene	0	N/A	N/A	N/A	N/A
Fluorene	0	N/A	N/A	N/A	N/A
Indeno[1,2,3-cd]pyrene	0.1	1.1 E-4	3.9 E-1	1.2 E+0	None
Naphthalene	0	3.4 E-5	1.2 E-1	1.2 E-1	5.8
Phenanthrene	0	N/A	N/A	N/A	N/A
Pyrene	0	N/A	N/A	N/A	N/A

**All values were provided by the State of California Office of Environmental Health Hazard Assessment Chemical Database*

Table 64. U.S. EPA RfD and RfC values for the 16 priority PAHs and known biological systems impacted

PAH	Biological Systems Impacted	RfD Value (mg/kg-day)	RfC Value (mg/kg-day)
Acenaphthene	Hepatic	6×10^{-2}	N/A
Anthracene	None	3×10^{-1}	N/A
Benz[a]anthracene	None	N/A	N/A
Benzo[a]pyrene (BaP)	Developmental, Reproductive, Immune	3×10^{-4}	2×10^{-6}
Benzo[b]fluoranthene	None	N/A	N/A
Benzo[g,h,i]perylene	None	N/A	N/A
Benzo[k]fluoranthene	None	N/A	N/A
Chloronaphthalene	Hepatic, Respiratory	8×10^{-2}	N/A
Chrysene	None	N/A	N/A
Dibenz[a,h]anthracene	None	N/A	N/A
Fluoranthene	Hepatic, Urinary	4×10^{-2}	N/A
Fluorene	Hematologic	4×10^{-2}	N/A
Indeno[1,2,3-cd]pyrene	None	N/A	N/A
Naphthalene	Nervous, Respiratory	2×10^{-2}	3×10^{-3}
Phenanthrene	None	N/A	N/A
Pyrene	Urinary	3×10^{-2}	N/A

*All values were provided by the U.S. EPA's IRIS database

Table 65. Minnesota Department of Health's HRLs and RAAs for PAHs in groundwater

PAH	Cancer HRL (µg/L)	Sub-chronic HRL (µg/L)	Chronic HRL (µg/L)
2-Methylnaphthalene			8
Acenaphthene		200	100
Anthracene		1000	600
Benzo[a]pyrene	0.1	0.5	0.5
Fluoranthene		200	70
Fluorene (9H-Fluorene)		200	800
Naphthalene		70	70
Pyrene		90	50

*All values were provided by the MDH's Human Health-Based Water Guidance Table

Table 66. IARC classification for common PAHs found in environmental exposure

PAH	IARC Group Classification	Classification Explanation
Acenaphthene	3	Not classifiable as to its carcinogenicity to humans
Anthracene	2B	Possibly carcinogenic to humans
Benz[a]anthracene	2B	Possibly carcinogenic to humans
Benzo[a]anthracene	2B	Possibly carcinogenic to humans
Benzo[a]pyrene (BaP)	1	Carcinogenic to humans
Benzo[b]fluoranthene	2B	Possibly carcinogenic to humans
Benzo[c]phenanthrene	2B	Possibly carcinogenic to humans

PAH	IARC Group Classification	Classification Explanation
Benzo[g,h,i]perylene	3	Not classifiable as to its carcinogenicity to humans
Benzo[j]fluoranthene	2B	Possibly carcinogenic to humans
Benzo[k]fluoranthene	2B	Possibly carcinogenic to humans
Chrysene	2B	Possibly carcinogenic to humans
Dibenzo[a,h]anthracene	2A	Probably carcinogenic to humans
Dibenzo[a,h]anthracene	2A	Probably carcinogenic to humans
Dibenzo[a,l]pyrene	2A	Probably carcinogenic to humans
Fluoranthene	3	Not classifiable as to its carcinogenicity to humans
Fluorene	3	Not classifiable as to its carcinogenicity to humans
Indeno[1,2,3-cd]pyrene	2B	Possibly carcinogenic to humans
Phenanthrene	3	Not classifiable as to its carcinogenicity to humans
Pyrene	3	Not classifiable as to its carcinogenicity to humans

**All values were provided by the IARC carcinogenic database*

Table 67. RfD values for PAHs

PAH	RfD Value (mg/kg-day)
Acenaphthene	6×10^{-2}
Anthracene	3×10^{-1}
Benzo[a]pyrene (BaP)	3×10^{-4}
Fluoranthene	4×10^{-2}
Fluorene	4×10^{-2}
Pyrene	3×10^{-2}

**All values were provided by the EPA's IRIS database*

PAHs are a health concern for waste incinerators, because of the elevated levels found in populations residing near incineration operations, again specifically older models operating prior to around the year 2000. Increased urinary PAH metabolites have been found 3.5-15 times greater for workers exposed to PAHs in older waste incineration sites (Oh et al., 2005). Incineration workers are at the greatest risk of exposure to PAHs through emissions and ash, with evidence supporting increased PAH metabolites and blood levels compared to unexposed populations (Oh et al., 2005; Ranzi et al, 2013). Technology is a factor, as older incinerators were found to produce higher levels of PAH emissions compared to newer incineration technologies (Oh et al., 2005; Ranzi et al, 2013).

Particulate Matter (PM)

PM, with a diameter of 2.5 micrometers (PM_{2.5}) or 10 micrometers (PM₁₀), is a byproduct of combustion that has long been associated with cardiovascular and pulmonary health. A plethora of research exists correlating PM_{2.5} and PM₁₀ with negative impacts for both short-term and long-term exposure. The EPA has primary and secondary standards for both PM_{2.5} and PM₁₀, with primary standards providing public health protection and secondary standards for public welfare protection, such preventing an inability to see because of smog. For PM_{2.5}, both the primary and secondary standards are set at 35 micrograms/cubic meter (µg/m³) for a 24-hour average, with a primary standard of 9.0 µg/m³ as an annual average and secondary standard of 15.0 µg/m³ as an annual average (EPA, 2025). PM₁₀ has a primary and secondary standard of 150 µg/m³ not to be exceeded more than once per year (EPA, 2025).

Short-term exposure can cause irritation of mucous membranes, aggravated asthma, coughing, shortness of breath, and an increased risk of cardiovascular events (APA, 2025). Even short-term exposure has been shown to result in a 1% increase in overall mortality for every 10 mg/m³ increase in PM₁₀, with a 3.4% increase in respiratory mortality and 1.4% increase in cardiovascular mortality (Winkler & Wiedensohler, 2025).

Long-term exposure has been shown to cause decreased lung function, asthma, worsen chronic obstructive pulmonary disease (COPD), and increase the risk of myocardial infarction, stroke, and premature mortality (APA, 2025). Studies have shown that for every 10 µg/m³ increase in PM_{2.5} long-term exposure, there is an 8% increase in risk of lung cancer (Hamra et al., 2014). Particulate matter has also been found to have a synergistic relationship with ambient air temperature, resulting in a higher risk of cardiovascular- and pulmonary-related mortalities during high heat days (Analitis et al., 2013; Burkart et al., 2013; Scortichini et al., 2018; Vanos et al., 2014).

Multiple studies of particulate matter resultant of MSW incineration demonstrate increased levels of particulate matter at and near incineration facilities. This increase in emissions results in reduced cell viability, and an increase in pre-term delivery, amongst populations near older incineration facilities (Candela et al., 2013, Cao et al., 2015). It should be noted that recent studies conducted at WTE facilities operating to European Union standards have not detected increases in ground level PM₁₀, as well as no significant increase in birth outcomes, preterm delivery, infant mortality, or congenital anomalies (Ghosh et al., 2019; Parker et al., 2019).

Landfills also emit particulate matter, specifically due to formation from gases such as nitrous oxides, sulfur oxides, and ammonia from degradation of waste. Particulate matter from landfills can spread due to deposition from wind, during movement of material, and vehicle traffic. Populations near landfills have been found to have increased levels of PM_{2.5} and have experienced negative health impacts. Increase in landfill PM_{2.5} has been shown to decrease lung capacity while increase instances of pneumonia, bronchitis, asthma, and shortness of breath in surrounding populations, especially during unexpected events such as windstorms and landfill fires (Gumede & Savage, 2017; Kret et al., 2018).

Particulate matter has an affinity to bind to other airborne toxins, creating an increased risk of negative health impacts when exposed to PM_{2.5} and PM₁₀. PAHs, for example, are able to bind to particulate matter, increasing exposure of combustion byproducts. The exposure of combustion byproduct emissions will be dependent on the compounds of multiple pollutants.

Factors for Consideration

The presence of dioxins, furans, PCBs, PAHs, and particulate matter, and impacts on human health in modern WTE facilities utilizing appropriate pollution controls and maintenance is not fully evaluated due to the lack of available data. The combustion of refuse-derived fuel (RDF), created by processing MSW to create a fuel source for WTE facilities, is known to release dioxins, PAHs, and particulate matter. Research suggests minimal exposure is present when facilities are utilizing sufficient pollution control devices with proper maintenance. WTE facilities that use RDF may have better combustion and lower emissions compared to facilities that use direct dump mixed waste, similar to traditional MSW incinerators.

Stricter emissions control measures have been found to reduce dioxin levels and a decrease of particulate matter (Buonanno, 2010; Buonanno et al., 2011). Research supports increased levels of combustion byproducts in WTE facilities and MSW incinerators operating prior to 2000. Recent studies indicate levels of dioxins emitted from properly controlled WTE facilities, especially when MSW is sorted before pyrolysis for RDF, do not contribute negatively to human health (Krajčovičová & Eschenroeder,

2007; EPA, 2025). Research supports that modern, well-run WTE facilities emit lower concentrations of dioxins compared to coal and oil-fired power plants (EPA, 2016).

Older WTE facilities continue to be a concern, especially when not properly maintained. Proper maintenance and air pollution control devices are critical to maintaining low levels of emissions, as studies indicate abnormal operations, even without long-term exposure, can increase dioxin and furan levels in blood and breast milk consumed by infants (Ollson et al., 2014).

Ash landfills are required to store the byproducts of WTE facilities and are another potential exposure that should be considered when assessing the risk of WTE facilities. The movement and handling of bottom ash and fly ash can influence levels of dioxins, PAHs, and particulate matter (Passarini et al., 2014). Proper transportation of ash is an exposure factor, and proper protocol for the long-term storage of ash is essential for limiting exposure. Inhalation of ash through emissions or the ingestion through contaminated water and vegetation are both potential routes of exposure. However, no studies have found a way to eliminate exposure, inhalation, ingestion, and dermal contact of ash, so exposure is likely to occur for populations near ash landfills and should be considered in evaluating the risk of the WTE process.

Location and ecological factors should be taken into consideration when determining the risk of operation, especially for older WTE facilities, ash landfills and the movement of ash, and MSW landfills. The movement of pollutants through waterways results in contamination of drinking water and groundwater for agriculture and increases exposure for both populations in the surrounding area, as well as those ingesting the vegetation and livestock that were exposed. Proximity to densely populated areas can increase exposure to contaminants due to compounding effects of other sources of pollution. Special precautions should be taken to ensure that areas with high population density and high pollution from other common sources in urban areas, such as transportation, do not have increased levels of ambient pollution and are maintained well below environmental standards and public health guidelines. Additionally, areas that may have especially high pollution from other sources, especially industrial facilities that have high levels of ambient air pollution, should be especially monitored to ensure compounding of pollutants does not occur.

Pyrolysis that exists at other facilities besides WTE, such as specific mixed-waste processing and MRFs, also increases exposure to combustion byproducts, due to the degradation of waste at high temperatures. Although limited research exists correlating pyrolysis at specific MSW facilities with certain exposures and health impacts, it can be assumed that a similar risk exists for this process.

Minnesota's MSW Facilities

Minnesota's MSW infrastructure contains various WTE facilities and ash landfills, all of varying age and location. The oldest WTE facilities began operating in 1948 and 1949, making them significantly older than the other WTE facilities. Of the other facilities, three began operations between 1986 and 1989, and two began operations in 2004.

Regulatory air pollution controls for WTE emissions have significantly improved since the first of Minnesota's WTE facilities began operating. Elevated levels of PAHs and dioxin-like compounds have been detected near bodies of water with the potential to impact groundwater (MPCA, 2024). The location of Minnesota's WTE facilities that are near bodies of water increases the likelihood of runoff from bottom ash and fly ash, as well as deposition of contaminant particles in the surrounding area. The likelihood of contamination of drinking water, water used for vegetation, and livestock via bioaccumulation is increased. Ash landfills located near drinking water sources and agricultural areas, present a risk to the surrounding populations.

Compounding effects of pollution can impact human health. Some ash landfills and WTE facilities in Minnesota are located near other industrial facilities and create an added risk to human health due to multiple potential sources of pollution. WTE facilities are also located in densely populated urban areas which contribute to additional sources of air pollution due to increased transportation, which should be considered. From these factors, the ATSDR exposure pathway can be assumed complete for combustion byproducts from WTE facilities and ash landfills, with a potential pathway at MSW landfills in Minnesota.

Summary for Combustion Byproducts

The combustion byproducts PCDDs, PCDFs, PCBs, PAHs, PM_{2.5}, and PM₁₀ are of considerable concern due to their negative impacts on human health. Exposure to these byproducts has been shown to increase the risk of disease such as cancer, pulmonary and cardiovascular diseases, hormonal interference, reproductive problems, developmental delays, and congenital malformations. Regulatory pollution control devices have significantly decreased emissions from WTE facilities, but older facilities are still of concern, especially in specific locations. WTE facilities and ash landfills that are near bodies of water increase the risk of exposure dioxins, PAHs, and particulate matter through ingestion of contaminated water, and uptake of vegetation, livestock, and their byproducts. WTE facilities located in densely populated areas may increase the risk of exposure to nearby populations when there are elevated levels of contaminants from other sources of pollution. Proper planning, sufficient pollution control, and advanced biomonitoring, especially during high heat days, may minimize the risk of exposure to these particular contaminants.

Heavy & Toxic Metals

Heavy metals, such as lead, mercury, chromium, and arsenic, as well as other toxic metals, have long been known to have negative impacts on human health. Heavy metals are persistent elements, widely used in industrial, commercial, domestic, agricultural, medical, and technological applications, thus prevalent in the environment. Electronics, paints, batteries, and furniture can contain various heavy metals that are included into the waste stream. Heavy metal exposure is a concern for WTE facilities, ash landfills, MSW landfills, MRFs, and mixed waste processing.

The most concerning heavy metals that have known health impacts are regulated in drinking water through EPA's National Primary Drinking Water Regulations (NPDWR). The NPDWR established maximum contaminant levels (MCLs), or the highest allowable amount in drinking water, as well as the maximum contaminant level goal (MCLG), or the level at which no known or expected health risks, for heavy metals and other contaminants. The EPA, through the Resource Conservation and Recovery Act's (RCRA), has established toxicity characteristic leaching procedure (TCLP) limits. The TCLP determines the leachability of compounds in a landfill setting. The results of TCLP testing provide hazardous waste characteristics. The metals of highest concern can be found in Table 68 along with their NPDWR MCL and MCLG quantities and the commonly known health effects from long-term exposure above the MCL. Table 69 includes the eight metals referred to as "TCLP metals" and their corresponding limits. The NPDWR MCL and MCLG testing is for aqueous media, while TCPL is an extraction method for solids.

Table 68. NPDWR's acceptable exposure levels and health impacts for heavy metals & toxic metals/metalloids

Heavy Metal & Other Metals of Concern	Health Impact from Long-Term Exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)
Antimony (Sb)	Increase in blood cholesterol; decrease in blood sugar	0.006	0.006
Arsenic (As)	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	0.010	0
Barium (Ba)	Increase in blood pressure	2.0	2.0

Heavy Metal & Other Metals of Concern	Health Impact from Long-Term Exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)
Beryllium (Be)	Intestinal lesions	0.004	0.004
Cadmium (Cd)	Kidney damage	0.005	0.005
Chromium (Cr)	Allergic dermatitis	0.01	0.01
Copper (Cu)	Liver or kidney damage	1.3	1.3
Lead (Pb)	Development delays, kidney problems, high blood pressure	0.01	0
Mercury (Hg)	Kidney damage; neurological effects	0.002	0.002
Selenium (Se)	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	0.05	0.05
Thallium (Tl)	Hair loss; changes in blood; kidney, intestine, or liver problems	0.002	0.0005

**All values were provided by the EPA's NWDR resources*

Table 69. RCRA's maximum concentration of contaminants for toxicity characteristic and health impacts

Heavy Metal & Other Metals of Concern	Health Impact from Long-Term Exposure above MCL	RCRA Metal TCLP Limit (mg/L)
Arsenic (As)	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	5.0
Barium (Ba)	Increase in blood pressure	100.0
Cadmium (Cd)	Kidney damage	1.0
Chromium (Cr)	Allergic dermatitis	5.0
Lead (Pb)	Development delays, kidney problems, high blood pressure	5.0
Mercury (Hg)	Kidney damage	0.2
Selenium (Se)	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	1.0
Silver (Ag)	Argyria	5.0

**All values were provided by the EPA's CFR 261.24*

Minimal Risk Levels and Health Risk Values for heavy metals have been established at federal and state levels. ATSDR MRLs for acute, intermediate, and chronic exposure through inhalation and ingestion can be found in Table, and Minnesota Department of Health HRLs can be found in Table 70.

Table 70. ATSDR MRLs for heavy metals & toxic metals/metalloids of concern

Heavy metal & toxic metal/metalloid	Acute inhalation MRL (mg/m ³)	Intermediate inhalation MRL (mg/m ³)	Chronic inhalation MRL (mg/m ³)	Acute oral MRL (mg/kg/day)	Intermediate oral MRL (mg/kg/day)	Chronic oral MRL (mg/kg/day)
Antimony	0.001	0.001	0.0003	1	0.0006	
Arsenic				0.005	0.0003	
Barium					0.2	0.2
Beryllium			0.000001			
Cadmium	0.00003		0.00001		0.0005	0.001
Chromium III Insoluble		0.005				
Chromium III Soluble		0.0001				

Heavy metal & toxic metal/metalloid	Acute inhalation MRL (mg/m ³)	Intermediate inhalation MRL (mg/m ³)	Chronic inhalation MRL (mg/m ³)	Acute oral MRL (mg/kg/day)	Intermediate oral MRL (mg/kg/day)	Chronic oral MRL (mg/kg/day)
Chromium VI					0.005	0.0009
Chromium VI Aerosol		0.000005	0.000005			
Chromium VI Particulates		0.0003				
Cobalt	0.0003		0.0001	0.03	0.02	
Copper				0.02	0.02	
Mercury			0.0003	0.002	0.00001	
Selenium						0.005

**All values were provided by the U.S. CDC ATSDR's Toxic Substances Portal*

Table 71. Minnesota Department of Health health risk limits (HRLs) for metals and metalloids in groundwater

Heavy metal & toxic metal/metalloid	Cancer HRL (µg/L)	Sub-chronic HRL (µg/L)	Chronic (µg/L)
Antimony			6
Barium			2000
Beryllium	0.08		
Cadmium		1	0.5
Chromium III			2000
Chromium VI			100
Nickel			100
Selenium			30
Silver			30
Thallium			0.6

**All values were provided by the MDH's Human Health-Based Water Guidance Table*

Heavy metals are found in particulate matter, such as PM_{2.5} and PM₁₀, which can easily be spread and inhaled or ingested. WTE fly ash is known to contain heavy metals such as lead, chromium, copper, and cadmium, and although technological advances continue to improve the separation of heavy metals from fly ash, fully eliminating the exposure is unlikely (Shen et al., 2025). Atmospheric deposition of particulates containing heavy metals can be windblown from ash piles, or WTE stacks, especially when sufficient pollution control devices are not utilized. Various studies have shown an increase in heavy metal exposure for populations surrounding waste incineration facilities, with an increase of lead and mercury in the blood (greater than 6 µg/L and 11 µg/L, respectively), as well as overall increase in urinary and serum heavy metals (Deng et al., 2016; Reis et al., 2007; Ranzi et al., 2013).

Incineration workers have been shown to often have the highest risk of exposure, especially those working in older facilities and those exposed to ash, compared to other populations. Research has indicated that those working in MSW incineration facilities have elevated levels of mercury and arsenic compared to unexposed groups, and long-term exposure has resulted in kidney damage and circulatory problems (Deng et al., 2016). Heavy metals in specific forms of combustion for fuel, such as pyrolysis, have not been included in epidemiologic studies, however, similar risks may be present.

Heavy metals have been detected in MSW landfills, and the respective leachate, that can contaminate groundwater and soil, thus impacting drinking water and vegetation. Products containing metals and

metalloids that are not properly sorted can be observed in landfills. Cadmium, arsenic, lead, chromium, cobalt, and other metals are found in leachate, and without proper control and monitoring, there is a risk of exposure to humans. Arsenic and chromium, for instance, are both detected in landfills due to wood preservatives, electronics, paints, and dyes – products that will continue to be added in the waste streams.

Other toxic metals or emerging metals of concern are often present in waste streams. Lithium, for example, has been increasingly found in landfill leachate and MRF runoff, due to the increase of electronic waste over the past few decades. Although lithium is used as a mood stabilizer for various mood disorders, there is increasing research on the long-term effects of lithium exposure. Recent studies have shown that long-term exposure to lithium may decrease kidney function and concentrating abilities, increase incidence of hypothyroidism, goiters, and worsen dermatological conditions such as psoriasis (Tondo et al., 2019; Kraszewska et al., 2019; Filipiak, Jaskóła, & Gattner, 2021). Those with long-term exposure have found to have increased creatine concentration and decreased glomerular filtration rate (GFR), suggesting decreased renal function, and is perhaps the most serious concern for long-term lithium exposure (Desmond & Ber, 2018). Lithium is currently on the EPA's First Contaminant Candidate List to evaluate whether regulation is needed under the Safe Drinking Water Act.

Occupational workers, or sanitation workers, at MRFs, and especially mixed-waste sorting and processing facilities, are at risk of exposure from both heavy metals and other toxic metals/metalloids, due to the mobilization of contaminants during sorting and recycling (Caravanos et al., 2011; Ohajinwa et al., 2019). Sanitation workers in facilities that sort MSW, such as mixed-waste processing facilities, have been found to have elevated levels of heavy metals, including lead, copper, mercury, arsenic, selenium, and copper in hair samples compared to surrounding populations (Khudzari et al., 2018, Ghobakhloo et al., 2023). Occupational workers who work in facilities that do any sorting and recycling of electronic waste (e-waste) have been shown to have significantly increased levels of lead, mercury, cadmium, chromium, and lithium in their blood (Leese et al., 2025). As the volume of electronic waste increases, the risk for workers sorting and processing e-waste will likely continue to increase.

Factors for Consideration

Location and ecological factors influence the potential exposure, especially for older WTE facilities, ash landfills, and MSW landfills, whether open or closed, and should be considered when determining the risk of operation. The migration of heavy metals through water bodies, whether groundwater or surface water, results in the contamination of drinking water and water used for agriculture. This increases exposure for populations in the surrounding area, as well as those ingesting the vegetation, livestock, and their byproducts.

Heavy metals, such as mercury, cadmium, and lead, can bioaccumulate in the food chain. Therefore, animals that ingest heavy metals and become byproducts for consumption increase the exposure of human populations, and increase the prevalence of negative health implications, such as kidney damage and developmental delays. Therefore, waste streams that are near vulnerable ecological zones that would increase heavy metal exposure to aquatic life and other animals for consumption, require careful biomonitoring (Jamil et al., 2023).

Proximity to areas that have other sources of heavy metals pollution can increase the risk of exposure. Populations near landfills, MRFs, mixed-waste sorting and processing, and WTE facilities that are located close to mining operations, smelting, and metal refining, likely will have increased exposure to heavy metals due to the pollution from those operations, even if MSW facilities are staying within regulations.

The impacts of water and soil from leachate in landfills can be attributed to the landfill's age, the types of landfilled materials, and effectiveness of engineering controls, such as liners, to limit leachate. Older

landfills present a higher risk based on volume of waste, the degradation of both waste and liner systems, and potentially the lack of liners. Degraded or improper liners increase the risk of leachate impacting groundwater, drinking water, and water used for agricultural purposes, and thus increases exposure to heavy metals and other toxic metals or metalloids (Gunarathne et al., 2024). Landfills without lining systems, often based on age, have a greater potential for leachate impact groundwater and soil, thus presenting heavy metal exposure to surrounding populations (Gunarathne et al., 2024).

Heavy metals in particulate matter can migrate through the atmosphere and be inhaled or deposited onto soil and surface water. Unloading waste, moving waste via machinery, and wind, increase the risk of exposure. The practice of daily coverings of landfills with approved methods such as soil, green waste, and geosynthetic covers has been shown to potentially decrease exposure of particles during the evening, but are not as effective during operational hours. Interim covers and final covers also are best practice for minimizing long-term exposure.

Similar to the factors to be considered with dioxin exposure, the unavailability of data on the presence of increased heavy metals in new or updated WTE facilities utilizing air pollution engineering controls and maintenance, compared to older facilities, is not fully understood. Research has indicated a decrease in heavy metal emissions in newer facilities that adhere to strict environmental regulations, but a precautionary approach, especially with older operations, should be taken to minimize exposure (Krajčovičová & Eschenroeder, 2007).

Minnesota's MSW Facilities

Minnesota's MSW infrastructure contains various WTE facilities, ash landfills, MSW landfills, mixed-waste processing facilities and MRFs, all of which are known to contain heavy metals and other toxic metals. Minnesota's WTE facilities and ash landfills are of varying age and location, requiring careful consideration for older facilities that were built before updated regulations were in place, regardless of retrofitting of pollution control devices.

Minnesota's WTE facilities located near bodies of water increases the likelihood of runoff from bottom ash and fly ash, as well as deposition of contaminant particles in the surrounding area. This increases the likelihood of impacts to drinking water, water used for vegetation, and animal byproducts via bioaccumulation. Ash landfills, located a near sources of drinking water and agriculture and aquatic species, thus present an increased risk to the surrounding populations, and likely are a completed pathway of exposure.

Minnesota's MSW landfills have also been found to be near bodies of water and have been found to have elevated levels of heavy metals and other metals of concern. MPCA's Closed Landfill Program (CLP) has conducted extensive groundwater sampling at and near closed landfills to monitor potential contaminants. Elevated levels of cadmium, arsenic, and lead have all been found in groundwater susceptible to human consumption (MPCA, 2024). Additionally, MPCA has reported on known pollution near "dumps" or unregulated landfills that were constructed before the 1960s and did not receive a valid permit. These landfills are known to have a lack of liners and maintenance, and contamination of groundwater surrounding these facilities has been confirmed. Additionally, C&D landfills were constructed before the requirement of liners, also have been confirmed by MPCA to have contaminated water surrounding the sites (MPCA, 2024). The exposure pathway for heavy metals from landfills in Minnesota is considered complete due to the reported presence of elevated levels.

Minnesota's MRFs likely process sources of heavy metals. Stormwater runoff is a potential source of contamination for groundwater and surface water near MRFs, and any future mixed-waste processing facilities.

Due to the compounding effects of contaminants, the likelihood of exposure and long-term effects is of concern. With many of Minnesota's MSW facilities located near other industrial facilities with known contaminants, there is an increased risk of exposure and negative impact to human health. Some facilities are located in densely populated areas, which often have additional sources of contamination, such as increased air pollution from an abundance of transportation, and therefore should be carefully considered.

Summary for Heavy & Toxic Metals

Heavy metals, such as lead, mercury, chromium, and arsenic, other toxic metals, and certain metalloids are of concern due to their prevalence in multiple waste facilities, combined with impacts on human health. Exposure to heavy metals has been shown to cause toxicity and damage to the kidneys, liver, and intestinal tract; increase blood pressure; and increase the risk of cancer. Heavy metals have been detected in groundwater near closed landfills in the state of Minnesota. An increased risk of exposure may exist for ash landfills and WTE facilities constructed prior to 2000. MRFs and future mixed-waste processing facilities may present a risk of heavy metals exposure as well, due to the processing of electronics and other materials made of heavy metals. Engineering controls for WTE facilities and landfills may decrease the overall exposure, but the known presence of these pollutants in Minnesota's water requires continuous monitoring to minimize exposure.

PFAS, Pharmaceuticals & Personal Care Products (PPCPs), & 1,4-Dioxane

PFAS, PFOA, 1,4-dioxane, and pharmaceuticals and personal care products (PPCPs), readily found in MSW waste streams, are emerging contaminants of concern. Landfills and composting facilities are sources of PFA and PPCP contamination through leachate and surface water runoff, and MRF and mixed-waste stormwater runoff are also potential points of exposure.

PFAS & 1,4-Dioxane

PFAS are a group of over 12,000 manmade POPs present in a variety of residential and industrial products. Sources of PFAS in the waste stream include packaging, clothing, furniture, carpets, wax, non-stick cookware, electronics, cosmetics, and other manmade items. These sources release PFAS directly when aqueous and during the degradation of waste (EPA, 2009). PFAS have been in the waste stream for decades, starting as early as the 1940s, and current water treatment methods are unable to fully remove PFAS from drinking water (EPA, 2022). PFAS are of concern due to health effects, ease of solubility, persistence in the environment, the difficulty of treatment, as well as the high prevalence in products that humans use daily. Primary exposure to PFAS is through ingestion of water or food containing PFAS. Inhalation is less common since most PFAS found in water are not volatile, although precursors for PFAS may be volatile and inhaled. PFAS are detected in at least 45% of drinking water sources in the United States but have recently begun being monitored and compared to drinking water standards through the NPDWR for a select few groups (USGS, 2023).

Table 72. NPDWR's acceptable exposure levels and health impacts for PFAS

PFA	Health impact from long-term exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)	HBWC for hazard index (mg/L)
HFPO-DA (GenX Chemicals)	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	0.00001	0.00001	0.00001
PFBS	Increase in blood pressure	N/A	N/A	0.002
PFHxS	Intestinal lesions	0.00001	0.00001	0.00001
PFNA	Kidney damage	0.00001	0.00001	0.00001
PFOA	Allergic dermatitis	0.01	0	N/A

PFA	Health impact from long-term exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)	HBWC for hazard index (mg/L)
PFOS	Liver or kidney damage	1.3	0	N/A

**All values were provided by the EPA's NWDR resources*

The EPA also has RfD values, or the daily oral exposure to a substance that is unlikely to cause non-carcinogenic effects, for multiple PFAS. RfD values exist for PFBA, PFDA, PFHxS, and PFHxA: 1×10^{-3} mg/kg-day for PFBA, 2×10^{-9} mg/kg-day for PFDA, 4×10^{-4} mg/kg-day for PFHxS, and 5×10^{-4} mg/kg-day for PFHxA (EPA IRIS).

PFAS are categorized by chain length of carbon atoms, with long-chain PFAS having a greater number of sulfonic acids and carboxylic acids compared to short-chain PFAS. Common long-chain PFAS that have been studied are PFOA (perfluorooctanoic acid), PFOS (perfluorooctane sulfonate), PFNA (perfluorononanoic acid), PFHxS (perfluorohexane sulfonic acid), and PFDA (perfluorodecanoic acid), while short-chain PFAS that have been studied more recently include PFBA (perfluorobutanoic acid), PFBS (perfluorobutane sulfonate), and PFHxA (perfluorohexanoic acid). Long-chain PFAS were commonly used from the 1940s to the early 2000s, until evidence indicated PFOA and PFOS caused lifelong, adverse health effects for exposed populations. Between 2000 and 2009, the use of long-chain PFAS was transitioned to short-chain PFAS, and the EPA regulations for long-chain PFAS. This transition reduced the potential of long-chain PFAS impacting water bodies, although an increase of short-chain PFAS into waste and water ways was observed. Initially considered less persistent in the body compared to long-chain PFAS, short-chain PFAS have found to be persistent, and may have increased solubility (Helmer, Reeves, & Cassidy, 2022). U.S. Food and Drug Administration (FDA) research suspects certain effects from short-chain PFAS have been underestimated due to their generally shorter half-life in the human body, and that health impacts, such as endocrine disruption, are similar in both long-chain and short-chain PFAS (Rice et al., 2020; Mokra, 2021).

PFAS are known to bioaccumulate in plants, animals, and humans. PFAS present in food such as plants, fish, and livestock become an additional exposure to humans. Both long-chain and short-chain PFAS persist in the environment and are colloquially known as “forever chemicals” due to resistance to degradation, strong carbon-fluorine bond, and persistence in the environment. PFAS persist for years and contamination of water from when PFAS first were manufactured exists in current bodies of water. This persistence means PFAS accumulate in the human body, unless slowly excreted through urine, menstruation, and breast milk over multiple days to years (ATSDR, 2024). The National Center for Health Statistics (NCHS) has found that 98% of individuals living in the United States have measured blood PFAS (ATSDR, 2024). Research is ongoing for the negative health implications from PFA exposure, with known effects existing for multiple biological systems.

Exposure to PFAS can lead to reproductive issues such as decreased fertility, pregnancy induced hypertension, and hormonal interference. PFAS contribute to developmental delays in children, including reduced cognitive, motor, and language development, and low birth weight and bone density. The hormonal disruption from PFAS can accelerate puberty and increase behavioral issues (Ames, Sharma & Lyall, 2025; EPA, 2022). PFAS diminish the immune system's ability to fight infections, reduce vaccine efficacy, and increase risk of cancer including kidney, testicular, and prostates (EPA, 2022). Ongoing research at the National Cancer Institute indicates that there may be an increased risk of non-Hodgkin lymphoma, leukemia, breast, thyroid, ovarian, and endometrial cancers (EPA, 2022; DCEG, 2025). PFAS are also linked to increased cholesterol and ulcerative colitis (EPA, 2022).

Products containing PFAS break down overtime in landfills, composting facilities, and other areas where waste can degrade, and PFAS are released as a liquid form, creating mobility in the environment. Other

classes of PFAS, such as FTOHs (fluorotelomer alcohols) and FTCA (fluorotelomer carboxylic acid) are precursors to other PFAS, creating a compounding effect during degradation. FTOHs, FTCA, and other PFA precursors are often more volatile than PFAS and are able to be inhaled in the air, as well as ingested in liquid form.

1,4-dioxane, although not a PFA, has multiple similarities to the forever chemicals in terms of chemical properties and health impacts. 1,4-dioxane is an emerging contaminant of concern and has an RfD of 3×10^{-2} mg/kg-day. It is a synthetic chemical that is used as a solvent in paints, paper, plastics, adhesives, textiles, and pharmaceuticals; household products such as soap and lotion; and used as a stabilizer for other chlorinated solvents. It is relatively resistant to degradation and is completely miscible in water. In November 2024, the EPA released a final risk determination for 1,4-dioxane, finding that it presents an unreasonable risk to human health to both those occupationally exposed to the chemical, as well as the general public (EPA, 2024). Health implications include risks of liver toxicity, harm to olfactory epithelium (tissue in the nasal cavity that is responsible for sense of smell), as well as an increased risk of cancer (EPA, 2024). 1,4-dioxane exposure includes inhalation, ingestion, and dermal contact.

PFAS and 1,4-dioxane are found in multiple waste streams. Landfill leachate and surface runoff are perhaps the most commonly investigated sources of exposure in MSW, as multiple sources of PFAS are detected in landfills and elevated levels of PFAS are found in landfill leachate (Helmer, Reeves & Cassidy, 2022; Coffin, Reeves, & Cassidy, 2023; Hepburn et al., 2019). These studies have indicated elevated concentrations of PFAS in both active and closed landfills across multiple states and countries. Although the concentration of specific PFAS varied depending on the area and types of waste, multiple studies confirmed that over 16,500 pounds of PFAS end up in U.S. landfills each year (Coffin, Reeves, & Cassidy, 2022; Hepburn et al., 2019; Tolaymat et al., 2023). PFAS are also present in landfill gas, especially untreated, becoming another source of exposure for human populations (Titaley et al., 2024).

PFAS and 1,4-dioxane are present in composting facilities, specifically ones that accept compostable packaging (Goossen, Schattman, & MacRae, 2023). They are present in MRFs and mixed-waste sorting and processing facilities, as food packaging, textiles, paints, cosmetics, etc., are managed through these facilities. Stormwater runoff at MRFs and mixed-waste sorting facilities are also pathways of exposure for PFAS.

PFAS can theoretically be present in ash landfills due to incomplete combustion, as incineration has been used to chemically break down PFAS (EPA, 2022). Some studies suggest that over 99% of PFAS are destroyed through pyrolysis, making it a common methodology to minimize PFA exposure in waste (Keller et al., 2024).

Pharmaceuticals and Personal Care Products (PPCPs)

PPCPs are a group of chemicals that include prescription and over-the-counter medications, and non-medical consumer chemicals such as soaps, sunscreens, cosmetics, lotions, etc. Due to evidence that PPCPs have an impact on ecological systems and the respective organisms living within, they are an emerging contaminant of concern. PPCPs are not often considered a risk to human health, as they are used in products being made for human use or consumption. However, one major health risk to humans is caused by excess antimicrobials, specifically antibiotics, in the environment.

Antimicrobial resistance (AMR) occurs when microbes, such as bacteria, viruses, and fungi, change over time to become resistant to the antimicrobial medications intended to defeat them, making infections difficult or impossible to treat. Although AMR happens naturally over time, human activity, such as the misuse and overuse of antibiotics, has expedited the emergence of these resistant microbes (WHO, 2023). AMR is a significant health threat, causing more than 2.8 million infections and 35,000 deaths in

the United States each year, and causing or contributing to 6.22 million deaths worldwide (Rodgers, 2019; WHO 2023).

Several studies have indicated that antibiotics are rarely metabolized before entering the waste stream (Dolliver & Gupta, 2008). These antibiotics often end up in either landfills or wastewater treatment plants, where they come into contact with microbes. These microbes, when exposed to various antimicrobials, can eventually develop resistance, and infections become significantly more difficult to treat. Leachate in MSW landfills has been shown to have large amounts of antibiotics and increased levels of AMR bacteria. Studies have identified various landfills where the majority of *Escherichia coli* (*E. Coli*) in leachate is to be highly resistant to antibiotics such as tetracycline, doxycycline, cephalothin, and minocycline (Threedeach et al., 2012). In multiple studies, AMR strains were found to be resistant to antibiotics across multiple antibiotic groups including B-Lactams like amoxicillin, quinolones including ciprofloxacin, sulfonamides, macrolides, lincosamides, chemotherapeutics, and chloramphenicol (Gunaratne et al., 2024). Perhaps most concerning, studies have shown carbapenem-resistant bacteria (CRB) in landfill leachate (Dadić, Hrenović, & Ivanković, 2025). Carbapenem are a class of antibiotics that are colloquially known as “last resort” antibiotics and are used when other antibiotics and treatments have been attempted with no success. They are most notably used to treat multidrug-resistant bacteria, or immunocompromised patients. Exposure to CRB in leachate could lead to a rise in infections that are difficult to treat.

Other pharmaceuticals have commonly been found in leachate that may be of potential concern. A study done across 12 states, including Minnesota, included 22 landfills where concentrations of pharmaceuticals in leachate were analyzed. The analysis found that 91% of landfills contained lidocaine, a local anesthetic; 92% contained carisoprodol, a muscle relaxant; 77% contained carbamazepine, an anticonvulsant (Masoner, 2016). Another study in North Carolina found that 100% of landfills had elevated levels of ibuprofen and carbamazepine, and a majority had elevated levels of acetaminophen, an analgesic and antipyretic; doxycycline, an antibiotic; and metformin, a biguanide (Rezaei Adaryani & Keen, 2022). Other studies have shown elevated levels of sulfamethoxazole, an antibiotic; metoprolol, a beta-blocker commonly used to manage hypertension and angina; estrone, a phenolic steroid; and hydrochlorothiazide, a thiazide diuretic that is prescribed for edema and hypertension (Furlong et al., 2017). Lithium was also present in many of the studies, however, lithium from electronic devices is still a larger concern to experts compared to lithium from prescription medications.

Levonorgestrel, norgestrel, and other birth control medications are of emerging concern due to their prevalence in leachate and impact on the environment, however, the primary sources of estrogen and progesterone in drinking water is from livestock and agricultural runoff (American Chemical Society, 2011). Although many pharmaceuticals are studied for their impacts on aquatic creatures and ecosystems, the increase in pharmaceutical waste may cause to be a future risk for human populations due to the prevalence of PFAS in the products. As mentioned, cosmetics, moisturizers, cleansers, shampoos, sunscreen, shaving products, etc., contain PFAS, and increase the associated risk to human health.

PPCPs are not only found in landfill leachate but also are frequently detected in leachate and runoff from composting facilities. Composting facilities that accept wasted food, compostable packaging, and biosolids, are found to have an elevated amount of PPCPs (Clarke et al., 2015). Less research has been done to study the exact concentrations of PPCPs in composting facilities, but the risk from pollutants remains similar. Occupational workers at MRFs and mixed-waste sorting and processing facilities come in contact with PPCPs, as the plastic containers may end up at those facilities for recycling. Pyrolysis is a common method for treating PPCPs and minimizing the exposure to PFAS within the products, therefore WTE facilities and ash landfills are likely a minimal source of PPCP contamination.

Factors for Consideration

Human populations are exposed to PFAS on a daily basis, with at least 98% of the population having varying amounts of PFAS in their blood. Exposure from leachate will increase the level of PFAS in exposed humans, further increasing the risk of health concerns. This also means small exposures of PFAS from MSW have the potential to increase the overall exposure level for populations and exacerbate any health concerns. MSW facilities, especially landfills without adequate engineering controls and those near other sources of PFAS pollution, increase the risk to surrounding populations. Due to the persistence and mobility of PFAS, they have the potential of greater spatial impact than other pollutants.

Landfill age, the presence and efficacy of liners and covers, other engineering controls, and climate are factors for PFAS and PPCPs in leachate. Leachate from younger landfills tends to have more short-chain PFAS due to the change from long-chain to short-chain PFAS in the manufacturing and industrial sectors. Short-chain PFAS may have higher solubility and may be at a greater concentration in leachate (Helmer, Reeves, & Cassidy, 2022). Climate is also an important factors, as increased precipitation leads to higher leachate flow rates and increased levels of surface runoff. In general, wet climates have been found to release greater PFA mass each year in landfills (Coffin, Reeves, & Cassidy; 2023).

Many of the same influencing factors for PFAS in landfills apply to PPCPs. Besides increased leachate flow rate and surface runoff, climate is a factor since increased moisture content and warmer conditions increases the prevalence of antimicrobial resistant genes in bacteria (Song et al., 2016). Leachate from active, modern landfills have been found to have significantly greater concentrations of pharmaceuticals compared to older, unlined landfills, likely due to the increase in medical advances and prescribed medications over the last few decades (Masoner, 2016).

Minnesota's MSW Facilities

PFAS, 1,4-dioxane, and PPCPs are present in Minnesota's waste streams. PFAS have been confirmed to be in multiple sources of surface water, groundwater, soil, and lakes. Although Minnesota will prohibit PFAS from avoidable uses by 2032, the PFAS already in the environment are long-lasting.

MPCA monitoring has found PFAS in 98% of closed landfills tested, or 100 out of the 102 (MPCA, 2024). Of those 100 with PFAS, 62 of them had levels exceeding environmental guidance.

PFAS have also been detected in surface water sites and groundwater sites. Of the 107 surface and groundwater sites tested, including 90 groundwater sites and 17 surface water sites, PFAS and pharmaceuticals were detected in most of the locations. PFBA and PFOSA were commonly detected, but PFHxS, PFOS, PFBS, and PFOA were also identified across multiple sites.

PFBA was detected the most frequently in surface water, followed by PFOA, PFHxA, and PFHpA. It should be noted that these levels did not surpass the Minnesota Department of Health's lowest drinking water guidance values (de Lambert et al., 2023). Pharmaceuticals were also detected in a majority of the surface water. Norgestrel, a birth control medication, and Metformin, a medicated used to manage blood sugar, were found the most frequently in the surface water samples (de Lambert et al., 2023). Additionally, a 2019 study found 11 antibiotics or anti-fungal medications, five antidepressants, two lipid-lowering drugs, and two hormonal medications detected in 50 lakes in Minnesota (Ferrey et al., 2021).

Reports have shown levels of PFAS at and near specific Minnesota MSW facilities. The east metro area of Minneapolis, including the Washington County Landfill, has documented elevated levels of PFAS that are above health-based guidance, whilst other MSW facilities have also been found to potentially have levels exceeding guidance (MPCA, 2020). Additionally, 1,4-dioxane, though not monitored at every facility, was shown to have concentrations greater than the Minnesota drinking water guidance value of 1 µg/L at approximately 25% of the MSW facilities (MPCA, 2020).

A 2019 study assessing the risk of PFAS in landfills sampled PFAS near Minnesota's SSO facilities and yard waste sites had elevated levels of PFAS compared to ambient concentrations in groundwater across Minnesota (MPCA, 2021). This study found that the most commonly detected PFAS in SSO facilities were PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFBS, PFHxS and PFOS, while yard waste facilities had elevated levels of PFBA, PFPeA, PFHxA, PFOA, PFBS, PFHxS, and PFOS (MPCA, 2021). When compared to the studies that analyzed PFA concentrations near landfills, on average, the SSO and yard waste sites had lower levels of PFAS compared to landfills (MPCA, 2021).

Although the exact sources of all PFAS and PPCPs in Minnesota's water cannot be definitively determined, elevated levels of PFAS exist at and near landfills and composting facilities, supporting a completed exposure pathway that contributes to overall PFA and PPCP exposure.

Summary of PFAS, PPCPs, and 1,4-Dioxane

PFAS and PPCPs remain emerging contaminants, with the ability to cause negative persistent health impacts. PFAS and 1,4-dioxane are persistent, soluble, and are found in waste streams and water throughout most of the United States. Although regulations exist for a select few PFAS, there are thousands of PFAS yet to be studied to determine a permissible amount in drinking water. PPCPs often contain PFAS within their product, but also have their own health implications, especially in terms of antimicrobial resistance. PFAS and PPCPs are found in leachate in Minnesota's landfills and composting facilities and present a risk at MRFs and waste-processing facilities. Due to the prevalence and health implications of PFAS and PPCPs, they are a major exposure risk for populations from MSW facilities.

Volatile Organic Compounds (VOCs)

VOCs are gases that are emitted from solids and liquids due to their evaporation, or "off gassing" at room temperature. Some VOCs are naturally occurring, but a majority that are contaminants of concern are components or byproducts of thousands of human created products. VOCs are found in both household and industrial products, with some of the most common being paints and solvents, glues and adhesives, wood preservatives, flooring and carpet, furniture, cleaners (including dry cleaning) and disinfectants, pesticides, inks and toners, building materials, and fuel. VOCs are often categorized based on their molecular structure and polarity. Common VOC classifications include acids, alkane, alkenes, alcohols, aromatic hydrocarbons, aldehydes, halogenated hydrocarbons, and ketones (Gan et al., 2023). Semi-volatile organic compounds (SVOCs) are less volatile compared to VOCs but are also found in MSW facilities and impact human health.

VOCs have both short-term and long-term health implications. Short-term exposure to VOCs can cause dizziness, headache, fatigue, nausea and vomiting, dyspnea (shortness of breath), irritation of mucous membranes of the eyes, nose, and throat, epistaxis (nose bleeds), and a decrease in liver enzymes such as serum cholinesterase (EPA). Long-term exposures can cause a variety of severe health issues, such as cancer, liver and kidney toxicity, damage to the nervous and circulatory systems, and anemia (EPA). The EPA NPDWR has MCLs and MCLGs for various VOCs in drinking water, along with the health effects when above the MCL. These values and concerns can be found in Table 73.

Table 73. EPA NPDR for VOCs and potential health Impacts

VOC of concern	MCL (mg/L)	MCLG (mg/L)	Potential health effects from exposure above MCL
Acrylamide	0.05% dosed at 1 mg/L	0	Nervous system or blood problems; increased cancer risk
Benzene	0.005	0	Anemia; decreased blood platelets; increased cancer risk
Carbon tetrachloride	0.005	0	Liver problems; increased cancer risk
Chlorobenzene	0.1	0.1	Liver, kidney, or nervous system problems
pDichlorobenzene (p-DCB)	0.075	0.075	Anemia; liver, kidney, spleen damage; blood changes
oDichlorobenzene (o-DCB)	0.6	0.6	Liver, kidney, circulatory system problems
1,2Dichloroethane (1,2-DCE)	0.005	0	Increased cancer risk
1,1Dichloroethylene (1,1-DCE)	0.007	0.007	Liver problems
cis1,2Dichloroethylene (cis-1,2-DCE)	0.07	0.07	Liver problems
trans1,2Dichloroethylene (trans-1,2-DCE)	0.1	0.1	Liver problems
Dichloromethane (DCM)	0.005	0	Liver problems; increased cancer risk
1,2Dichloropropane (1,2-DCP)	0.005	0	Increased cancer risk
Di-2-ethylhexyl adipate (DEHA)	0.04	0.04	Liver problems; reproductive difficulties; weight loss
Ethylbenzene	0.7	0.7	Liver, kidney problems
Hexachlorocyclopentadiene (HCCPD)	0.05	0.05	Liver, stomach problems
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems
Tetrachloroethylene (PCE or PERC)	0.005	0	Liver problems; increased cancer risk
Toluene	1	1	Nervous system, kidney, liver problems
1,2,4Trichlorobenzene (1,2,4-TCB)	0.07	0.07	Changes in adrenal glands
1,1,1Trichloroethane	0.2	0.2	Liver, nervous system, circulatory system problems
1,1,2Trichloroethane	0.005	0.003	Liver, kidney, immune system problems
Trichloroethylene (TCE)	0.005	0	Liver problems; increased cancer risk
Vinyl chloride	0.002	0	Increased cancer risk
Xylenes (total)	10	10	Nervous system damage

**All values were provided by the State of California Office of Environmental Health Hazard Assessment Chemical Database*

Many of the VOCs that are regulated in drinking water also have oral RfDs and inhalation RfCs and oral and inhalation slope factors associated with exposure, which can be found in Table 74.

Table 74. Oral RfDs and slope factors and inhalation RfCs and slope factors for VOCs

VOC of Concern	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m ³)	Oral Slope Factor (per mg/kg-day)	Inhalation Unit Risk (per µg/m ³)
Acrylamide	2 x 10 ⁻³	6 x 10 ⁻³	8.3 x 10 ⁻¹	1.7 x 10 ⁻⁴
Benzene	4 x 10 ⁻³	3 x 10 ⁻²	1.5 x 10 ⁻²	2.2 x 10 ⁻⁶
Carbon tetrachloride	4 x 10 ⁻³	1 x 10 ⁻¹	7 x 10 ⁻²	6 x 10 ⁻⁶

VOC of Concern	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m ³)	Oral Slope Factor (per mg/kg-day)	Inhalation Unit Risk (per µg/m ³)
Chlorobenzene	2 x 10 ⁻²			
pDichlorobenzene (p-DCB or 1,4-DCB)	n/a	8 x 10 ⁻¹		
oDichlorobenzene (o-DCB or 1,2-DCB)	9 x 10 ⁻²			
1,2Dichloroethane (1,2-DCE)			9.1 x 10 ⁻²	2.6 x 10 ⁻⁵
1,1Dichloroethylene (1,1-DCE)	5 x 10 ⁻²	2 x 10 ⁻¹		
cis1,2Dichloroethylene (cis-1,2-DCE)	2 x 10 ⁻³			
trans1,2Dichloroethylene (trans-1,2-DCE)	2 x 10 ⁻²			
Dichloromethane (DCM)	6 x 10 ⁻³	6 x 10 ⁻¹	3.3 x 10 ⁻³	1.7 x 10 ⁻⁸
1,2Dichloropropane (1,2-DCP)		4 x 10 ⁻³		
Di-2-ethylhexyl adipate (DEHA)	6 x 10 ⁻¹	n/a	1.2 x 10 ⁻³	
Ethylbenzene	1 x 10 ⁻¹	1		
Hexachlorocyclopentadiene (HCCPD)	6 x 10 ⁻³	2 x 10 ⁻⁴		
Styrene	2 x 10 ⁻¹	1		
Tetrachloroethylene (PCE or PERC)	6 x 10 ⁻³	4 x 10 ⁻²	2.1 x 10 ⁻³	2.6 x 10 ⁻⁷
Toluene	8 x 10 ⁻²	5		
1,2,4Trichlorobenzene (1,2,4-TCB)	1 x 10 ⁻²			
1,1,1Trichloroethane	2	5		
1,1,2Trichloroethane	4 x 10 ⁻³	n/a	5.7 x 10 ⁻²	1.6 x 10 ⁻⁵
Trichloroethylene (TCE)	5 x 10 ⁻⁴	2 x 10 ⁻³	5.2 x 10 ⁻²	4.8 x 10 ⁻⁶
Vinyl chloride	3 x 10 ⁻³	1 x 10 ⁻¹	7.2 x 10 ⁻¹ **	4.4 x 10 ⁻⁶ **
Xylenes (total)	2 x 10 ⁻¹	1 x 10 ⁻¹		

*All values were provided by the EPA's IRIS database

**Variation for this value is dependent on length of exposure

VOCs in outdoor air are also regulated in a sense, but these regulations are based on ozone standards, and not the VOC levels, due to the fact VOCs react with nitrogen oxides and sunlight in the atmosphere to create ozone. Besides ozone, VOCs form second organic aerosols (SOAs) which are major components of PM_{2.5}, when reacting with other atmospheric compounds (Cao et al., 2024). There are regulations to limit VOC emitting components in products, but these are formulas for product formulations, not concentration in air. However, unofficial benchmarks suggest that exposure to VOCs should remain under 0.5 mg/m³. The U.S Occupational Health and Safety Administration (OSHA) sets permissible exposure limits (PELs) for specific VOCs, but they are primarily used to minimize indoor air VOC exposure to occupational workers.

The main route of exposure for VOCs is inhalation. VOCs that are emitted from products, such as paint, flooring, and adhesives, are gases that are easily inhaled, and smoke from burning or combustion contains VOCs that can be inhaled. Direct dermal contact with VOCs can occur from absorption through skin of specific solvents, but it is significantly less common. Ingestion is also a route of exposure since VOCs are common ground-water contaminants from liquid sources such as cleaning products and paint thinners (EPA).

VOCs are formed and contribute to landfill gas from the degradation of sources of VOCs, such as solvents, paints, and building materials, as well as the decomposition of organic matter. VOCs and

SVOCs have been found to generally travel 400-1,500 m (1,312-4,921 ft) from a landfill to surrounding areas (Pan et al., 2023). VOCs can also dissolve into leachate, contaminating groundwater if leachate migrates, and they can also contaminate surface water due to runoff, which travels farther from the landfill compared to atmospheric VOCs.

Across various studies in the United State, the most common VOCs found in high concentrations in the atmosphere around landfills are vinyl chloride, cis-1,2-DCE, trans-1,2-DCE, and BTEX which is the grouping of benzene, toluene, ethylbenzene, and xylene (Pan et al., 2021; Yim & Kim, 2007). These VOCs have significant health implications from chronic exposure, such as increased risk of cancer, damage to the nervous system, liver and kidney toxicity, and anemia (EPA NPDWR). VOCs such as carbon tetrachloride, tetrachloroethylene (PCE or PERC), trichloroethylene (TCE), and methyl tert-butyl ether are especially persistent in water.

VOCs are found in leachate, but have less variability compared to VOCs in landfill gas. The most common VOCs found in landfill leachate are benzene, toluene, ethylbenzene, and xylene (BTEX) (He et al., 2023). VOCs including carbon tetrachloride, PEC (or PERC), TCE, and methyl tert-butyl ether are also found in leachate. Leachate can impact soil, groundwater, surface water, vegetation, and surrounding aquatic species, creating various routes of ingestion for human populations.

Terpenes, specifically di-limonene, aromatic hydrocarbons such as benzene, and oxygenated compounds including esters, alkanes, ketones, and alcohols are all commonly found in the atmosphere at compost facilities due to the breakdown of vegetables, fruit, kitchen waste, and yard waste (Agapiou et al., 2016; Pan et al., 2023). Like landfills, VOCs can also be found in the leachate from composting facilities which can expose nearby populations. Workers at composting facilities are also at an increased risk, due to their proximity to waste emitted VOCs when transporting, moving, rotating, and performing other movements of the composting process.

VOCs are also found in MRFs and MWPFs and present a risk to the workers in those facilities. BTEX has been consistently detected in these facilities, however, the levels tend to be lower compared to landfills and composting facilities, and were not found to be high enough for negative health effects (Elmegrahi, Karani, & Morris, 2007). However, without proper personal protective equipment and proper hygiene, this risk could potentially increase.

In WTE facilities, VOCs are a common byproduct, especially during the incineration of plastic, and can be found in stack gases and ash residue. Gaseous VOCs get into the atmosphere for populations to inhale, while residue and ash can be dispersed via wind from both the facilities and ash landfills. Residues can also infiltrate the end product of pyrolysis, RDF, and have been found to release VOCs during storage and use (Hejna & Białowiec, 2025). Therefore, workers are exposed during the creation, storage, and burning of RDF, while nearby populations may be exposed when the RDF is used in the WTE process. 1,3-butadiene is a VOC that is formed during the incineration of various plastics, such as polyvinyl chloride (PVC), and biodegradable plastics including polybutylene succinate (PBS). When inhaled, 1,3-butadiene may have similar effects as VOCs, such as neurological dysfunction, reproductive and development toxicity, liver and kidney toxicity, and an increased risk of cancer (ATSDR, 2012). DCM, benzene, carbon tetrachloride, toluene, styrene, PCE, 1,2-DCE, styrene, and ethylbenzene are some of the more common VOCs that are produced during the WTE process.

Semi-volatile organic compounds (SVOCs) are found more frequently in leachate as the volatility of SVOCs is less than VOCs. SVOCs include many of the pollutants assessed in more specific sections of the reports, such as PAHs, phthalates and phenols, pesticides, and personal care products.

Factors for Consideration

Climate is an influencing factor on the levels, concentrations, and migration of VOCs. High temperatures cause increased reactions and create an increased atmospheric pollution of VOCs and semi-volatile organic compounds (SVOCs) with a greater surface area impacted. Increased humidity worsens the pollution of VOCs at landfills, since the VOCs cannot diffuse over a larger surface area due to water vapor impacting diffusion. High air pressure decreases VOCs and SVOCs in the atmosphere around landfills. Therefore, areas most at risk are locations with high temperatures, high humidity, and low air pressure. Wind speed impacts migration of VOCs and SVOCs and potential dilution. High winds can be beneficial as dilution happens quicker (Pan et al).

Various removal technologies are available for landfill leachate, depending on the characteristics of the VOC. For example, hydrophilic VOCs may be decreased more effectively with sequencing batch reactor or anoxic/oxic processes, while hydrophobic contaminants are more likely to be sufficiently removed through ultrafiltration or biochemical reactor process (He et al., 2023).

Factors such as the type of compost, the time to compost, and the composting methodology have been shown to impact the VOC emissions. Wasted food has been shown to release a greater amount of VOCs compared to composting yard waste (Renninger et al., 2018). Composting in full enclosures exhausted to a biofilter had the lowest emissions; covered composting under negative air pressure exhausted to a biofilter, and more traditional covered composting were found to have less emissions compared to uncontrolled composting (Renninger et al., 2018). Waste that has been anaerobically digested prior to composting has been found to reduce VOCs. Trapping VOCs through photocatalytic oxidation, membrane separation, or plasma catalysis, also decreases the levels of VOCs, as does biological methods of bio-scrubbers and membrane bioreactors (Dhamodharan et al., 2019).

In WTE, the type of pyrolysis influences the composition of released VOCs. Slow pyrolysis that uses a low heating rate over a long period of time, leads to heavier VOCs but at a lesser concentration or amount of total emissions, while fast pyrolysis using high heating rates and shorter times, produces lighter VOCs but at a higher concentration or magnitude (Hejna & Białowiec, 2025). The type of feedstock also impacts VOC removal in the process, and the emissions of VOCs vary based on the type of plastic. PVC has been found to release the highest amount of VOCs, specifically benzene, toluene, 1,2-DCE, and styrene (Jang et al., 2022). Other non-degradable plastics tend to have higher concentrations of these same VOCs, as well as ethylene and chloroform. However, biodegradable plastics tend to emit higher concentrations of 1,3-butadiene compared to non-biodegradable plastics (Jang et al., 2022).

More generally, similar influencing factors also exist for VOCs as other pollutants. In landfills, age of facility, use and type of covers and liners, and proper maintenance and monitoring are influencing factors, while at WTE facilities and pyrolysis, air pollution control devices, age of facility, and maintenance are factors that could increase or decrease VOC emissions.

Minnesota's MSW Facilities

VOCs are present at Minnesota's MSW infrastructure, due to incineration of waste and uncovered landfills. Monitoring by the MPCA has confirmed VOCs prevalent in surface water and groundwater near multiple landfills and WTE facilities across the state. Landfills for demolition debris are unlined, and often part of the closed landfill program, and have elevated levels of VOC contamination in the groundwater near the sites (MDH, 2024; MPCA, 2023; EPA). Therefore, this is a completed exposure route for human populations near landfills in the state of Minnesota, and VOCs.

There are also VOCs that are not regulated by the EPA, such as 1-butanol and 2-propen-1-ol that are considered unregulated contaminants according to the Minnesota Department of Health, and ongoing assessments to determine the risk and potential levels in water are ongoing.

Summary of VOCs

VOCs are present in waste streams due to being byproducts from everyday residential, commercial, and industrial products. VOCs have a variety of health impacts, including increased risk of cancer, damage to the nervous and reproductive systems, developmental toxicity, and toxicity of the liver and kidneys.

VOCs are most often inhaled but can be ingested or come into direct dermal contact with human populations. Landfill and compost gaseous VOCs, and VOCs from the combustion of waste, are the most studied due to their prevalence from degradation or incineration of products that emit VOCs. VOCs have been detected in Minnesota's surface waters, especially around closed landfills, open landfills, and WTE facilities, and represent a risk for workers and surrounding communities.

Noxious & Odorous Gases

Various noxious gases, such as hydrogen sulfide (H_2S), sulfur oxides (SO_x), nitrogen oxides (NO_x), carbon dioxide (CO_2), carbon monoxide (CO), and ammonia (NH_3); and odorous gases such as methane (CH_4) are contaminants of concern for MSW facilities. These gases migrate from landfills through underground pipes and subsurface geology, or in the atmosphere, exposing sanitation workers at landfills and neighboring populations (ATSDR). Landfills and composting facilities emit gases that are byproducts of waste decomposition. High concentrations of CH_4 and CO_2 are emitted from landfills and compost. NH_3 and H_2S emissions have an increased public health concern. MRFs and mixed-waste processing facilities have the potential to expose workers and nearby populations to the same gases of landfills but are often emitted at lower levels (Yama, 2020). MRFs and mixed-waste sorting and processing facilities that are smaller, confined, and have poor ventilation can create an increased risk of exposure and health impacts. Pyrolysis, WTE facilities, and ash landfills are potential exposure points for SO_x , NO_x , and CO_2 .

Hydrogen sulfide and ammonia are two gases associated with the foul odor emitted from landfills, composting facilities, MRFs, and mixed-waste sorting and processing facilities. Sulfuric compounds of dimethyl sulfide and methyl mercaptan present at the facilities have unpleasant odor as well. NH_3 and H_2S have low odor thresholds, meaning that populations often detect levels of NH_3 and H_2S that are below levels that cause health effects (NYDH). However, landfills can emit concentrations of these two gases at levels that have negative impacts on human health. The EPA has inhalation RfCs of $5 \times 10^{-1} \text{ mg/m}^3$ for NH_3 and $2 \times 10^{-3} \text{ mg/m}^3$ for H_2S (EPA IRIS).

Short-term exposure of elevated levels of NH_3 , H_2S , and other sulfuric compound gases can cause coughing, irritation of mucous membranes, headache, nausea, and shortness of breath (NYHD). Sleeping difficulties, weight loss, chest pain, and aggravation of pre-existing conditions such as asthma, COPD, and heart disease also are observed for both short and long-term exposure to these gases. Long-term exposure of landfill emitted hydrogen sulfide, dimethyl sulfide, and methyl mercaptan to workers and nearby populations is associated with increased mortality from lung cancer and cardiorespiratory morbidity, an increase in multiple respiratory diseases such as COPD and asthma and increases respiratory infection occurrence amongst children (Mataloni et al., 2016). Lung cancer and landfill emitted H_2S were associated with both open "dumps" and covered landfills (Mataloni et al., 2016; Siddiqua, Hahladakis, & Al-Attia, 2021). Landfill workers have a higher level of exposure to NH_3 and H_2S , and thus are at a greater risk of exposure compared to surrounding populations. Hydrogen sulfide has been known to prevent energy metabolism and have toxic effects on neurological health for those working in close contact to the gas, while workers who inhale high concentrations of ammonia can suffer from lung oedema (EASHW, 2014).

Negative mental health impacts and alteration of daily activities have also been recorded for populations living near landfills emitting hydrogen sulfide, due to the distinct rotten-egg smell that comes from (Heaney et al., 2011). Ammonia also presents a risk for secondary byproducts that are

pollutants. For instance, NH_3 that reacts with sulfuric and nitric acid creates ammonium sulphate and ammonium nitrate, both of which are particulate matter that could impact human health.

Methane is highly flammable and explosive, but landfill gas explosions are not common. In a typical landfill, CH_4 concentration is between 40-60% by volume, significantly above its Upper Explosive Limit (UEL) of 15% by volume in the air, making explosions unlikely (ATSDR). However, if an explosion or fire were to occur, other contaminants of concern could be released into the atmosphere, exposing nearby populations. CO_2 is released from combustion, including when CH_4 burns in landfills, and incomplete combustion can lead to the formation of particulate matter. CH_4 and CO_2 , both potent greenhouse gases, and can contribute towards climate-related health issues.

Landfills workers and compost workers have a higher risk of methane exposure, which in high concentrations, has been found to cause vision problems, memory loss, mood and behavioral changes, slurred speech, nausea, vomiting, shortness of breath, reduced coordination and a fast heartbeat (Paolini et al., 2018; NYDH). Most cases of high methane exposure to populations outside of workers are at biogas plants, and not part of the MSW waste stream. Methane exposure is also likely to occur for workers at MRFs and mixed-waste sorting and processing facilities, but studies have shown that methane emissions are lower in those facilities compared to landfills.

MSW incineration, pyrolysis of feedstock, WTE facilities, and ash landfills also present their own risks from gas emissions. SO_x , NO_x , CO_2 , and hydrochloric acid are byproducts of the WTE process, including pyrolysis, and are present in ash/char. H_2S can be formed from incomplete combustion due to insufficient oxygen. Studies have shown that contact with fly ash is an effective way to remove H_2S (Wu et al., 2018; Gao et al., 2023). H_2S also reacts with heavy metals in the fly ash to form stable metallic sulfide components, therefore H_2S is not a major concern for WTE facilities (Wu et al., 2018).

Nitrogen oxides such as nitric oxide, nitrogen dioxide, and nitrous oxide can be released during pyrolysis and general waste incineration. When inhaled, NO_x can cause respiratory irritation and lung oedema, and long-term exposure can impact the immune, reproductive, and peripheral nervous systems (EASHW, 2014). Association has been found between MSW incinerators emitting NO_x and pulmonary fibrosis, emphysema, and respiratory illnesses in children (Shimizu et al., 2007). Dermal contact with any of these compounds can also cause skin irritation and burns, and when interaction with water occurs, acid rain forms (EASHW, 2014, ATSDR). NO_x also can react with other compounds to create particulate matter and ozone. The EPA has emissions regulations for nitrogen dioxide, with a primary standard of 100 ppb for a 1-hour average, and a primary and secondary standard of 53 ppb as an annual average (EPA, 2025).

Sulfur oxides, especially sulfur dioxide, are harmful to human health and the environment. The incineration of waste releases SO_x into the environment and when inhaled, can cause harm to the respiratory system (EPA, 2025). SO_x from waste incineration has been found to cause irritation of mucous membranes, aggravate pre-existing heart disease and asthma, and increase risk of respiratory illnesses (Liang et al., 2021; EPA, 2025). Workers who come into dermal contact with SO_x may also experience severe burns and eye damage (EASHW, 2014). Like NO_x , SO_x interactions can form acid rain and particulate matter, both of which have their own health implications. The primary National Ambient Air Quality Standard (NAAQS) for sulfur dioxide is 75 ppb for a 1-hour average and a secondary standard of 10 ppb as an annual average (EPA, 2025).

CO_2 and CO are created during waste incineration. As previously stated, CO_2 is a greenhouse gas and presents a larger scale risk. CO is a dangerous byproduct of incomplete combustion, often due to fluctuation of moisture levels and material composition. High concentrations of CO, especially indoors and in areas of poor ventilation, can cause dizziness, confusions, unconsciousness, and death (EPA,

2025). Elevated levels of CO outside can impact those with pre-existing heart disease and angina (EPA, 2025). Although CO pollution outdoors is unlikely to be at a level of concern, the EPA has a primary standard of 9 parts per million (ppm) for an 8-hour average, and 35 ppm for a 1-hour average, with both never to be exceeded more than once per year (EPA, 2025).

Factors for consideration

Landfill type, maintenance, monitoring, and technology can impact the level of gas emissions the population is exposed to. MSW landfills have been found to emit less gas than open dumps, and remediation efforts to convert open dumps to MSW landfills can reduce emissions, while reducing the risk of landfills fires and improving waste management (Lakhout, 2024). Covering landfills also can reduce the level of emissions, while proper monitoring of active and closed landfills is necessary to prevent elevated emissions. More advanced technologies, such as gas capture, reduces emissions, and therefore those facilities would have a lower risk of exposure to the public. Monitoring of emissions, and proper ventilation and pollution controls are influencing factors for both MRFs and mixed-waste sorting and processing.

For composting, the type of operations and technology used also has an impact on emissions. For instance, ongoing research is studying whether when waste is anaerobically digested prior to composting, if NH₃ emissions are reduced (Nordahl et al., 2023). Aeration and the makeup of the material (e.g., pet waste compared to yard waste compared to wasted food) are contributing factors for the amount of emissions from composting (Nordahl et al., 2023). Composting facilities that accept wasted food and pet waste have higher CH₄ emissions compared to facilities that only accept yard waste.

Similar to other pollutants, the air pollution control devices of WTE facilities and pyrolysis are influencing factors that determine the amount of emissions and exposure level to populations. Older facilities, facilities without sufficient air pollution control devices, and facilities that have insufficient combustion, are more likely to be a risk of exposure to nearby populations. Proximity to other sources of pollution and proximity to human populations are also factors that should be considered for overall risk.

Minnesota's MSW Facilities

WTE facilities including pyrolysis, ash landfills, composting facilities, MSW landfills, MRFs and mixed-waste sorting and processing facilities are all part of Minnesota's MSW infrastructure. Although there is a lack of data to determine a complete exposure pathway for noxious gases in Minnesota, the likelihood is extremely high, and presence of a foul odor would imply a complete exposure.

Minnesota has open dumps, closed landfills, MSW landfills, and composting facilities, all of which emit some level of noxious and odorous gases. Considering these gases are emitted from the decomposition of waste, a process occurring in every landfill and composting facility, it is probable that NH₃, H₂S, and CH₄ are all present throughout Minnesota's waste facilities. Waste decomposition also occurs at MWPFs before continuing to the next step in the waste stream, although the level of emissions is likely not as great as facilities where waste continuously breaks down. Some decomposition could occur at MRFs when recyclables are not cleaned beforehand and slightly increase the risk of exposure to noxious gases.

WTE facilities, whether through pyrolysis from feedstock or mixed waste, are known to emit NO_x, SO_x, and CO, although air pollution control devices are meant to minimize the pollutants. These pollutants have EPA regulations for hour and annual averages that are required to be followed. Although levels of NO_x, SO_x, and CO, have been detected due to Minnesota's WTE facilities, the concentration in the air that determines risk and level of exposure, is unknown.

Summary for Noxious and Odorous Gases

Noxious and odorous gases present a risk to exposed populations, due to their likely prevalence and potential to impact human health. They can impact a variety of systems, such as immune, reproductive, cardiovascular, pulmonary, and neurological. The type of facility and waste, technology used, age of facility, and pollution control, such as scrubber at WTE facilities and covers for landfills, factor into the overall risk.

Plastics & Plasticizers

Plastic is used globally with around 450 million tons of plastic being produced each year. The United States is one of the largest consumers of plastic, using between 35-37 million tons each year, on average (Ritchie, Samborska, & Roser, 2023, EPA, 2024). The majority of that plastic ends up in landfills. In 2018, the United States used 35 million tons of plastic, but over 75% of it, about 27 million tons, were disposed of in landfills. Nationally, less than 9% of plastic was recycled, and less than 16% was used for WTE operations (EPA, 2024). In 2023, the reported recycling rate of plastic in Minnesota was marginally better at 11.5%. Almost 20% of waste that ends up in landfills is plastic.

Plastics represent a unique risk to the waste stream, MSW facilities, and surrounding populations. Plastics can either be intentionally created or degraded in the environment to create macro, micro, and nano-plastics, which can be consumed by humans and animals. Plastics often also contain various harmful chemicals, such as plasticizers that are meant to make plastic more durable and flexible. The majority of plastics are either polypropylene (PP), PE, polystyrene (PS), PVC, and polyethylene terephthalate (PET) (Hüffer et al., 2019). PE and PP make up 15-25% of the world's total plastic, and are the common plastics for construction, packaging, textiles and containers (Geyer et al., 2017). Most liners to prevent leachate infiltration in landfills are made of PE. PVC is often used for construction and medical devices, PS is used in insulation, packaging materials, and food containers, and PET is used for beverage bottles and certain textiles, like polyester clothing (Geyer et al., 2017).

Microplastics

Microplastics are generally between 1 nanometer (nm) and 5 millimeter (mm) in diameter, while those greater than 5 mm are macroplastics, and those smaller than 1 nm are nanoplastics. Microplastics are grouped into primary or secondary sources. Primary sources are intentionally made as microplastics, and include microbeads in cosmetics and toothpaste, particles in laundry detergent pods and scrubbing agents, and certain biomedical products. Secondary microplastics are an unintentional result of fragmentation, degradation, chemical transformation, biological actions, or other ways that larger plastics can become microplastics (Wang, Zhao, & Xing, 2021).

Microplastics are found in water, soil, vegetation, and animal byproducts such as meat and seafood, and are easily ingested. Microplastics can also be inhaled as tiny fibers in dust and can also be absorbed through the skin via clothing and cosmetics.

Microplastics can transport other contaminants such as heavy metals, pesticides, pharmaceuticals, PFAS and other POPs, as well as microbes. Microplastics have been found to elevate the prevalence of antimicrobial resistant bacteria. Their increased capacity for biofilm formation, which creates an increase of pathogen potential for bacteria, has shown to increase the occurrence of antimicrobial resistant bacteria (Anand et al., 2021). Some studies have shown that there are 5.7-103 times more antibiotic-resistant bacteria on microplastics compared to other waste in landfills and leachate (Su et al., 2021).

Microplastics accumulate in the human body, and correlations have been found between negative health impacts for certain biological systems and prevalence of microplastics in that system.

Microplastics in fecal matter have revealed an association with inflammatory bowel disease (Yan et al.,

2022). Microplastics have been found to accumulate in the lungs and cause respiratory issues, and accumulate in artery plaque, increasing risk of heart attack, stroke, and death (Mayo Clinic, 2024). Microplastics have also been found in human placenta for various mothers, which includes the contaminants they carry and leach (Ragusa et al., 2021).

Microplastics are found in landfills and can expose human populations through ingestion of contaminated ground and surface water, as well as the vegetation, aquatic life, and livestock that humans consume. Microplastics travel from landfill to exposure points through leachate, runoff, flooding, wind, and even animal excrement (Wojnowska-Baryła, Bernat, & Zaborowska, 2022). Microplastics are also found in MRFs, from contaminated recyclables, but often from on-site generation during shredding, milling, and extrusion of plastic (Suzuki et al., 2022). Mixed-waste processing, or “dirty” MRFs, may have greater levels of microplastics compared to MRFs, as other contaminants may cause degradation of the plastic at a quicker rate, releasing more microplastics during the processing of plastic (Brown et al., 2023). Microplastics can migrate to surface and groundwater due to stormwater runoff. Additionally, workers at MRFs, mixed-waste processing, and landfills are at a high risk of exposure, including higher rates of inhaled microplastics during the shredding and milling process.

Composting facilities are a source of microplastic pollution. Items such as plastic-coated paper items are considered to be fully compostable to the general public, but the coating is unable to biodegrade and becomes a source of microplastics. Other items contain plastic and are observed in the compost waste stream, such as stickers on fruit, often due to improper sorting of biowaste. Many products may be certified as compostable, like compostable dinnerware, but break down into microplastics because they can only be processed at industrial composting facilities (Sakali et al., 2024).

Microplastics are not a high-risk concern as a byproduct of pyrolysis or WTE generation, as plastics are often used as feedstock for the process. Studies have shown that pyrolysis may eliminate over 99% of the microplastic in the incinerated waste stream once combustion occurs (Keller et al., 2024).

Plasticizers

Plastics, including macro, micro, and nano, are frequently treated with plasticizers to improve the overall product. These plasticizers often contain harmful chemicals with the potential to leach from the plastic and infiltrate water and soil. The most studied plasticizers are phthalates and phenols, and are associated with multiple negative health impacts.

Phthalates are found not only in plastic, but in nail polish, personal care products such as shampoo and cosmetics, wood preservatives, adhesives, electrical appliances, and many other household products. Phenols are found in nylon, pharmaceuticals, paints, varnishes, detergents, pesticides, and a variety of various industrial uses. Phenols exist naturally in the environment, but manufactured phenols are the focused concern. The health impacts of phthalates and phenols are ongoing, as effects and toxicity may vary, however their impacts on the endocrine and reproductive systems are perhaps the most researched.

The routes of exposure for both phthalates and phenols include inhalation, ingestion, and dermal contact, leading to skin absorption. Phthalates are ingested through contaminated water and food, especially pre-packaged food, fast food, food stored in plastic containers, and any food that encounters plastic, or other materials, while hot. Phthalates are ingested by young children, due to their propensity for putting random objects in their mouths. Inhalation of phthalates can occur from dust and aerosols, such as perfume or dust from vinyl flooring, especially when temperatures are warmer (Huang et al., 2013). Phthalates are absorbed through the skin, which often occurs from personal care products. Phenols have similar routes of exposure, as they are also absorbed through the skin from medicinal products, such as analgesic and antiseptic ointments, but can be irritating to skin and mucous

membranes, and can even cause burns (EPA, 2016). Inhalation of phenols is less common than phthalates, as the most common sources are products that release phenols when burning, such as tobacco and treated wood (ATSDR, 2008). Ingestion of phenols is common through impacted water and food.

Phthalates are endocrine disrupters, meaning they interfere with the endocrine and reproductive systems. They interfere with the androgen and estrogen (oestrogen) receptors in males and females, causing a variety of health impacts. For men, they are known to decrease fetal testicular testosterone and cause testicular dysgenesis syndrome (TDS). TDS can decrease male fertility and sperm count, cause malformation of the male reproductive tract, such as cryptorchidism and hypospadias, and can increase the risk of testicular cancer (Wang et al., 2016; Benjamin et al., 2017; EPA). In females, the endocrine disruption from phthalates can decrease fertility, increase risk of endometriosis, delay puberty, and cause a plethora of gestational issues when pregnant (Benjamin et al., 2017). Phthalates can cross the placental barrier, leading to fetal developmental toxicity. Health impacts on the hepatic, urinary, immune, and nervous systems are continuously being studied.

Multiple state and federal agencies have studied phthalates and their impacts on human health, as well as set regulations. The EPA has been assessing the public health risk from phthalates, with multiple phthalates under peer review. The U.S. Consumer Product Safety Commission (CPSC) prohibits children's toy and childcare items containing more than 0.1% of eight different phthalates. California's Proposition 65 requires businesses to provide warnings about exposure to six phthalates. Table 75 contains whether the EPA, CPSC, or state of California regulate phthalates, and the potential health concerns for each. These health concerns may be different for each entity, so concerns for all regulatory agencies or states are included.

Table 75. Regulated phthalates by the EPA, CPSC, and California Prop 65, and their potential health impacts

Phthalate abbreviation	Name	EPA review for concern	CPSC regulations	California Prop 65 regulations	Health concern
DEHP	di (2-ethylhexyl) phthalate	Yes	Yes	Yes	Fetal developmental toxicity; increased risk of cancer; harm to male reproductive system; most widely used
DBP	dibutyl phthalate	Yes	Yes	Yes	Fetal developmental toxicity; harm to male and female reproductive systems
DIBP	diisobutyl phthalate	Yes	Yes	No	Harm to male and female reproductive systems
BBP	butyl benzyl phthalate	Yes	Yes	Yes	Fetal developmental toxicity
DnPP/DPENP	di-n-pentyl phthalate	Yes	Yes	No	Fetal developmental toxicity; harm to reproductive system (unspecified)
DnHP/DHEXP	di-n-hexyl phthalate	No	Yes	Yes	Harm to male and female reproductive systems
DINP	diisononyl phthalate	Yes	Yes	Yes	Fetal development toxicity; increased risk of cancer;

Phthalate abbreviation	Name	EPA review for concern	CPSC regulations	California Prop 65 regulations	Health concern
					harm to male reproductive system; live damage
DIDP	diisodecyl phthalate	Yes	No	Yes	Fetal developmental toxicity; harm female reproductive system; liver damage
DCHP	dicyclohexyl phthalate	Yes	Yes	No	Harm to male reproductive system

**All health impacts are from the U.S EPA and the state of California's Office of Environmental Health Hazard Assessment*

EPA RfDs exist for certain phthalates, such as 1×10^{-1} mg/kg-day for DBP, 2×10^{-1} mg/kg-day for BBP, 8×10^{-1} mg/kg-day for DEP, and 2×10^{-2} mg/kg-day for DEHP (EPA IRIS).

U.S. EPA RfDs exist for certain phthalates, such as 1×10^{-1} mg/kg-day for DBP, 2×10^{-1} mg/kg-day for BBP, 8×10^{-1} mg/kg-day for DEP, and 2×10^{-2} mg/kg-day for DEHP (EPA IRIS). HRLs and MRLs for phthalates, phenols, and other plasticizers can be found in Table 76 and Table 77.

Table 76. ASTDR MRLs for phthalates, phenols, and other plasticizers of concern

Phthalate / phenol / plasticizer	Acute oral MRL (mg/kg/day)	Intermediate oral MRL (mg/kg/day)	Chronic oral MRL (mg/kg/day)
2,3,4,6-Tetrachlorophenol	0.08		
2,4,5-Trichlorophenol		1	
2,4,6-Trichlorophenol		0.005	
2,4-Dichlorophenol		0.02	
2,4-Dinitrophenol		0.00007	
2-Chlorophenol		0.08	
4-Chlorophenol		0.9	
Cresols		0.1	0.1
Di (2-ethylhexyl) phthalate (DEHP)	0.003	0.0001	
Dibutyl phthalate (DBP)	0.5		
Diethyl phthalate (DEP)	7	7	
Di-n-octyl phthalate (DNOP)	3	0.4	
Phenol	1		
Polychlorinated biphenyls (PCBs)		.03 ug/kg/day	.02 ug/kg/day
Tributyl phosphate	1.1	0.08	0.08
Tris(1,3-dichloroisopropyl)phosphate (TDCPP)		0.04	0.04
Tris(2-butoxyethyl) phosphate (TBEP)	4.8	0.09	
Tris(2-chloroethyl) phosphate (TCEP)		0.6	0.2

**All values were provided by the U.S. CDC ATSDR's Toxic Substances Portal*

Table 77. Minnesota Department of Health HRLs for phthalates, phenols, and other plasticizers in groundwater

Phthalate / phenol / plasticizer	Acute HRL (µg/L)	Short-term HRL (µg/L)	Sub-chronic HRL (µg/L)	Chronic HRL (µg/L)	Cancer (µg/L)
2,4,6-Trichlorophenol					30
2,4-Dichlorophenol				20	
2,4-Dimethylphenol				100	
2,4-Dinitrophenol				10	
2-Chlorophenol				30	
2-Methylphenol (o-cresol)				30	
3-Methylphenol (m-cresol)				30	
4-Methylphenol (p-cresol)				3	
4-tert-Octylphenol		100	100	100	
Bisphenol A (BPA)		100	20	20	
Butyl benzyl phthalate (BBP)	100	100	100	100	
Di (2-ethylhexyl) phthalate (DEHP)	20	20	20	20	7
Dibutyl phthalate (DBP)	20	20	20	20	
Diethyl phthalate (DEP)				6000	
Dimethylphthalate (DMP)				70000	
Nonylphenol		100	40	20	
Phenol				4000	
Polychlorinated biphenyls (PCBs)					0.04
Tributyl phosphate		4	4	4	
Tris(1,3-dichloroisopropyl)phosphate (TDCPP)			20	8	0.8
Tris(2-butoxyethyl) phosphate (TBEP)		30	30	30	
Tris(2-chloroethyl) phosphate (TCEP)		300	200	200	5

*All values were provided by the U.S. CDC ATSDR's Toxic Substances Portal

Several phenols and their phenolic compounds are also endocrine disruptors, and have serious health impacts on the nervous, cardiovascular, respiratory, reproductive, gastrointestinal, and hepatic systems. Like phthalates, phenols act as androgen and oestrogen antagonists, and long-term exposure can lead to reduced sperm count and sexual dysfunction in males, developmental delays in males and females, early puberty for females, and an increased risk of breast cancer (Huang et al., 2021; EPA, 2016). Other cancers that may be associated with phenols include skin, lung, brain, and bladder (Yaqub et al., 2016). Long-term exposure to phenols has also been associated with cardiac arrhythmias, hypertension, chronic bronchitis, and liver enlargement (EPA, 2016; Yaqub et al., 2016; Huang et al., 2021). Gastrointestinal damage, leading to weight loss, diarrhea, and anorexia have also been reported for chronically exposed populations (EPA, 2016).

The most recognized phenol is bisphenol A (BPA). BPA was used primary in the production of polycarbonate plastics and epoxy resins, and found in water bottles and bottle caps, food storage containers and cans, medical devices, water pipes, and many other consumer products. BPA became a concern when it was detected in most childcare products such as baby bottles, sippy cups, teethingers, and pacifiers. BPA is associated with a variety of reproductive and developmental issues. BPA was found to affect brain development in fetuses, infants, and children, caused behavioral issues in children,

impacted metabolism, and altered puberty development (EEA, 2023). Although BPA has been phased out, there are concerns about whether the replacements, BPS and BPF (bisphenol S and bisphenol F), are any safer. Even with BPA restricted in its manufacturing and uses, it is still the most prevalent phenol in groundwater, surface water, soil, and landfill leachate (Seibert et al., 2019; Wee & Aris, 2017).

Phthalates and phenols have been found to be in landfill leachate, and due to their prevalence in everyday goods, will continue to enter into the waste stream. Phthalates and phenols from plastic waste are slow to leach for the first ~50 days, but increase exponentially after (Same et al., 2023; Ayamba et al., 2020). Heat facilitates the leaching of phthalates and phenols from plastics, which is why plastic food packaging, films, containers, etc. leach phthalates and phenols when heated, or when hot food is added (Fasano et al., 2012). It has been shown that they can leach from degrading plastic and resins in both aerobic and anaerobic conditions (Sridevi et al., 2012).

The phthalates DEHP, DMP, DBP, and DMP (dimethyl phthalate) have been assessed to determine which phthalates may leach into the environment easier. Due to the solubility of DMP and DEP, there is a high prevalence in landfill leachate (Teuten et al., 2009). DEHP and DBP have been observed with an increase in migration when exposed to heat. For instance, the amount of DEHP and DBP migration from plastic doubled when exposed to ~176°F (80°C) compared to ~41°F (5°C) (Ayamba et al., 2020).

In general, phenols are more soluble than phthalates, with a greater potential for phenols to leach from waste. BPA is found to have the highest concentration in landfill leachate (Teuten et al., 2009). Phenols with shorter alkyl chains are leached easier than long chains, therefore materials with bisphenol and dimethyl phenol degrade faster than other phenols (e.g., butylphenol and octyl phenol) (Teuten et al., 2009).

Phthalates and phenols, observed in high concentrations in landfills and leachate, are also found in MRFs, mixed-waste processing facilities, and composting facilities. Water, food, and biosolids are likely to contain phthalates and phenols and are processed in compost. Properly made compostable food containers are included in compost, however, containers that are not fully compostable often make their way into the process and could leach phthalates and phenols, and then contaminate groundwater, surface water, by leachate and runoff.

Since MRFs receive a large amount of plastics, there is a high likelihood of phthalate and phenol exposure from MRFs. As the plastics travel through the recycling waste streams and are reprocessed, phthalates will continue to be recycled as well. At mixed-waste processing facilities and MRFs that melt plastic, whether for recycling or feedstock, phthalates will be present. Thus, workers have the highest risk of phthalate and phenol exposure at these facilities, and the nearby populations may be exposed by stormwater runoff.

Waste incineration can destroy plastic but can also release phthalates and phenols. Elevated levels of phthalate metabolites and bisphenol metabolites have been found in urine of MSW incineration workers, and increased levels of plasticizers were measured in various facilities where pyrolysis of plastic waste for fuel occurred (Lu et al., 2020; Růžicková, 2023).

Factors for Consideration

Many of the same factors for consideration for other pollutants exist for plastics and plasticizers. Air pollution control devices for WTE facilities such as scrubbers, baghouses, and electrostatic precipitators all can help lower the emissions of phthalates and phenols during the combustion of plastic and materials with resin. Well maintained landfill liners, proper maintenance and monitoring, and sufficient methodology to prevent runoff, are all factors that would influence the amount of plastic and plasticizer contaminated leachate seeped into groundwater and soil. Proximity to water sources is a factor for all waste facilities for phthalates, phenols, and microplastics.

Methanogenic leachates extract more phthalates and phenols from waste materials compared to acidic conditions for the final stage of AD (Masoner et al., 2014; Yazici et al., 2011). Studies have shown that closed landfills have higher levels of phthalates, but it is unknown if that is due to the alkaline leachate that is more commonly found in older landfills, or if it is from the changes in manufacturing (Same et al., 2023). Climate is also a factor. Areas with high levels of rainfall result in increased runoff, and areas with elevated temperatures observe increased phthalate and phenol leaching. Different plastics are made with different plasticizers, and each have their own unique leaching mechanisms based on pH, density, salinity, and amount of oxygen.

Minnesota's MSW Facilities

Microplastics are an emerging contaminant of concern in Minnesota's MSW infrastructure. Polymers are also emerging contaminants of concern; however, many polymers are of low risk to human health and are more of an ecological concern. Phthalates and phenols in plastics are a concern to human health, and both phthalates and phenols have been detected in Minnesota's ground and surface water. Monitoring microplastics is a relatively new science, but it can be assumed that microplastics are present in Minnesota's water and soil. As landfills, MRFs, composting facilities, and mixed-waste sorting and processing facilities are commonly found with elevated phthalates, phenols, and microplastics in their proximity, it can be assumed this is a completed exposure in Minnesota's MSW stream as well.

Summary for Plastics and Plasticizers

Plastics, specifically microplastics, and their plasticizers, phthalates and phenols, are persistent and prevalent in the environment with negative human health impacts. Microplastics have their own risk of toxicity, while also aiding in the breeding and spreading of antimicrobial resistance bacteria. Phthalates and phenols leached from plastics, including microplastics, are known endocrine disruptors and potential human carcinogens. Due to the health impacts from these contaminants, their ubiquitous presence at MSW facilities and the broader environment, and their prevalence in Minnesota's water and soil, these microplastics and phthalates present a risk to workers in MSW facilities, those who live in close proximity, as well as those who ingest contaminated water and food.

Biological Hazards: Bioaerosols, microbials, Parasites, & Vectors

Biological hazards are always present in MSW streams, due to the role they play in degrading waste through aerobic or anaerobic digestion. These hazards enter into the MSW stream through a multitude of products and byproducts, such as wasted food, yard waste, pet, livestock, and wildlife excrement, hygiene and sanitary products, and medical waste. Microbes, either as bioaerosols or surface bound and waterborne forms, include bacteria, viruses, fungi, protozoa, and other microscopic parasites. Larger parasites, such as parasitic worms, and vectors, such as rats and bugs, also find their way into the waste stream.

Bioaerosols

Bioaerosols are airborne particles that consist of microbials, including bacteria, viruses, fungi, and protozoa, as well as other biological sources such as pollen. They are a subset of organic dusts, which consist of airborne particles that originate from any organic matter, such as phosphorous particulate. Bioaerosols are consistently around humans and are usually found at levels that are considered relatively harmless. However, at higher concentrations and magnitude, they can cause a variety of diseases and health problems.

There are a multitude of types, classes, and strains of bacteria. The most common ones studied are Enterobacteriaceae and Actinomycetes, both mesophilic and thermophilic. Enterobacteriaceae are a family of Gram-negative bacteria that include pathogens such as *Salmonella*, *Escherichia coli* (*E. coli*), and *Shigella*, that are commonly studied due to their prevalence in the environment. Gram-negative

bacteria have toxins present within the cell walls, known as endotoxins, that are released when the bacteria are killed, or during cell division. These endotoxins are often more heat-stable, as they are not living organisms, but just released from one.

Actinomycetes are a phylum of Gram-positive bacteria that can decompose organic matter, similar to fungi. Gram-positive bacteria contain exotoxins, which unlike endotoxins, are released consistently, and often become a larger health concern. One of the most well-known illnesses caused by exotoxins is Botulism. These groups of bacteria and their respective toxins, as well as fungi, are the most studied in terms of MSW exposure.

Bioaerosols account for a significant portion of occupational exposure for MSW workers, with some studies finding that 50%-60% of occupational contaminant exposure for workers at mixed-waste processing and composting facilities is from bioaerosols (Poulsen & Midtgard, 1996). Across various epidemiological studies, compared to baselines, bioaerosols were 2-4 times higher in landfills, 2-10 times higher at MRFs, 10-100 times higher at compost plants, and 10-1,000 times higher during the collection of waste (Poulsen & Midtgard, 1996; Poulsen et al., 1995; Bünger et al., 2000). Bioaerosol concentrations are the highest during the turning, shredding, screening, and other agitation activities of waste. Thus, bioaerosols averaged anywhere from 10,000 – 1,000,000 cfu/m³ across various studies whilst safe occupational exposure limits should be below 1,000 cfu/m³ (Poulsen & Midtgard, 1996; Poulsen et al., 1995; Pearson et al., 2015).

Across MSW facilities, the most common bioaerosols identified at consistent, elevated levels are comprised of the fungi *Aspergillus fumigatus* (*A. fumigatus*) and *Aspergillus Niger* (*A. niger*), also known as black mold, both mesophilic and thermophilic actinomycetes such as *Thermoactinomyces*, and Enterobacteria such as *Escherichia coli* (*E. coli*) (Poulsen & Midtgard, 1996; Poulsen et al., 1995).

A decrease in lung function verified through the Forced Expiratory Volume (FEV) and Forced Vital Capacity (FVC) measurements was found for workers at composting facilities, due to elevated levels of actinomycetes spores. (Helda et al., 2015). Elevated levels of serum immunoglobulins IgG and IgE, and increased rates of chronic bronchitis, respiratory infections, and conjunctivitis were found amongst compost workers due to increase in fungi and actinomycetes (Van Krampen et al., 2012, Bunger et al., 2007). Exposure to endotoxins and exotoxins also led to an increase in nausea and diarrhea, especially when above 10 ng/m³ (Bünger et al., 2000, Helda et al., 2015).

Communities that are near composting plants have an increased risk of bioaerosol exposure and health impacts, such as airway irritation, but studies have not yet demonstrated exposure to communities farther than 500 m (Herr et al., 2003; Poulsen & Midtgard, 1996).

Besides compost facilities, those collecting waste are at a high risk, due to the movement of material during collection. Collection workers that were found to have been exposed up to 72 EU¹³/m³ endotoxins had significantly elevated levels of serum immunoglobulins IgG and IgA (Poulsen & Midtgard, 1996). Solid waste collection workers had an increased risk of work-related allergic pulmonary diseases and chronic bronchitis due to Enterobacteriaceae, actinomycetes, and fungi (Cointreau, 2006).

MRFs and mixed-waste processing workers have an increased risk of exposure to bioaerosols due to the elevated levels of bacteria and fungi detected at the facilities compared to surrounding areas. The incidence of lung cancer has been found to be higher amongst paper recycling facilities compared to the other work forces, with the length of employment a contributing factor (Rix et al., 1997). Increased exposure of organic dust has been found to cause FEV to decrease over a singular working shift of sorting recyclable and non-recyclable waste (Sigsgaard et al., 1994). For those working at MRFs, a strong correlation exists between the levels of total airborne dust and endotoxins, positive tests of (1-3)-beta-

D-glucan that verify invasive fungal infections, and an increase in respiratory and gastrointestinal diseases (Gladding, Thorn, & Stott, 2003).

Microbials

Infectious and hazardous microorganisms are also able to be ingested, as well as infect through contact through mucous membranes, such as eyes, nose, and mouth, or directly into the bloodstream through a wound.

Antimicrobial resistant bacteria are often found in leachate, in both landfills and composting facilities, therefore the bacteria that is found in leachate may be especially hazardous if humans are exposed. Resistant bacteria may be found due to the improper disposal of medical waste.

Various studies have analyzed the common bacteria found in leachate contaminated soil, including phyla of Proteobacteria, Chloroflexi, Actinomycetota (also called Actinobacteria), and Acidobactiota (also called Actinobacteria) (Gu et al., 2022). Enteric bacteria, such as *E. coli*, *Salmonella*, and *Shigella*, are often found in the leachate of compost and landfills. The prevalence of these microbes in leachate polluting groundwater is less studied due to confounding factors.

The EPA's NPDRs require monitoring of *Cryptosporidium*, *Giardia lamblia*, *Legionella*, and enteric viruses (e.g., norovirus, poliovirus, etc.), as well as tests that indicate whether potentially harmful bacteria may be present (total coliforms turbidity, and heterotrophic plate count). Not every possible bacteria can be specifically monitored but these tests are able to determine the prevalence and levels of bacteria in drinking water.

Leachate contains viruses that can persist for days or weeks and could potentially expose human populations. Studies have shown that groundwater contamination of viruses from leachate is uncommon, due to the length of time for leachate to seep into groundwater compared to the life of a virus, but there have been viruses identified in leachate of MSW landfills. For instance, an increased prevalence of Sars-CoV-2 was found in leachate during the Covid-19 pandemic, due to excessive amounts of PPE from non-medical facilities being put into the waste stream (Anand et al., 2021).

Mixed-waste processing workers, and other waste workers who come into close contact with unsorted, or poorly sorted materials, have a higher risk of exposure to bacteria and viruses due to fecal matter, medical waste, and other sources that may contain human biological matter. Medical waste is usually designated to be treated at a special disposal facility, but improperly disposed needles, facemasks, bandages, and gloves, either from healthcare settings or households, find their way into MSW facilities. Infectious diseases can survive on surfaces, especially bloodborne pathogens, and can be a threat long after disposal. For instance, Hepatitis A (HAV) can survive on surfaces for months and could infect a worker who accidentally is punctured by a needle (Mayo Clinic, 2024). Strains of influenza, SARS, poliovirus, and rhinovirus can persist on surfaces for multiple days, and become a source of exposure to workers.

Parasites

Some parasites, specifically protozoa parasites, are considered microbes, but other variations of parasites exist in MSW streams. Parasites are often found in fecal matter, whether from humans, pets, livestock, or wild animals, and make their way into composting facilities, mixed-waste processing, and landfills.

The two protozoa parasites *Cryptosporidium* and *Giardia lamblia* are regulated and monitored by the NPDR, due to their prevalence in drinking water. Other species of parasites, such as *Dicrocoelium dendriticum*, *Strongyloides stercoralis*, *Entamoeba histolytica*, and *Entamoeba coli* have been found in landfill and compost leachate throughout the globe (Mbelede, Ikeh, & Onoye, 2021). Other parasites

that may exist in leachate are pinworms, hookworms, and tapeworms. Parasites can only survive for extended periods of time outside a host during certain phases, usually as either eggs, larvae, and cysts, while adult forms quickly die outside a host.

Workers at waste facilities, including compost, landfills, and mixed-waste, have a greater risk of parasite exposure compared to those surrounding the facilities. Without proper PPE, hygiene, and other protective measures, exposure of parasites may occur via ingestion or direct contact. However, the prevalence of parasitic infections from waste management is much greater in low-income countries and is a lesser risk in areas that have environmental regulations (Eassa et al., 2016).

Vectors

Vectors are living organisms that transmit infectious pathogens, such as bacteria, viruses, and parasites, from one living creature to another. These vectors can be biological or hematophagous, such as arthropods like mosquitos, fleas, and ticks, or mechanical, such as rats, flies, and bats. Common biological vector-borne illnesses include Lyme disease, malaria, Dengue, Zika, typhus, Chagas disease, and certain types of encephalitis, while mechanical vectors transmit pathogens that cause diseases such as typhoid, cholera, meningitis, rabies, and Ebola (WHO, 2024).

Vectors are found in composting facilities and landfills, as well as mixed-waste facilities and MRFs, but little evidence supports elevated risks to the workers and populations around these facilities, and risk of exposure is lower compared to other contaminants of concern.

Factors for Consideration

There are various factors that impact the level of risk associated with facilities for workers, as they are the ones most likely to come into contact with biological agents. Certain types of recycling facilities have different products which can affect the risk. For instance, the incidence of lung cancer has been found to be higher amongst paper recycling facilities compared to the other work forces, with the length of employment a contributing factor (Rix et al., 1997). Mixed-waste processing facilities have a higher risk of exposure to household biological waste (e.g., needles, hygiene products, masks, gloves, bandages) compared to MRFs, as this waste is more likely to be put into generalized waste and not in sorted recycling containers.

Facility safety protocols, proper PPE, and sufficient hygiene are factors for worker exposure. Respiratory protection, such as masks and respirators, gloves, gowns and coveralls, eye protection such as face shields and goggles, and proper footwear reduce exposure risks. Proper hygiene of consistently washing hands with soap and warm water, especially before eating or touching mucous membranes, reduces the risk of exposure from ingestion and dermal contact with biological hazards. Proper maintenance, cleaning, and training are factors that can improve worker safety at all facilities.

Certain types of bacteria thrive in different environments, thus there may be variation in facilities. For instance, anaerobic bacteria such as *Clostridium* thrive in older, oxygen-poor landfills, while obligate aerobes, like *Mycobacterium tuberculosis*, require oxygen and may be a greater threat in newer landfills. Temperature and pH also impact the types of bacteria prevalent in these facilities. Additionally, the same factors of liners in landfills, open dumps or covered MSW landfills, maintenance and monitoring practices, and location near areas where transmission into waterways, surface water, and groundwater is high, impact risk.

Vector-borne illnesses are significantly less prevalent in the United States compared to many of the areas investigated, due to differences in regulations, water treatment, climate (cooler and dryer), and healthcare access.

Minnesota's MSW Facilities

Microbes are found on essentially every surface, product, and living thing. Microbes play a necessary role in waste degradation, specifically in landfills and composting facilities, and also leach into the environment. There was no specific data on elevated concentrations of specific microbes near MSW facilities in Minnesota. Facilities that have elevated levels of other contaminants, may have a greater risk as the same modes of exposure exist for microbes as other waste. Studies conducted for water samples of wells in Minnesota detected pathogens in 70% of the wells tested, with more bacteria and protozoa detected than viruses, but the source of pathogens was not able to be determined (Stokdyk et al., 2020). Therefore, a potential exposure pathway exists for those near MSW facilities, while a completed pathway exists for workers within these facilities.

Summary of Biological Hazards

Biological contaminants can be unhealthy if exposed to individuals. Bacteria, viruses, and fungi as bioaerosols, waterborne, or surface bound forms, can cause a variety of diseases, from common such as norovirus, to rare such as poliovirus. Bioaerosols represent a larger exposure factor compared to microbes in leachate, due to influencing factors, such as the time taken to move the waste that includes the microbes, the type of material and facility, and the challenge to control airborne particles. Exposure has mainly been focused on worker health in composting facilities, mixed-waste processing, MRFs, and landfills, with evidence supporting the majority of exposure is within or extremely close to the MSW facilities. Occupational illness and impacts for workers are primarily respiratory from bioaerosols. Strict water regulations and monitoring should assist in minimizing the risk of exposure to populations residing near facilities, whilst proper PPE, training, maintenance, and hygiene should impact exposure of workers within these facilities.

Pesticides

Pesticides, or substances that are primarily intended to prevent, repel, reduce, destroy, or kills pests, are commonly found in surface water and ground water, especially near agricultural areas.

Although the most common pesticides include insecticides, herbicides, fungicides, and rodenticides, other types include algaecides, bactericides, and molluscicides, along with many others. Insecticides, herbicides, and fungicides have the largest prevalence in drinking water, and therefore are more thoroughly studied for their potential health impacts when exposed to human and ecological populations. Many insecticides are classified by chemical structure, with the most common classes being organophosphates, organochlorines, carbamates, and pyrethroids, while herbicides may include phenoxyacetic acids, triazines, and amides. There is a high variability of the chemical composition of pesticides. This variability is not just based on the type of pest, but also on the type of vegetation that is attempting to be preserved, the surrounding agriculture, and the climate. Pesticides have been in use for decades, with their effects studied and evaluated, while others are emerging contaminants of concern. Pesticides of all types are readily found in MSW streams, particularly in landfills and composting facilities.

Pesticides are present in landfills through two main routes: direct disposal of the pesticides and containers, and as residual on vegetation, food, soil, and other products that may have been contaminated (such as plastic landscaping edging). Pesticides in landfills can be found in leachate, which can migrate into groundwater and soil, and can infiltrate surface water and soil through landfill runoff. It has also been found that the vapor from certain, volatile pesticides can drift through the atmosphere and expose populations. Particle drift from pesticide granules and dust may also occur. The migration and routes of exposures for different pesticides may impact water, vegetation, and livestock, depending on the pesticide characteristics.

Rinsed, empty pesticide bottles maintain residues and trace amounts of pesticides. Plastic containers used for pesticide storage that are in recycling streams and eventually transported to MRFs are potential sources of residual pesticides. MWPFs also may receive these containers, and other pieces of waste that have been contaminated.

Compost facilities, whether mixed biosolid waste or yard waste only, contain pesticides from the vegetation, soil, and food that are transported to the facilities. The pesticide residues may migrate based on the physical properties of the compound. Residue from volatile pesticides with vapors can be inhaled during the movement of materials, while other pesticides are designed to be highly soluble and may be found in surface runoff and leachate (Tudi et al., 2022). Pesticides are persistent and may degrade slowly, thus the final composted product may contain pesticides and present an unexpected route of exposure. Pesticides bioaccumulate, therefore compost that contains pesticides may accumulate in vegetation and livestock, potentially presenting a risk to human populations.

Pesticides are not to be incinerated unless through a specific process to minimize any emissions. There is the potential for pesticides to be in waste that is used for incineration, whether as mixed-waste or RDF from pyrolysis. Pesticides have been detected in flue gas in both incineration facilities, as well as pyrolysis for RDF facilities. A potential exists for emissions escaping and exposing nearby populations (ATSDR, 2008).

The health impacts of pesticides vary depending on the chemical composition. Pesticides that are monitored due to the EPA's NPDWR can be found in Table 78, along with their health effects and established MCLs and MCLGs. Other pesticides that may have known health implications but not monitored in drinking water due to solubility and other characteristics, may still have an RfD, RfC, oral slope factor, or inhalation unit risk. These findings can be found in Table 79 and Table 80. Some of the pesticides in the two tables may no longer be used in the United States, whether banned, severely regulated, or voluntarily phased out, but guidelines and monitoring for health impacts are continuous.

Table 78. NPDWR MCLs and MCLGs for pesticides due to potential health impacts

Pesticide	Health impact from long-term exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)
Alachlor	Damage to liver, kidneys, spleen, and eyes*; increased risk of laryngeal cancer**	0.002	zero
Atrazine	Damage to heart, liver, and kidneys*; reproductive challenges such as pre-term deliveries and miscarriages**; endocrine disruption**; potential carcinogen**	0.003	0.003
Carbofuran	Damager to central nervous system, peripheral nervous system*; male reproductive toxicity**	0.04	0.04
Chlordane	Damage to nervous and reproductive systems*; damage to liver and kidneys*; increased risk of cancer**	0.002	zero
2,4-D	Kidney, liver, or adrenal gland problems*	0.07	0.07
Dalapon	Kidney damage/nephrotoxicity**; damage to nervous system*	0.2	0.2
DBCP	Reproductive difficulties*; increased risk of cancer*	0.0002	zero
Dinoseb	Male reproductive toxicity*; female reproductive toxicity**	0.007	0.007
Diquat	Infertility**; cataracts**; damage to liver, kidneys, lungs, and skin**	0.02	0.02
Endothall	Digestive system toxicity**	0.1	0.1
Endrin	Skin irritation**; digestive system toxicity**; central nervous system effects**	0.002	0.002

Pesticide	Health impact from long-term exposure above MCL	NPDWR MCL (mg/L)	NPDWR MCLG (mg/L)
Glyphosate	Potential carcinogen**	0.7	0.7
Heptachlor	Neurological impacts such as tremors and convulsions*; potential damage to the liver, kidneys, and immune system**; increased risk of cancer**; developmental toxicity**	0.0004	zero
Heptachlor epoxide	Damage to liver*; increased risk of cancer**	0.0002	zero
Hexachlorobenzene	Damage to liver, nervous system, and reproductive system*; developmental toxicity**; increased risk of cancer**	0.001	zero
Lindane	Impacts on liver, blood, nervous, cardiovascular, and immune systems*; potential reproductive impacts*: increased risk of cancer**	0.0002	0.0002
Methoxychlor	Reproductive and endocrine toxicity**; damage to liver and kidneys*	0.04	0.04
Oxamyl (Vydate)	Overstimulation of nervous system*; general toxicity**	0.2	0.2
Pentachlorophenol	Increased risk of cancer*; skin and eye damage*; toxicity of kidneys and liver*; respiratory and immune system damage*	0.001	zero
Picloram	Liver damage**	0.5	0.5
Simazine	Female reproductive toxicity**; developmental toxicity**	0.004	0.004
Toxaphene	Increased risk of cancer**	0.003	zero
2,4,5-TP (Silvex)	Liver toxicity**	0.05	0.05

*Values were provided by the EPA's NPWDR resources. Health impacts were directly through the EPA or CDC's ATSDR and are the same verbiage

**Health impact is from California's OEHHA, IARC, or epidemiological studies but not mentioned

Table 79. RfDs for pesticides with health impacts

Pesticide	Oral RfD (mg/kg-day)	Pesticide	Oral RfD (mg/kg-day)
Alachlor	1×10^{-2}	Glyphosate	1×10^{-1}
Atrazine	3.5×10^{-2}	Heptachlor	5×10^{-4}
Carbofuran	5×10^{-3}	Heptachlor epoxide	1.3×10^{-5}
Chlordane	5×10^{-4}	Hexachlorobenzene	8×10^{-4}
2,4-D	1×10^{-2}	Methoxychlor	5×10^{-3}
Dalapon	3×10^{-2}	Oxamyl (Vydate)	2.5×10^{-2}
DBCP	2×10^{-4}	Pentachlorophenol	5×10^{-3}
DDT	5×10^{-4}	Pentachloronitrobenzene (PCNB)	3×10^{-3}
Dinoseb	1×10^{-3}	Picloram	7×10^{-2}
Demeton	4×10^{-5}	Prometon	1.5×10^{-2}
Diquat	2.2×10^{-3}	Simazine	5×10^{-3}
Endothall	2×10^{-2}	2,4,5-TP (Silvex)	8×10^{-3}
Endrin	3×10^{-4}		

*All values were provided by the EPA's IRIS database

Table 80. Oral slope factors and inhalation unit risks of cancer for pesticides assessed by the IRIS program

Pesticide	Oral slope factor (per mg/kg-day)	Inhalation unit risk (per µg/m³)
Chlordane	3.5 x 10 ⁻¹	1 x 10 ⁻⁴
Heptachlor	4.5	1.3 x 10 ⁻³
Heptachlor epoxide	9.1	2.6 x 10 ⁻³
Hexachlorobenzene	1.6	4.6 x 10 ⁻⁴
Toxaphene	1.1	3.2 x 10 ⁻⁴
DDT	3.4 x 10 ⁻¹	9.7 x 10 ⁻⁵

**All values were provided by the U.S. EPA's IRIS database*

Table 81. Minnesota Department of Health's HRLs for pesticides in groundwater

VOC of concern	Acute HRL (µg/L)	Short-term HRL (µg/L)	Sub-chronic HRL(µg/L)	Chronic HRL (µg/L)	Cancer HRL (µg/L)
2-(2,4,5-Trichlorophenoxy) propionic acid (2,4,5-TP)				50	
2-Methyl-4-chlorophenoxyacetic acid (MCPA)				3	
Acetochlor		30	30	20	
Acetochlor ESA		500	500	300	
Acetochlor OXA		100	100	90	
Alachlor		100	60	9	
Alachlor ESA			100	50	
Alachlor OXA			100	50	
Aldicarb				1	
Atrazine				3	
Bentazon		60	50	30	
Chlorothalonil		20	2	1	6
Chlorpyrifos	2	0.6	0.6	0.6	
Chlorpyrifos oxon	0.9	0.4	0.4	0.4	
Clothianidin		200	200	200	
Cyanazine	3	3	3	1	
Cyanazine acid (CAC)	3	3	3	1	
Cyanazine amide (CAM)	3	3	3	1	
Deethylatrazine (DEA)				3	
Deethylcyanazine (DEC)	3	3	3	1	
Deethylcyanazine acid (DCAC)	3	3	3	1	
Deethylcyanazine amide (DCAM)	3	3	3	1	
Dicamba				200	
Dichlorodiphenyldichloroethane (DDD)					1
Dichlorodiphenyldichloroethylene (DDE)					1
Dichlorodiphenyltrichloroethane (DDT)					1
Dichlorophenoxyacetic acid (2,4-D)		30	30	30	
Dieldrin		0.2	0.2	0.2	0.006

VOC of concern	Acute HRL (µg/L)	Short-term HRL (µg/L)	Sub-chronic HRL(µg/L)	Chronic HRL (µg/L)	Cancer HRL (µg/L)
Dimethenamid		600	600	300	
Dimethenamid Ethanesulfonic acid (ESA)		600	600	300	
Dimethenamid Oxanilic acid (OXA)		600	600	300	
Dinoseb		8	8	8	
Disulfoton				0.3	
Ethyl dipropylthiocarbamate (EPTC)	300	300	90	40	
Fomesafen		200	200	20	
Glyphosate		1000	1000	500	
Heptachlor					0.08
Heptachlor epoxide					0.04
Hexachlorobenzene					0.2
4-Hydroxychlorothalonil		2	2	2	
Imidacloprid	100	2	2	2	
Isoxaflutole		20	10	7	
Linuron				1	
Metolachlor / s-Metachlor		300	300	300	
Metolachlor ESA			7000	1000	
Metolachlor OXA		5000	5000	5000	
Metribuzin	30	10	10	10	
Metribuzin DA / DADK / DK	30	10	10	10	
Pentachlorophenol	7	7	7	7	0.3
Picloram				500	
Prometon				100	
Propachlor				90	
Pyraclostrobin	300	100	100	100	
Simazine				4	
Sulfentrazone	3000	60	60	60	
Sulfentrazone 3-Carboxylic Acid	3000	60	60	60	
Thiamethoxam		400	200	200	
Toxaphene					0.3
Trichlorophenoxyacetic acid (2,4,5-T)				70	
Triclocarban					
Triclosan		50	50	50	

**All values were provided by the MDH's Human Health-Based Water Guidance Table*

Factors for Consideration

Various factors could influence the exposure source, route of exposure, and magnitude of exposure of pesticides for populations near MSW facilities. Influencing factors include existence, quality, and maintenance of liners at landfills; whether landfills are open dumps or MSW, covered landfills; and maintenance of facilities to reduce stormwater runoff. The processing of pesticide containers for WTE purposes can also factor into exposure, as direct dump incineration from a MWPF, likely results in higher

pesticide concentration in flue gas compared to pyrolysis for RDF from sorted, clean recyclables as feedstock.

PPE for workers is a factor for pesticide exposure. Since pesticides can be inhaled as vapor, ingested as liquid, or have direct dermal contact, depending on the type of pesticide, PPE that minimizes these risks, as well as proper hygiene, impact the risk to workers at all types of MSW facilities.

Climate is a factor that can impact the exposure of pesticides. For instance, hexachlorobenzene, a POP, was found to have a varying half-life in the atmosphere based on humidity and heat. In tropical and subtropical environments, the half-life was found to be around 0.63 years, in temperate and boreal regions it was approximately 1.94 years, and the half-life was 6.28 years in polar regions (ATSDR, 2008). The half-life in groundwater was significantly longer than in surface water, with 5.3-11.4 years compared to 2.7-5.7 years (ARSDR, 2008).

Minnesota's MSW Facilities

Pesticides are present in Minnesota's surface water and groundwater based on results of the Unregulated Contaminates Monitoring Project for 2023. Reporting from the Unregulated Contaminants Monitoring Project for 2023 found at least 55 different pesticides in surface water and groundwater across 107 measured site samples.

The most common pesticides observed were s-metolachlor, atrazine, and the degradation products of atrazine: deethylatrazine (CIAT), didealkylatrazine (CAAT or DACT), deisopropylatrazine (CEAT), and hydroxyatrazine (OIET). The degradation products of s-metolachlor, metolachlor oxanilic acid (OXA) and metolachlor ethanesulfonic (ESA), prometon, 2,4-D, alachlor oxanilic acid (a degradation product from alachlor), and cyanazine acid (a degradation product from cyanazine) were detected in Minnesota's water. The insecticides clothianidin, imidacloprid, and thiamethoxam were detected, and the most frequently detected fungicides were azoxystrobin, carbendazim, and propiconazole (MDH, 2025). Concentrations of these pesticides were below drinking national drinking water standards. A MCL is not available for s-metolachlor, however, samples tested were below Minnesota's drinking water guideline of 300 µg/L.

The detection of these pesticides prove them to be in Minnesota's water sources, but the exact point of exposure can not be determined, therefore the exposure pathway remains potential. The contamination could be from MSW facilities, as well as agriculture and wastewater. However, as these pesticides are in the water, it can be assumed that they are in the waste stream and increases the risk of them continuing to accumulate in water, vegetation, livestock, and humans.

Summary of Pesticides

Pesticides, specifically herbicides, insecticides, and fungicides, have been found in Minnesota's water systems, often due to the high usage of pesticides in agricultural areas. It is possible that runoff and leachate from MSW facilities that contain pesticide containers, contaminated products, and vegetation, contribute to the infiltration into surface water, groundwater, and soil, although agricultural runoff is likely the main source of exposure. Many pesticides are considered POPs and are able to bioaccumulate in food sources and humans and can have significant health impacts such as toxicity of the liver and kidneys, developmental and reproductive toxicity, damage to the eyes and skin, damage to the nervous, immune, and cardiovascular systems, and an increased risk of cancer.

Appendix C – Survey Results Memo

Appendix C.1 Overview

RRS conducted a Statewide Materials Management Survey for MPCA from April to July 2025. The purpose of the survey was to capture an understanding of current waste management conditions and the desired future of materials management in the state. Given the wide range of stakeholders, the survey questions were tailored to specific audiences. The audience for the survey included: County and city/town representatives, Tribal government representatives, waste hauler representatives, recycling facility representatives, composting facility representatives, anaerobic digestion facility representatives, reuse and/or repair retail representatives, food recovery organizations, environmental or community-based organization representatives, or residents. These audiences were identified as being key stakeholders for understanding materials management practices around the state. Other types of stakeholders exist but were not explicitly listed in this survey. The survey consisted of 126 questions in total (including logic-based questions), but individual audiences were not prompted to answer all questions. Each audience segment had an average of 11 questions.

Distribution

The survey was open for roughly 3 months. Though RRS created the survey, MPCA distributed the survey through multiple channels. Social media (Facebook, Instagram, and LinkedIn) was used to distribute the survey. RRS created language and collateral for MPCA to share (Figure 63). In addition to social media, MPCA sent direct outreach to several existing contact lists: MPCA county contacts, Solid Waste Matters Newsletter, MPCA Tribal Liaisons, Reuse Minnesota, food recovery contacts, and EJ Table. MPCA also provided translations for the resident portion of the survey into Hmong and Spanish. The county contacts were asked to respond as a government representative and to share the survey with their residents if possible. RRS provided outreach language for county contacts to use for resident communication for ease of distribution.

Appendix C.2 Survey Responses

639 individuals started the survey, but not all completed it. The survey had a total of 488 complete responses. Complete responses are considered those that submitted the survey. All questions were optional, and in some cases, respondents elected to skip certain questions. Incomplete responses (those not submitted) were not counted towards the analysis of the survey. Some of the tables and figures in this report use shortened descriptions or simplified acronyms for ease of display. The full wording of all survey questions is provided in Appendix C for reference.

Demographic information

Of the 488 responses, 72% of the respondents were residents. The next largest group of respondents were county and city/town representatives at 16%. Figure 70 and Table 82 show the full distribution and number of respondents per audience segment.

Figure 70. Distribution of respondent type by audience segment

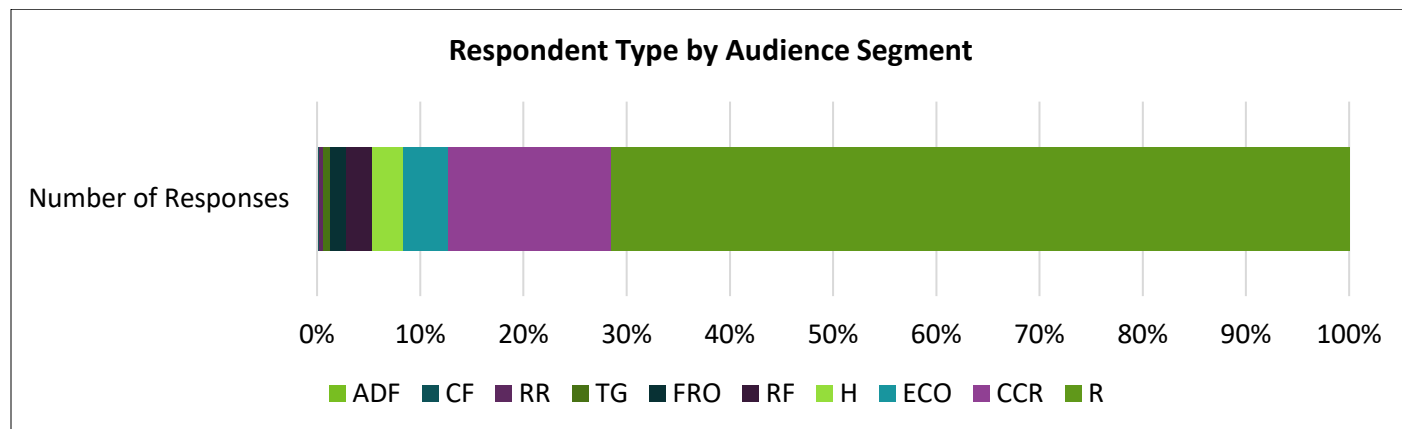
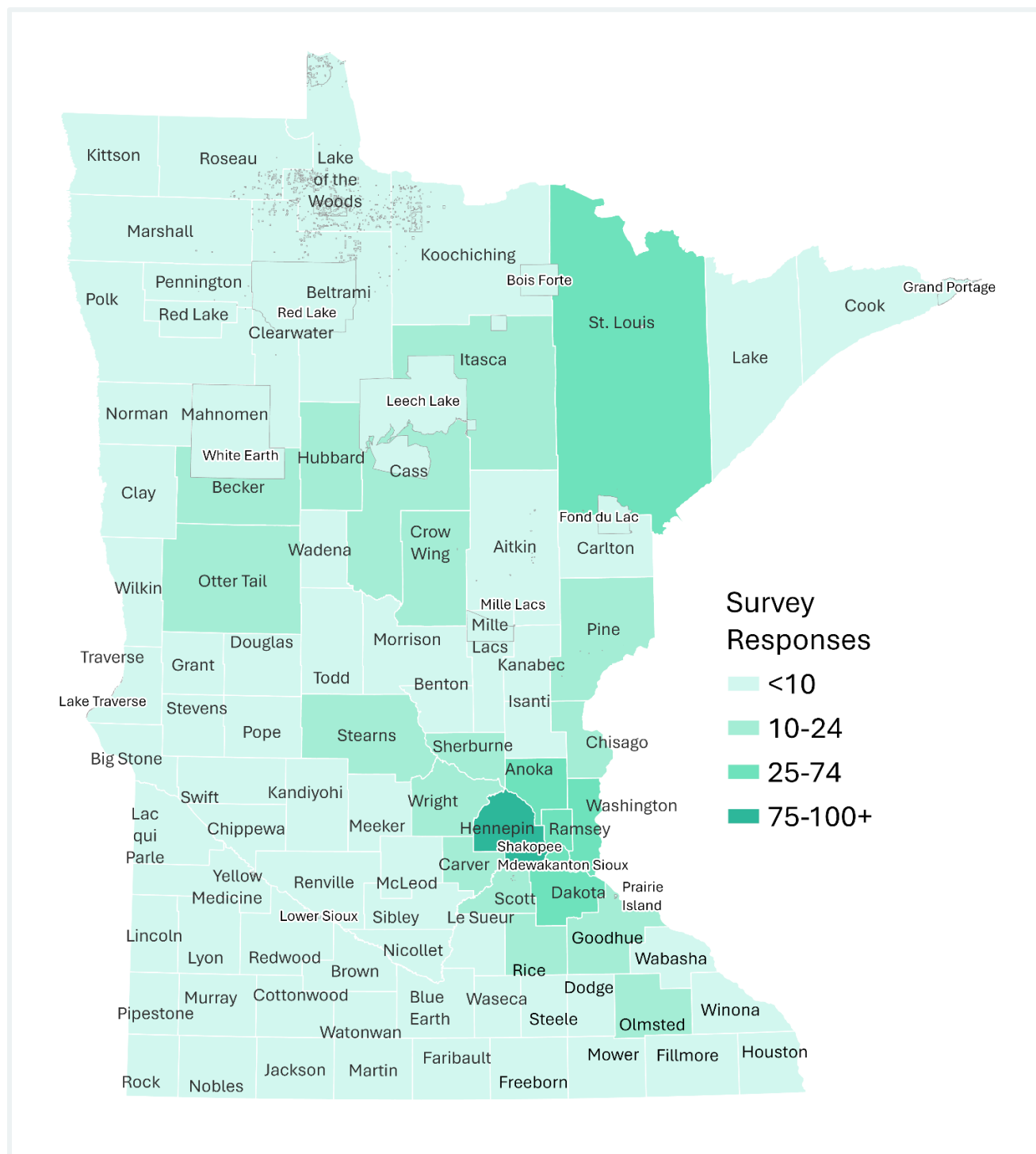


Table 82. Number of responses per audience segment

	ADF	CF	RR	TG	FRO	RF	H	ECO	CCR	R
Audience Segment	Anaerobic Digestion	Composting Facilities	Reuse & Repair	Tribal Governments	Food Recovery Organizations	Recycling Facilities	Haulers	Environmental & Community Organizations	County & City/Town Officials	Residents
# of Responses	0	1	2	3	8	12	15	21	77	349

Each respondent was asked to select the region of the state they service or live in (for residents) using a provided map (Appendix F); Northeast, Northwest, Southeast, Southwest, Central, the TCMA, or the entire state. Then, respondents were asked to select the county or counties they were either representing or responding from. The majority of respondents were in the TCMA (53%). Southwest Minnesota had the fewest number of respondents at 4%. Hennepin County had the highest density of responses (123 respondents). The following map (Figure 71) highlights the density of respondents across the state.

Figure 71. Density of survey respondents across Minnesota



Appendix C.3 County & City/Town Responses

There were 77 respondents that identified as a county or city/town representative. Of those respondents, there were 46 different counties selected in the sample, mainly Hennepin County (11 respondents), Washington County (9 respondents), and Dakota County (4 respondents). Most of the respondents noted that they represent a county (65%) while 35% were municipal respondents representing a city or town.

Municipal respondents (selected city/town) were asked which hauling system their municipality operates: open (residents choose their own hauler), open system with some self-organized areas (most areas open, but some neighborhoods or HOAs coordinate service), organized with multiple haulers serving different zones, or organized with one single hauler contracted by the municipality. 42% of the municipal respondents noted that they have organized single hauler systems, shown in Figure 72.

Figure 72. Distribution of municipal hauling systems

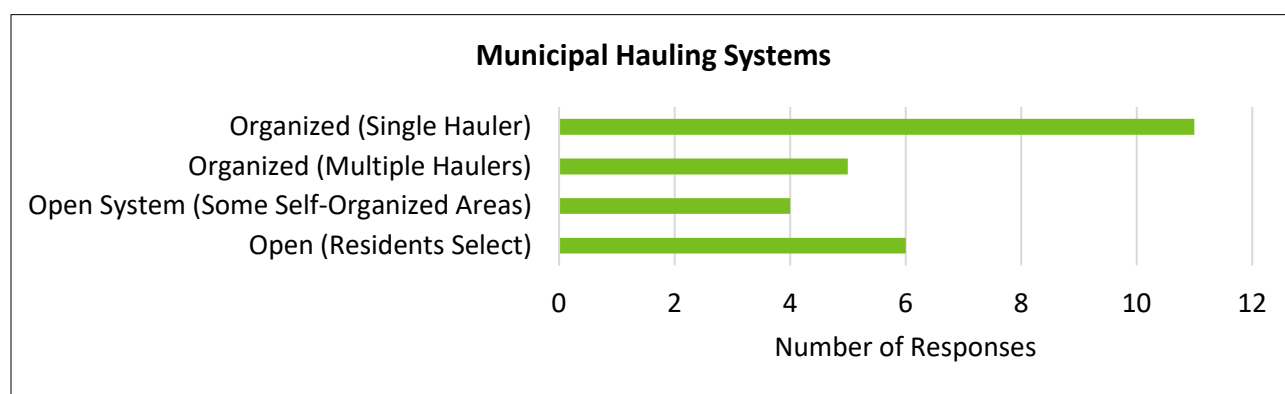
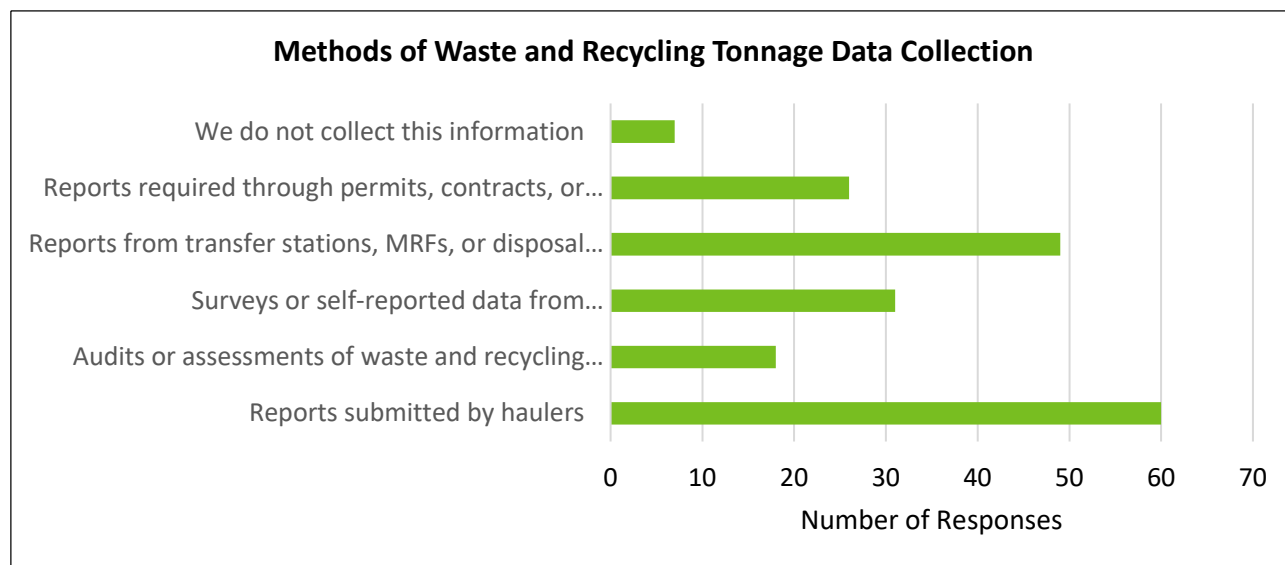


Figure 73. Distribution of methods to collect tonnage data

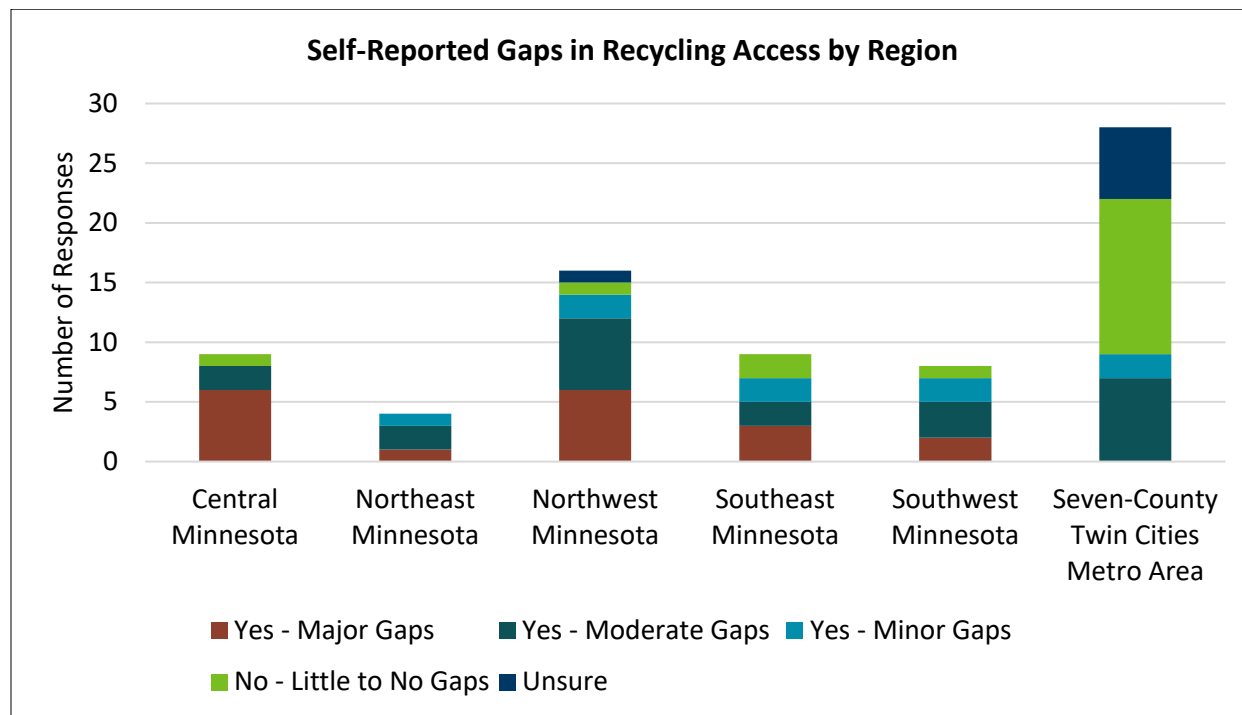


County and municipal representatives were both asked how their jurisdictions collect tonnage data on waste and recycling. The most common responses were reports submitted by haulers (79%) or reports from transfer stations, MRFs, or disposal facilities (64%), shown in Figure 73. Only 5 respondents indicated that they do not collect tonnage data.

The next question asked if there were gaps in the recycling infrastructure within the respondents' jurisdiction and the approximate distance in miles to the nearest recycling facility or drop-off location.

Responses were relatively even, as 25% said there are major gaps (more than 10 miles away), 29% said there are moderate gaps (5 to 10 miles away), 12% said there are minor gaps (1 to 5 miles away), 24% said there are little to no gaps (less than 1 mile away), and 9% said they were unsure. Figure 74 shows these responses in connection to the respondents' location. Respondents in Central Minnesota and Northwest Minnesota were more likely to report major gaps, while most respondents in the TCMA reported little to no gaps.

Figure 74. Self-reported recycling access gaps by region



Then, respondents were asked about specific kinds of recycling access, participation, and infrastructure gaps they see in their area, selecting all the gaps that apply. The biggest gap reported was limited funding or budget constraints (39 respondents), followed by weak or unstable end markets for recycled materials (34 respondents), and low public participation and/or awareness (31 respondents). Lack of political or leadership support was ranked as the lowest gap reported (14 respondents). The full list of specific gaps is shown in Figure 75. Additionally, the recycling gaps were compared to the respondents' reported location. Each gap was summarized by region of the state. Table 83 shows the most reported recycling gap by region. Notably, the gaps are different for each region with the exception of both the Southeast and Southwest regions reporting there being weak or unstable end markets for recycled materials.

Figure 75. Self-reported recycling gaps

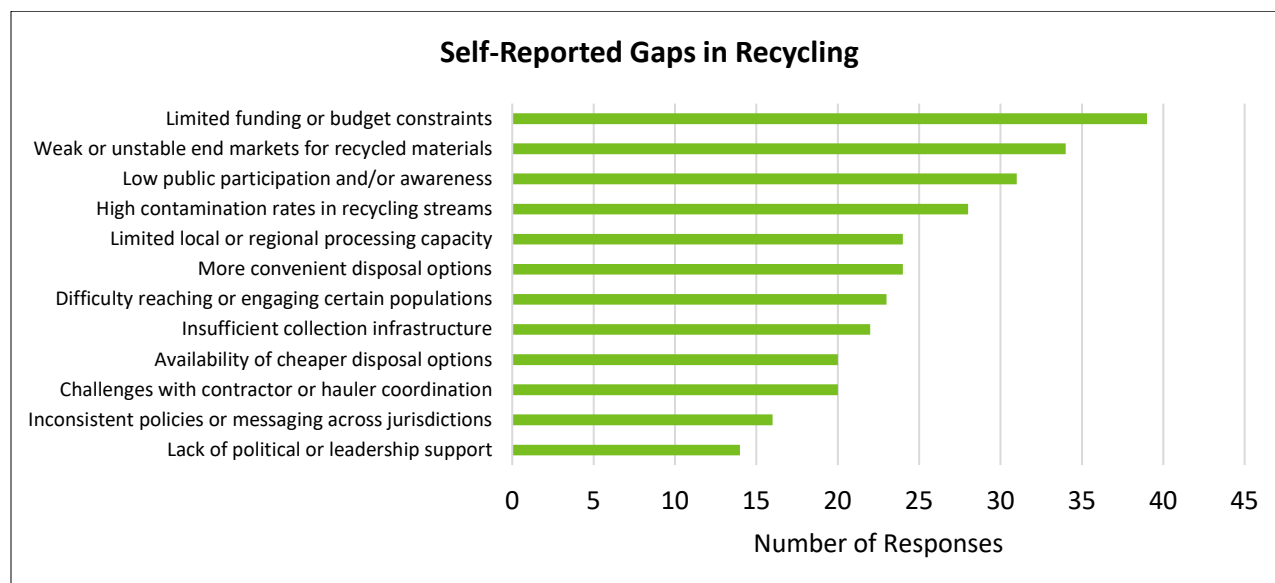


Table 83. Most reported recycling gap by region

County	Most reported gap
Central Minnesota	High contamination rates in recycling streams
Northeast Minnesota	Limited local or regional processing capacity
Northwest Minnesota	Limited funding or budget constraints
Southeast Minnesota	Weak or unstable end markets for recycled materials
Southwest Minnesota	Weak or unstable end markets for recycled materials
TCMA	Difficulty reaching or engaging certain populations (e.g., non-English speakers, renters)

On a similar note, county and municipal respondents were asked about the most significant barrier to increasing recycling rates in their service area. The most reported barrier was weak end markets for recycled materials (27 respondents), low participation and/or awareness (22 respondents), and cheap or more convenient alternative disposal options, such as landfills or waste-to-energy (21 respondents). 16 respondents selected “Other” with the option to leave a text-based response. Of the text-based responses, three themes arose around the types of barriers: system-level challenges, community engagement, and resource constraints. In rural areas, communities face issues from dispersed populations, low material volumes, and inadequate infrastructure for materials like bulky items and organics. In some communities, high renter turnover, language and cultural barriers, and widespread confusion or skepticism about recycling reduce participation and increase contamination. Others noted financial and staffing limitations. All “Other” responses for this question can be found in the Appendix. Table 84 shows the most reported barriers to increasing recycling rates by region. Weak end markets were the most noted barrier for four of the six regions.

Figure 76. Reported barriers to increasing recycling rates

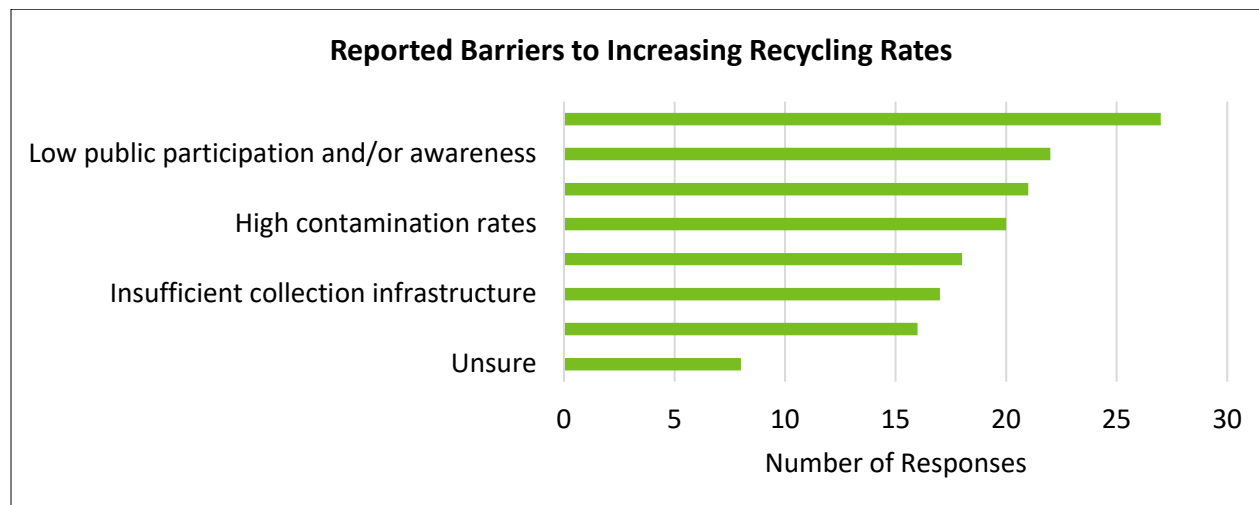


Table 84. Most reported barrier to increasing recycling rates by region

County	Most reported barrier
Central Minnesota	Insufficient collection infrastructure
Northeast Minnesota	Weak end markets for recycled materials
Northwest Minnesota	Weak end markets for recycled materials
Southeast Minnesota	High contamination rates, Limited processing capacity, Weak end markets for recycled materials (Tied)
Southwest Minnesota	Weak end markets for recycled materials
TCMA	Low public participation and/or awareness

County and city/town respondents were also asked if their county has current partnerships with community organizations, schools, or businesses to promote waste reduction and recycling. 36% of respondents said they have 4 or more partnerships, 28% said they have 1-3 partnerships, and 37% have no formal partnerships. If respondents reported they have some partnerships, they were asked to list existing partnerships in an open response question. Respondents described a wide range of community partnerships that support their recycling programs, with common partnerships with schools, businesses, municipalities, and nonprofits being most noted. Many counties work closely with schools through grants, technical assistance, recycling collections, wasted food initiatives, and student education programs. Partnerships with businesses often involve grant funding, BizRecycling programs, and technical support (Minnesota Waste Wise was mentioned). Municipalities were also listed as partners or county contracts that help expand recycling access, improve recycling infrastructure, and coordinate drop-off sites, especially in rural areas. Several respondents also highlighted collaborations with nonprofits, community groups, and specialized contractors for services such as bulky item recycling, composting, and education campaigns. Regional and inter-county partnerships (such as Ramsey and Washington R&E, Partnership on Waste and Energy) play a role in aligning policies, providing technical assistance, and improving outreach efforts. All responses to this question are found in the Appendix.

The next question asked how respondents would use additional funding, specifically for recycling education and outreach. Respondents were asked to rank individual activities based on impact on their jurisdiction. A number one ranking would mean that the activity would have the highest impact. The responses to the question were analyzed both by average rank score and top three counts, resulting in the same top three choices; however, the most ranked second top choice was “updating digital

platforms or tools for public engagement.” Expanding school-based waste reduction and recycling education programs were ranked as having the most potential impact for respondents, with an average score of 4.08. Launching targeted campaigns to reduce contamination in recycling (4.11) followed closely. Table 85 shows the full distribution of the averaged activity rankings.

Table 85. Average ranking of impact for proposed outreach and education activities

Outreach and education activities	Average score
Expanding school-based waste reduction and recycling education programs	4.08
Launching targeted campaigns to reduce contamination in recycling	4.11
Hiring or expanding dedicated outreach and educational staff	4.61
Strengthening partnerships with local organizations to reach priority populations	4.74
Updating digital platforms or tools for public engagement (e.g., websites, apps, social media)	4.82
Creating toolkits or best practices for businesses and institutions	5.11
Providing outreach specific to multi-family housing or underserved communities	5.31
Hosting community workshops, events, or hands-on training	5.82
Developing multilingual and culturally tailored outreach materials	6.40

After that, respondents were asked another ranking question. This time, they were scoring specific kinds of technical assistance on how helpful they would be to improve waste and recycling operations in their jurisdiction. A ranking of 1 represented being the least helpful, while 5 represented being extremely helpful. The highest scoring type of technical assistance was strategies to reduce contamination in recycling streams (3.99), followed by developing and implementing waste reduction programs (3.96), and support for grant writing and funding opportunities (3.86). Table 86 shows the full distribution of scores.

Table 86. Average ranking of helpfulness of various types of technical assistance

Type of technical assistance	Average score
Strategies to reduce contamination in recycling streams	3.99
Developing and implementing waste reduction programs	3.96
Support for grant writing and funding opportunities	3.86
Improving data collection and reporting	3.82
Best practices for public outreach and community engagement	3.73
Updates on policy, regulations, and compliance requirements	3.57
Strategies for expanding recycling access in underserved areas	3.44
Guidance on optimizing collection, hauling, and processing efficiency	3.31

The last question was open ended and asked respondents to share if they have other methods of support that would be helpful for them regarding waste and recycling operations in their jurisdiction. Respondents emphasized that the most useful support for county and municipal recycling operations would be increased and more flexible funding, particularly through expanded SCORE allocations and state grants, noting that financial constraints and limited staffing remain the largest barriers. Many called for statewide consistency, particularly in messaging, reporting requirements, and data systems. Respondents also highlighted the need for better end-market development and transparency, especially

for hard-to-recycle materials and rural areas where collection is not economically viable. Education and outreach support, including state-led campaigns, standardized resources, and training, were identified as critical for improving public participation and reducing contamination. Respondents also wrote about the importance of policy and regulatory action, including stronger enforcement of existing requirements, extended producer responsibility, and investment in composting and alternative recycling infrastructure. The full list of responses and the respondent location are found in the Appendix C.

Appendix C.4 Reuse & Repair Responses

There were 2 finished responses for the reuse and/or repair retailer audience segment. Findings for this audience should be interpreted cautiously due to low response numbers. The results are included here for completeness but should not be considered representative of this audience.

Reuse and repair respondents were asked to note which materials or items their organization handles. Then, logic-based questions were displayed to further refine which items the organization handles. Given there are two responses, Table 87 shows the types of materials handled by respondent “A” and “B.” Respondent A listed operating in Hennepin and Ramsey Counties. Respondent B noted that they operate in Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties.

Table 87. Types of materials handled by reuse/repair retailer respondents

Material or item	Respondent A	Respondent B
Electronics, Physical Media, & Office Supplies	☒	
Household electronics or appliances	☒	
Physical media	☒	
Office and school supplies	☒	
Other	“Anything we receive is evaluated for possible reuse”	
Furniture, Home Improvement, and Construction Materials	☒	☒
Furniture	☒	☒
Construction and building materials	☒	
Home improvement items	☒	
Other	“Anything we receive is evaluated for possible reuse”	
Clothing, Textiles, and Craft Supplies	☒	☒
Clothing or textiles	☒	☒
Textiles	☒	
Arts and crafts materials	☒	
Other	“Anything we receive is evaluated for possible reuse”	
Vehicles, Bicycles, and Outdoor Equipment	☒	☒
Vehicles or watercraft	☒	☒
Bicycles and related parts	☒	

Material or item	Respondent A	Respondent B
Outdoor gear	☒	
Other	"Anything we receive is evaluated for possible reuse"	
Containers, Packaging, and Household Items	☒	
Food containers and packaging	☒	
Pet supplies	☒	
Home kitchenware	☒	
Home décor	☒	
Storage and organization items	☒	
Other	"Anything we receive is evaluated for possible reuse"	
Specialty or Niche Items	☒	☒
Musical instruments and equipment	☒	
Photography equipment	☒	
Fitness equipment	☒	
Medical equipment and supplies	☒	☒
Children's items	☒	
Collectibles and antiques	☒	
Other	"Anything we receive is evaluated for possible reuse"	"Leather items"

The next question asked about the most significant infrastructure challenges the respondents' businesses faced, if any. Respondent A noted a lack of sufficient storage space for incoming processed items, issues with processing or repair capabilities and a lack of washing or sanitization infrastructure. Respondent B listed that they do not currently face infrastructure challenges. Similarly, the next question asked about top financial challenges for the business. Respondent A noted challenges with competing with inexpensive new products and Respondent B mentioned low consumer demand or awareness and also referenced competition with inexpensive new products.

After that, the next question asked respondents to select actions that would be needed to help scale or expand their business. Both Respondent A and B selected policy changes to support reuse/repair businesses and consumer education and marketing support. Respondent A chose new partnerships or collaborations with other businesses or governments as well.

Respondents were then asked about data tracking for reuse operations. Respondent A said they do collect data, and it is regularly updated. In the follow-up questions, they note they collect data on materials diverted, weight/volume of materials, and the types of materials they handle on a monthly basis. Respondent B does not track reuse data at this time and did not provide reasoning to why in the follow-up question. To the question if their organization would benefit from support or tools to improve data tracking capabilities, both respondents said "Maybe."

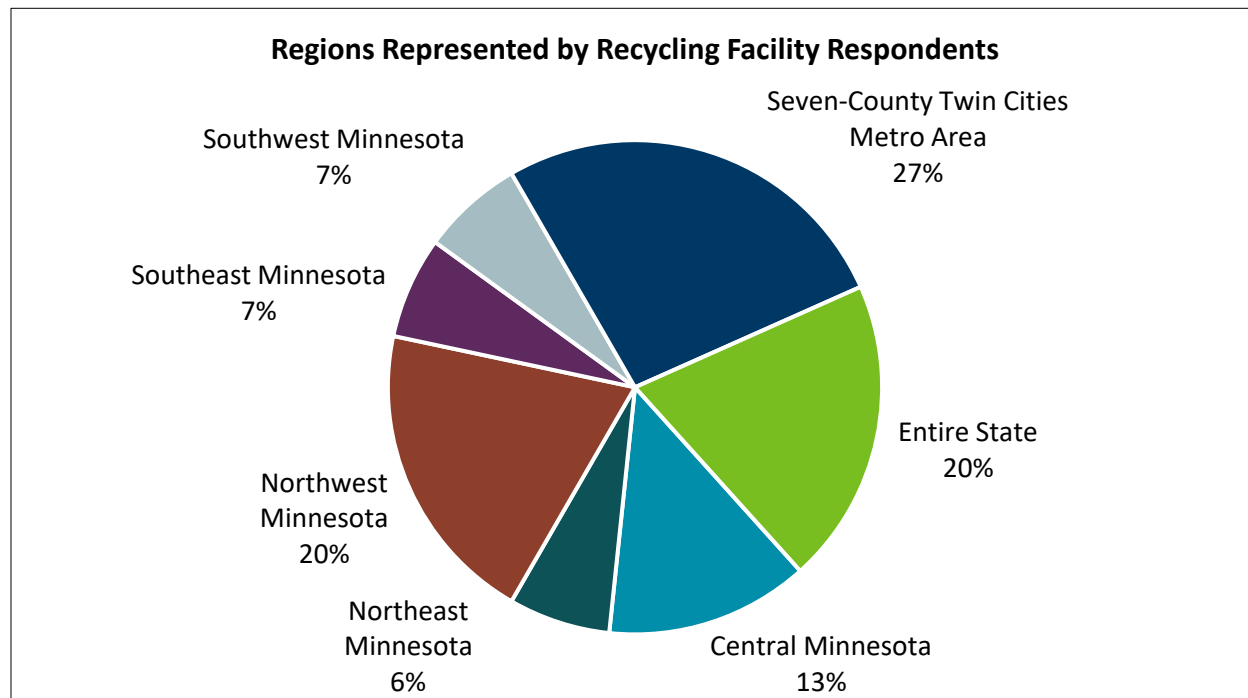
Additionally, respondents were asked if they participate in any reuse-focused collaborations, networks, or shared infrastructure projects. Respondent A said they are a part of Reuse Minnesota. Respondent B noted they operate independently.

Lastly, respondents were asked to select which factors most influence whether consumers choose to buy secondhand or reuse products. Respondent A mentioned that the price compared to new products, convenience of access, and social or environmental/waste reduction attitudes toward secondhand shopping were the most influential. Meanwhile, Respondent B noted that price compared to new products, peer influence or recommendations, and brand reputation of the business/store were the most influential factors.

Appendix C.5 Recycling Facility Responses

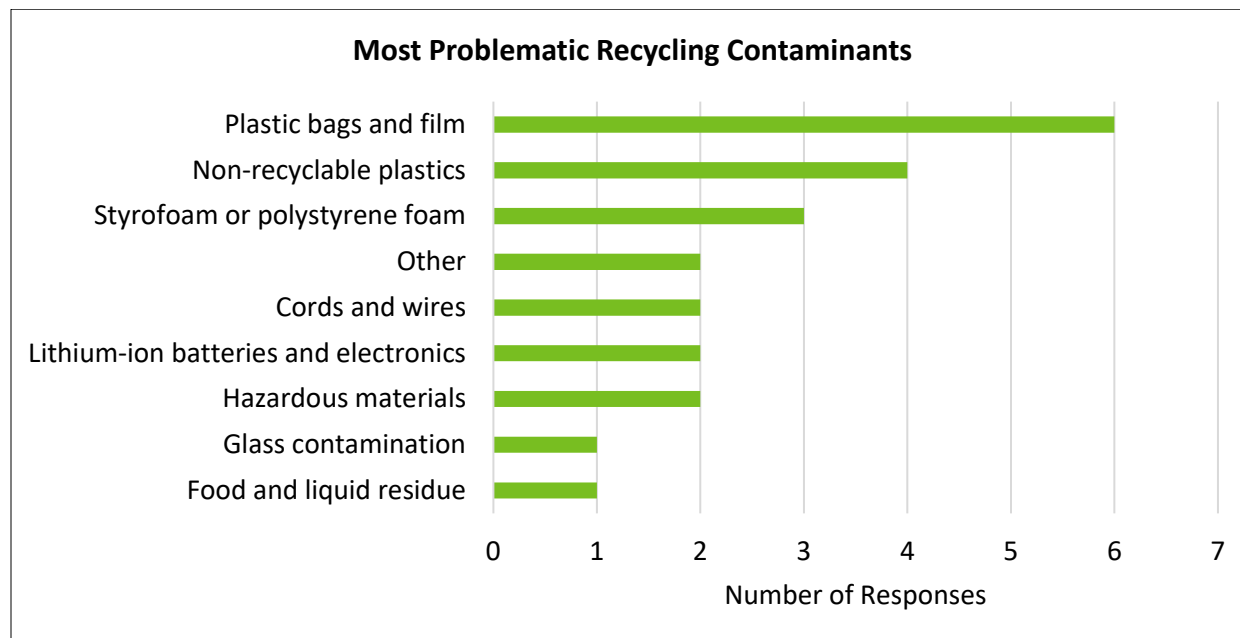
There were 12 complete recycling facility responses. Figure 77 shows the distribution of regions represented by the respondents. The TCMA is the most represented region for the recycling facility respondents (27%), followed by those operating through the entire state (20%).

Figure 77. Regions represented by recycling facility respondents



Recycling facility respondents were asked which contaminants are the most problematic in their recycling stream. The most problematic contaminant noted by respondents was plastic bags and film (6 respondents) and non-recyclable plastics (4 respondents). Figure 78 shows the full distribution of problematic recycling contaminants. The two "Other" responses listed hazardous materials and electronics as an issue and a respondent said, "All contamination increases costs, especially plastic bags and tangles that wrap around equipment requiring downtime. The biggest THREAT to our industry is different – batteries are contaminants that pose a significant threat."

Figure 78. Most problematic contaminants in recycling facilities



The next set of questions asked respondents if their facility experienced any instances in the past 5 years related to lithium-ion batteries. Six respondents selected that they have had no incidents related to lithium-ion batteries, but four noted that they had a minor fire or thermal event (4 responses), a major fire or explosion requiring emergency response (3 responses), or multiple incidents over time (3 responses). In total, 6 respondents have had some varying degree of lithium-ion battery incidents. The respondents who have had an incident were asked follow up questions about the incident(s). The first follow-up asked how the fire was detected. Most said smoke or flames were visible (4 responses). Then, respondents were asked about fire detection or suppression tools used at their facilities. Five respondents said they train staff for fire safety specific to lithium battery incidents, 3 noted they use Type D fire extinguishers, and 3 said they use thermal imaging or infrared camera systems. After that, respondents were asked about actions taken to control the incident. The use of a fire extinguisher (4 responses) and calling the fire department (4 responses) were the most frequent responses taken. Additionally, 3 respondents noted they dumped the load to prevent spread and 2 indicated “other.” The other responses said they separated materials, or their Fire Rover sprayed the fire. The incident(s) resulted in major property damage for 3 respondents or minor property damage for 2 respondents. Other outcomes included evacuation of personnel or public (2 responses), no significant impact (2 responses), temporary service disruptions (1 response), or emergency response required (1 response). Finally, responses who had a fire incident were asked to rank, from most helpful to least helpful, potential investments to reduce lithium battery fire risks. The top 3 average ranked actions were the installation of thermal imaging or infrared detection systems, enhanced staff training for lithium battery-related fires, and public outreach and education to reduce improper battery disposal. All ranked investments are shown in Table 88.

Table 88. Average rankings of investments to reduce lithium-ion battery fire risks

Priority investments to reduce lithium-ion battery fire risks	Average score
Installation of thermal imaging or infrared detection systems	2.83
Enhanced staff training for lithium battery-related fires	3.33
Public outreach and education to reduce improper battery disposal	3.67

Priority investments to reduce lithium-ion battery fire risks	Average score
Temperature alert systems for high-risk areas (e.g., flam sheds, bunkers)	3.83
Purchase of suppression blankets or specialized extinguishers	4.00
Battery-specific collection containers or sorting protocols	5.00
Facility layout/design improvements to isolate high-risk materials	5.33

Next, recycling facility respondents were asked to select up to three of the most significant safety risks that staff face at their facilities. Manual handling injuries (6 responses) and exposure to hazardous or unknown materials (5 responses) were the top two safety risks identified by respondents. Figure 79 shows the full distribution of safety risks identified by respondents.

Figure 79. Top self-reported safety issues for recycling facility staff



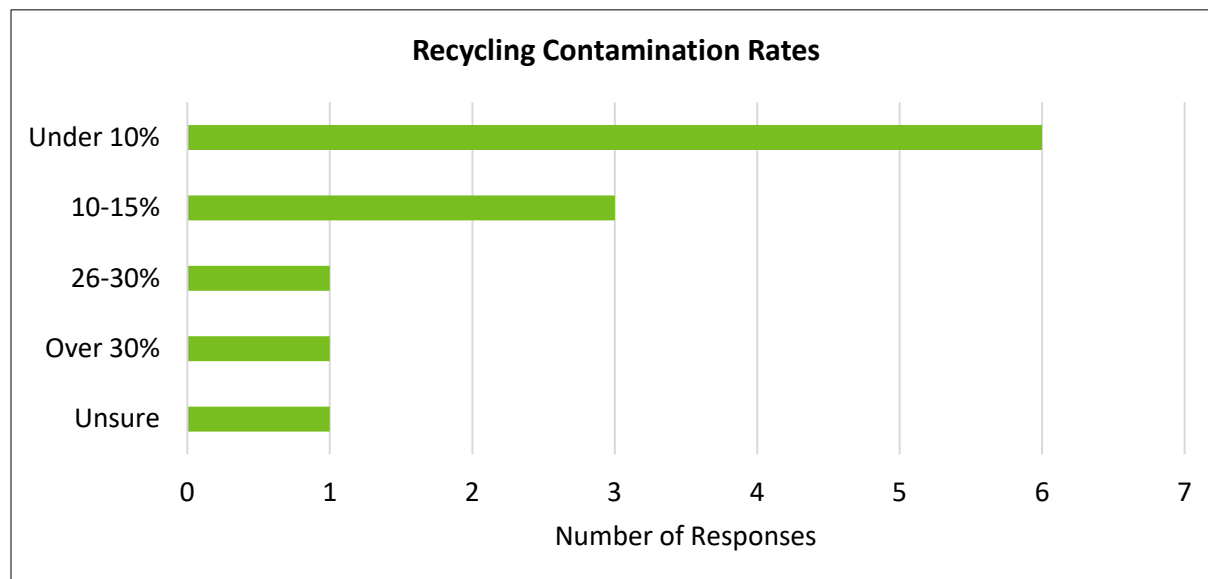
Next, recycling facility respondents were asked about contamination in their facility. Respondents were asked to rank how contamination affected their facility's operations from most disruptive to least disruptive impact. The rankings were averaged to create a score for each impact outcome. The most disruptive outcome of contamination was slower processing speeds, reduced overall recycling efficiency, and increased labor costs for sorting and handling. The full distribution of impacts is shown in Table 89. Respondents were also asked to estimate their facility's contamination rate. Most respondents had a contamination rate of under 10%, as shown in Figure 80.

Table 89. Average ranking of contamination impacts on recycling facility operations

Contamination impacts on recycling facility's operations	Average score
Slower processing speeds (e.g., bottlenecks or delays in sorting and processing due to contamination)	3.09
Reduced overall recycling efficiency (e.g., contamination reducing the effectiveness of the entire recycling process)	3.27
Increased labor costs for sorting and handling (e.g., additional manual labor required to remove contaminants or sort materials)	3.64
Higher disposal costs (e.g., additional fees for disposing of contaminated materials that cannot be recycled)	3.73

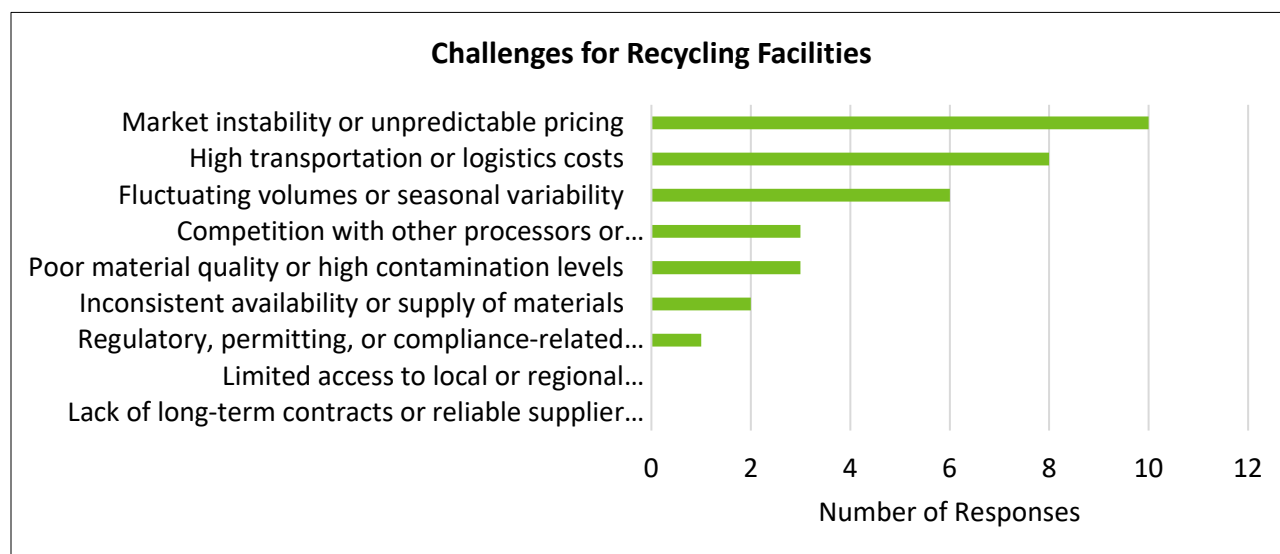
Contamination impacts on recycling facility's operations	Average score
Increased equipment downtime and repair costs (e.g., damage to sorting machinery, conveyor systems, or other equipment)	4.55
Lower market prices for contaminated materials	5.00
Increased fire and worker safety hazards	5.91
Increased rejection rates from end markets	6.82

Figure 80. Self-reported recycling contamination rates at recycling facilities



Additionally, respondents were asked to select some of the largest challenges faced with management of their facilities. The top challenge respondents noted was market instability or unpredictable pricing (10 respondents) or high transportation or logistics costs (8 respondents). The full ranking is shown in Figure 81.

Figure 81. Top challenges for recycling facilities



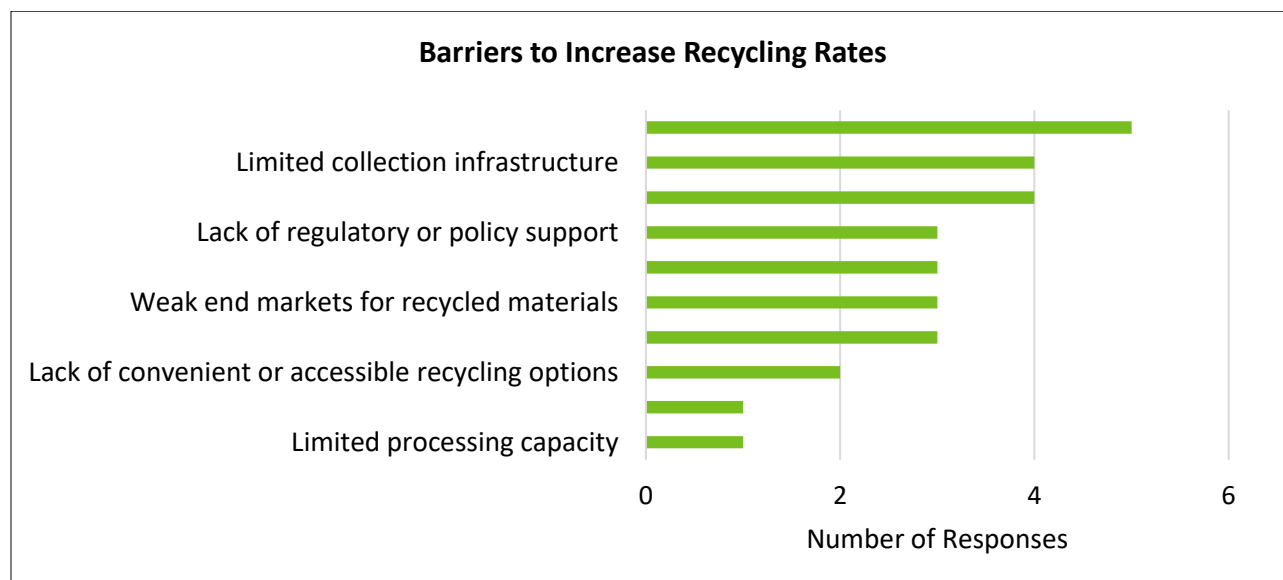
Respondents were asked to select the greatest challenges in securing end markets for recycled materials. The most common issues were with market volatility and fluctuating prices (8 respondents) and lack of demand for certain recycled commodities (8 respondents). Other challenges included limited access to end buyers or markets (4 respondents), changing regulatory or policy requirements (3 respondents), price sensitivity in buyer market (2 respondents), competition with virgin materials (2 respondents), lack of infrastructure or processing capacity (1 respondent), and inconsistent material quality (1 respondent).

Furthermore, recycling facility respondents were asked to select their facility's biggest workforce challenges. The most common challenge was hiring and retaining skilled workers (9 respondents). Other challenges included high turnover rates (5 respondents), low employee engagement or morale (4 respondents), difficulty with seasonal or fluctuating workforce needs (4 respondents), workplace safety concerns (3 respondents), inadequate compensation or benefits (3 respondents), and lack of workforce training programs (2 respondents).

Respondents were asked to select the equipment investments that would most improve their facility's efficiency. The top equipment upgrade choice was an ungraded conveyor system or baler (8 respondents). Additionally, further ranking for equipment improvements included material handling equipment (7 respondents), recycling-specific software or data management systems (6 respondents), advanced sorting technology (4 respondents), shredders or crushers (3 respondents), air quality control systems (3 respondents), better contamination detection and removal systems (2 respondents), and weight measurement or tracking systems (1 respondent).

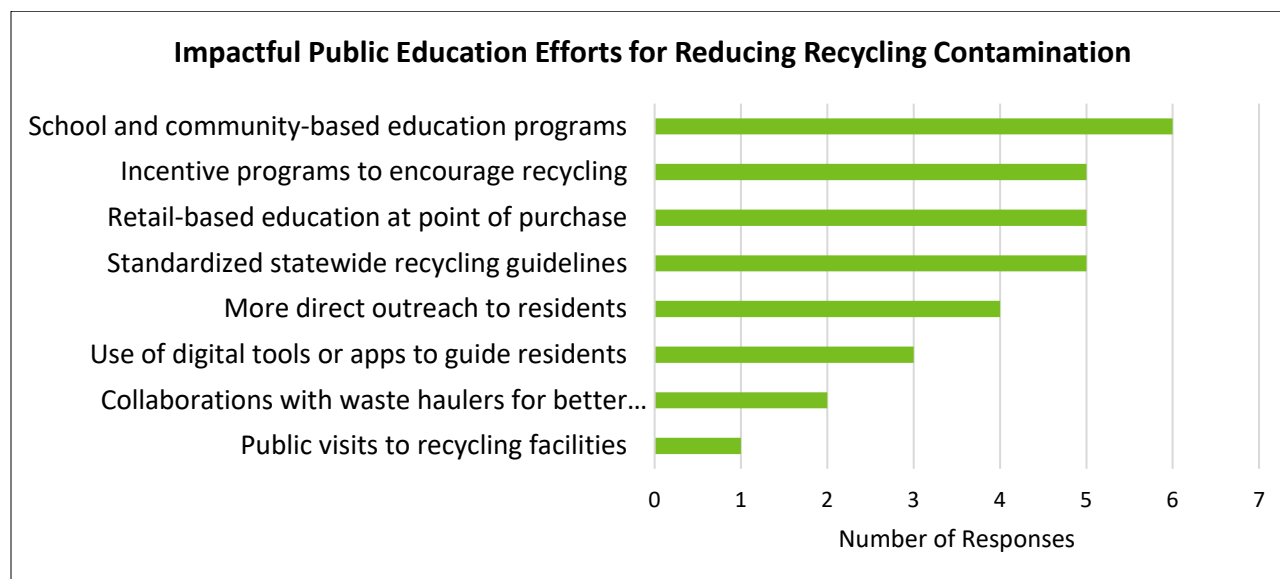
Additionally, respondents were asked to select the most significant barriers to increasing recycling rates in their service area. The top barriers for increasing recycling rates were financial constraints (5 respondents), limited collection infrastructure (4 respondents), and lack of public participation and/or awareness (4 respondents), as shown in Figure 82.

Figure 82. Barriers to increasing recycling rates in recycling facility respondents' service area



Finally, recycling facility respondents were asked to select their opinion on the most impactful public education efforts for reducing recycling contamination. The top choice was school and community-based education programs (6 respondents). The full list of efforts is shown in Figure 83.

Figure 83. Public education efforts for reducing recycling contamination, chosen by recycling facilities



Appendix C.6 Composting Facility Responses

There was one complete response for composting facilities. Findings for this audience should be interpreted cautiously due to low response numbers. The results are included here for completeness but should not be considered representative of this audience. Given the single response, the full set of responses to each question are shown below in Table 90.

Table 90. Composting facility respondents' full set of responses

Question	Response
What are the most common contaminants in the organic waste stream at your facility/site?	Plastic bags and packaging
How does contamination most impact your facility/site's operations?	Increased labor for contaminant removal Decreased processing efficiency Increased operational costs
Which equipment investments would most improve your facility's efficiency?	Improved screening and contamination removal systems
What's your estimated contamination rate at your facility?	Under 5%
What are the most significant barriers to increasing composting rates at your facility/site?	Lack of public participation and/or awareness Operational cost constraints
What public education efforts would have the greatest impact on reducing contamination in composting?	Standardized statewide composting guidelines More direct outreach to residents (e.g., mailers, social media) School and community-based education programs

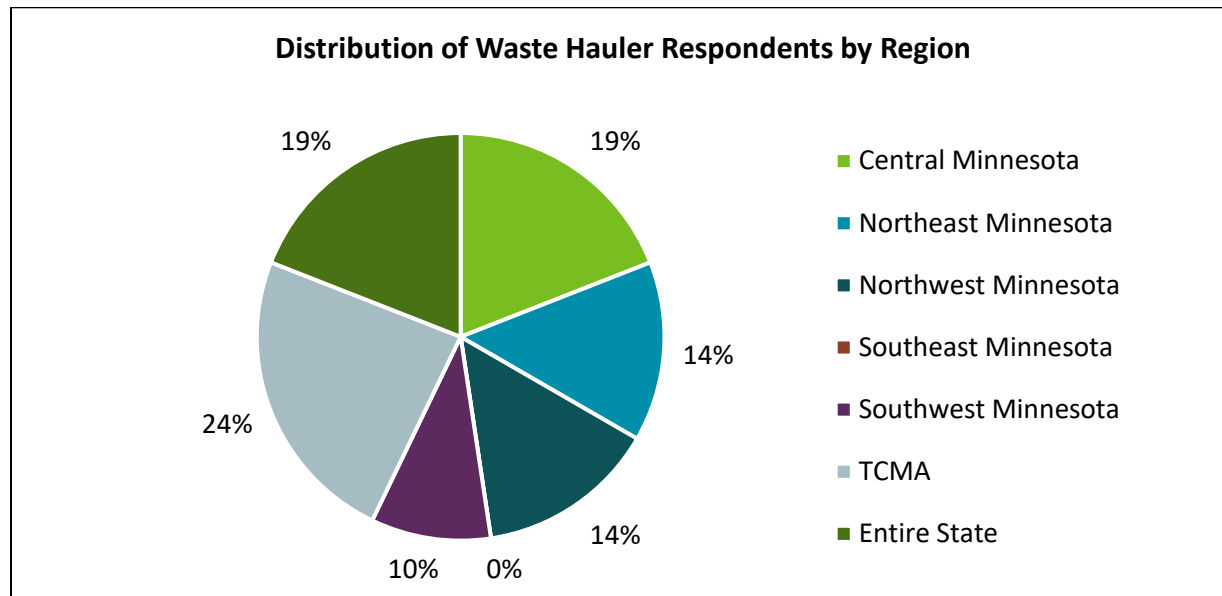
Appendix C.7 Anaerobic Digestion Facility Responses

There were 0 complete responses for anaerobic digestion facilities. This section is blank.

Appendix C.8 Waste Hauler Responses

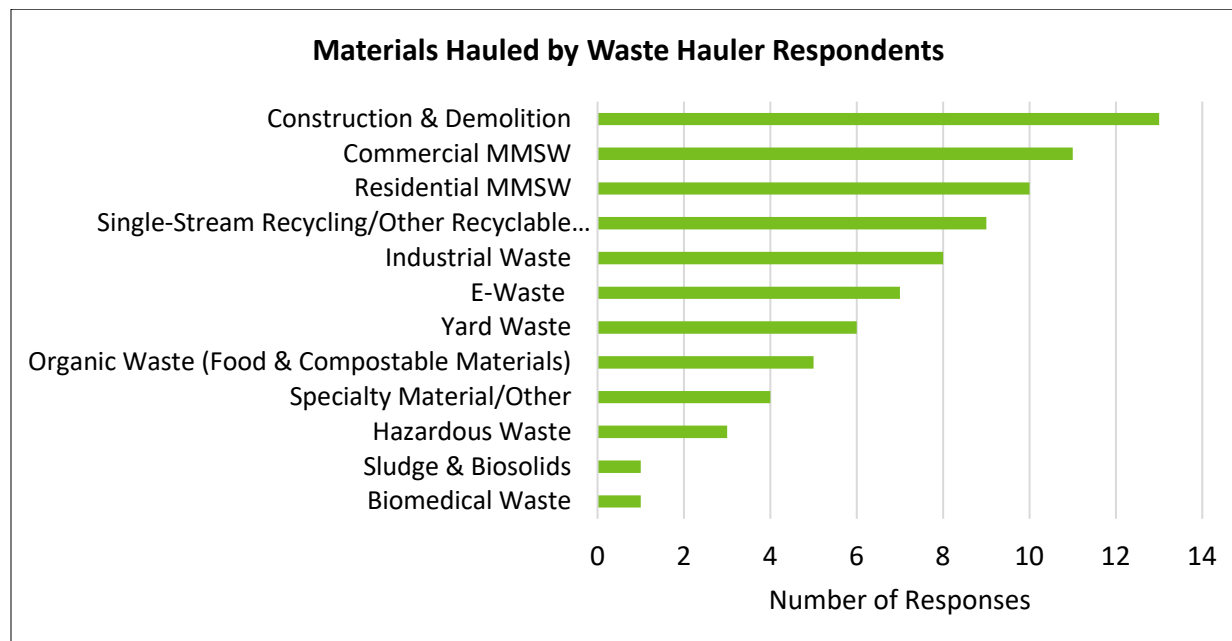
There were 15 respondents that identified as a waste hauler. Waste hauler respondents were evenly distributed across the state, except for no respondents representing Southeast Minnesota, as shown in Figure 84.

Figure 84. Waste hauler regional representation



Respondents were first asked which types of materials they haul. Most respondents noted hauling construction and demolition waste (13 respondents), commercial MMSW (11 respondents), and residential MMSW (10 respondents). The least represented material for haulers in this sample were sludge and biosolids and biomedical waste (1 respondent each). All the materials hauled by respondents are shown in Figure 85.

Figure 85. Self-reported materials hauled by waste type



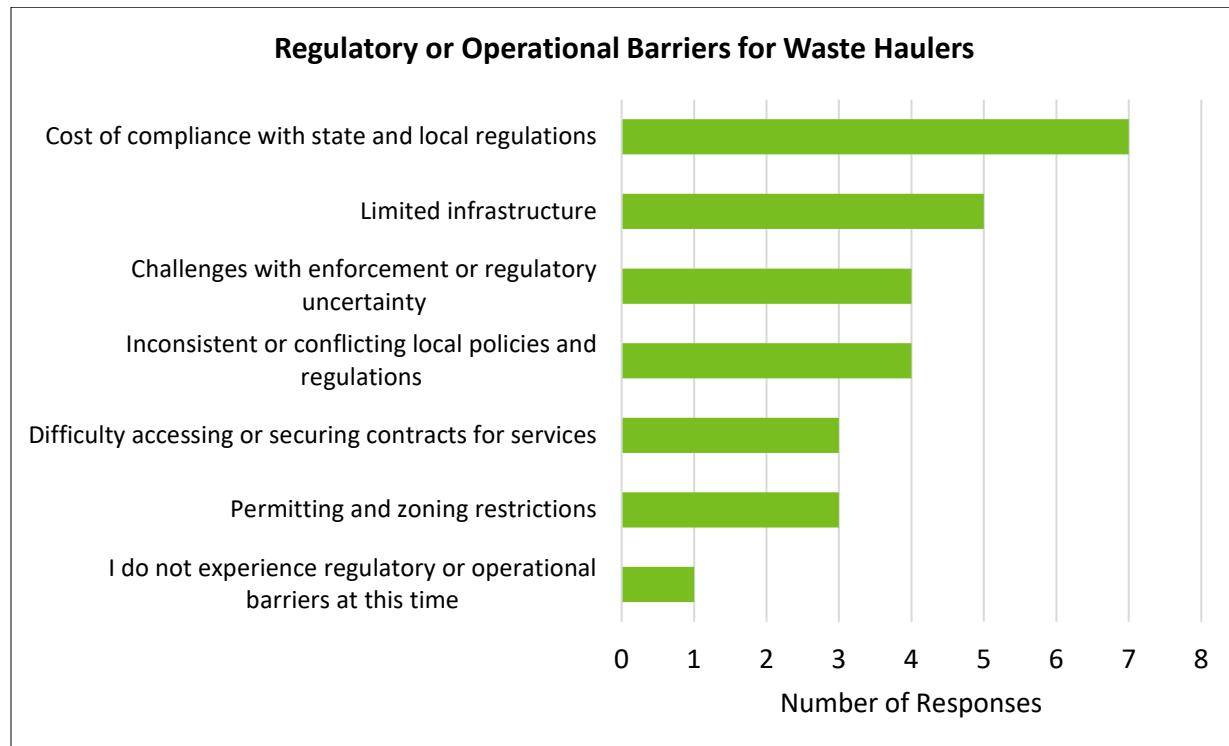
Next, if the respondent indicated that they haul recyclable materials, they were asked to identify up to three of the most common contaminants in their recycling streams. Plastic bags or bagged recyclables were the top contaminant (5 respondents) and non-recyclable plastics were the top second choice (3 respondents). Scrap metal in non-metal streams was another for 2 respondents. Soiled paper and cardboard, electronics or small appliances, yard or organic waste, bulky items, construction and demolition debris, and “other” each had 1 respondent. The “other” respondent noted that non-recyclable items in the recycling stream were a common contaminant.

The next set of questions related to fire and safety hazards found in the waste stream. 57% of respondents said they have experienced a fire or safety hazard related to hazardous materials, while 43% have not. The most frequent location where the fire or safety incidents occurred was at a transfer station or MRF (7 respondents) or inside a collection truck (5 respondents). Then, respondents were asked to indicate which material(s) they believed caused or contributed to the incident, with the most mentioned material being lithium-ion batteries (8 respondents). The hazards were most likely to be detected by smoke or visible flames (5 respondents), and the haulers dumped the loads to prevent spread (8 respondents), called the fire department (6 respondents), or used a fire extinguisher (5 respondents) to take control of the incident. Lastly, respondents who have had an incident were asked to rank potential priority investments for reducing lithium-ion battery fire risks. The top preferred investments were public outreach and education to reduce improper battery disposal and battery-specific collection containers or sorting protocols.

Waste hauler respondents were asked if there were any actions that could improve route efficiency for their service area. The majority of respondents indicated that they do not need to improve route efficiency; however, the top two actions that could improve route efficiency selected were route optimization software and/or technology (4 respondents) and increased customer education to reduce contamination and rejected loads (4 respondents).

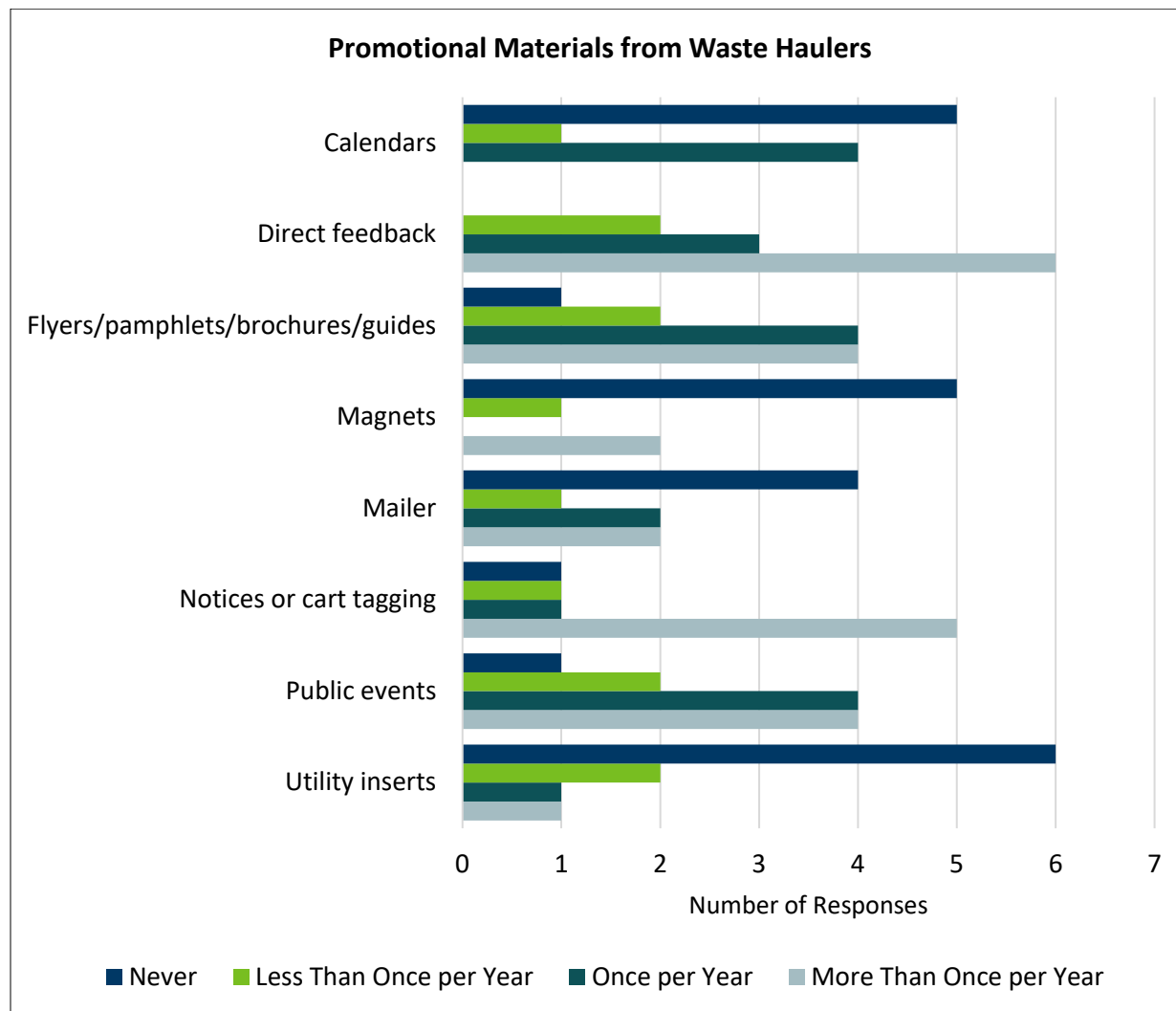
Haulers were then asked to describe if they experience any regulatory or operational barriers that impact their business. Cost of compliance with state and local regulations was the most frequent response (7 respondents), followed by limited infrastructure (5 respondents). The full list of barriers is shown below in Figure 86.

Figure 86. Self-reported regulatory or operational barriers for waste haulers



The respondents were also asked if they provide promotional educational materials to their customers. 12 respondents said “yes,” 2 said “no”, and 1 said “unsure.” If respondents said yes, they were asked about which kinds of materials or education they provide and how often they distribute it. Direct feedback (via e-mail or mail) was the most frequent form of feedback, with 6 respondents mentioning they provide direct feedback more than once per year. Notices or cart tagging were also used by 5 respondents more than once per year. The least used promotional material noted by respondents was utility inserts, as 6 respondents noted never using them. Public events, flyers, and calendars were used once per year by 4 respondents each. The full distribution of promotional materials and their frequency is shown in Figure 87.

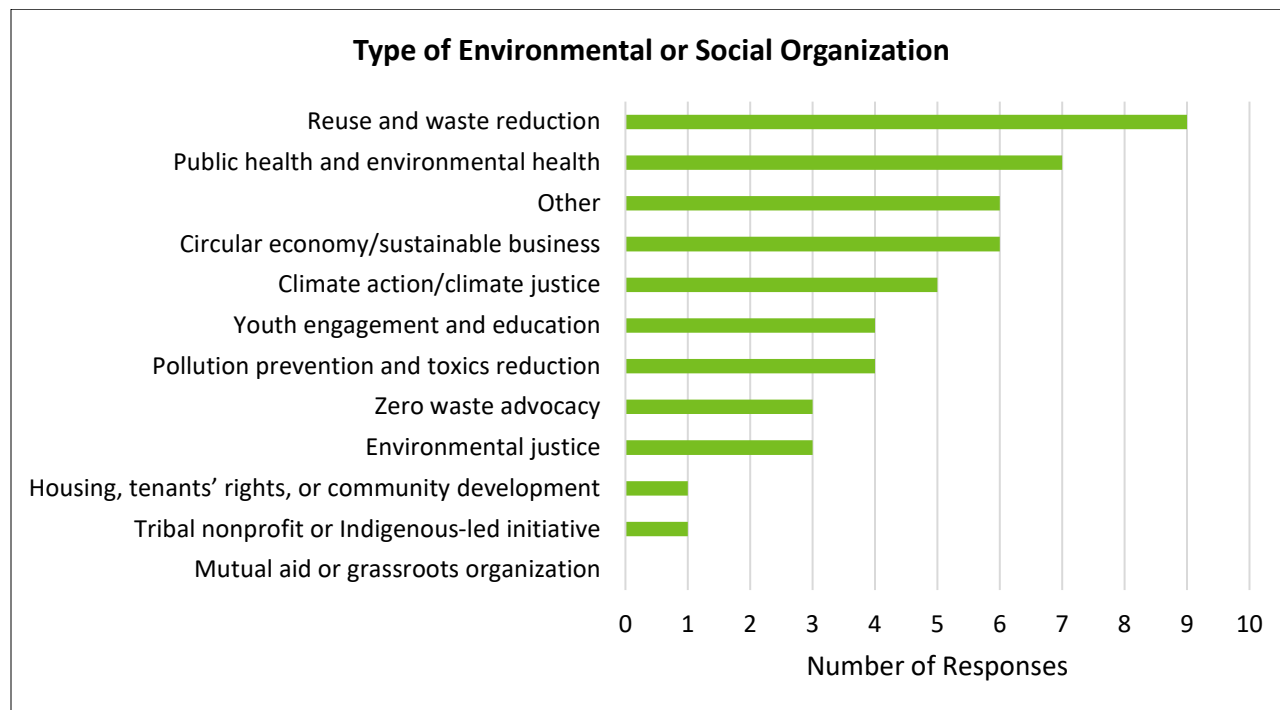
Figure 87. Promotional materials & frequency used by waste haulers



Appendix C.9 Environmental & Community Organization Responses

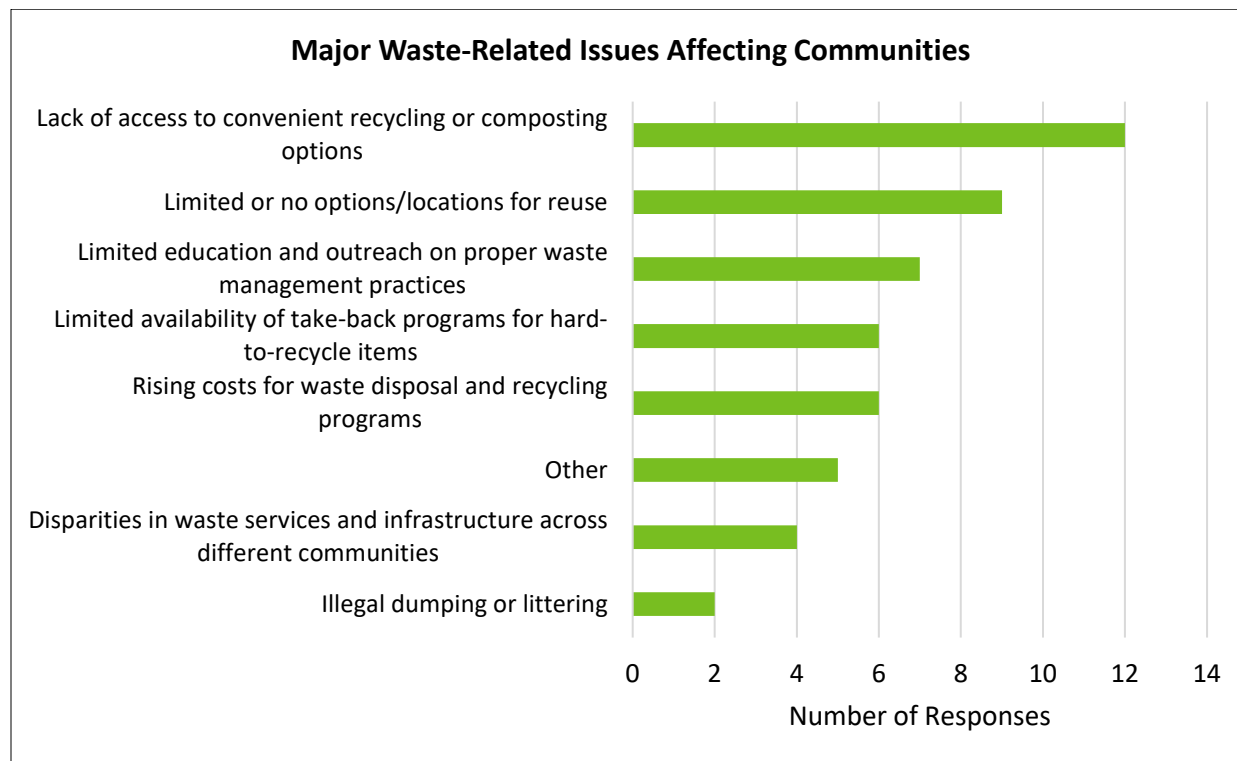
There were 21 complete responses from environmental and community organizations. Most of the respondents in this category were organizations related to reuse and waste reduction (9 responses), but there were a wide mix of represented organizations as shown in Figure 88. Some of the “other” organization types included: *Consultant, recycling association, public elementary school, History preservation, nonprofit cultural heritage, and Watershed District.*

Figure 88. Types of environmental or social organization of respondents



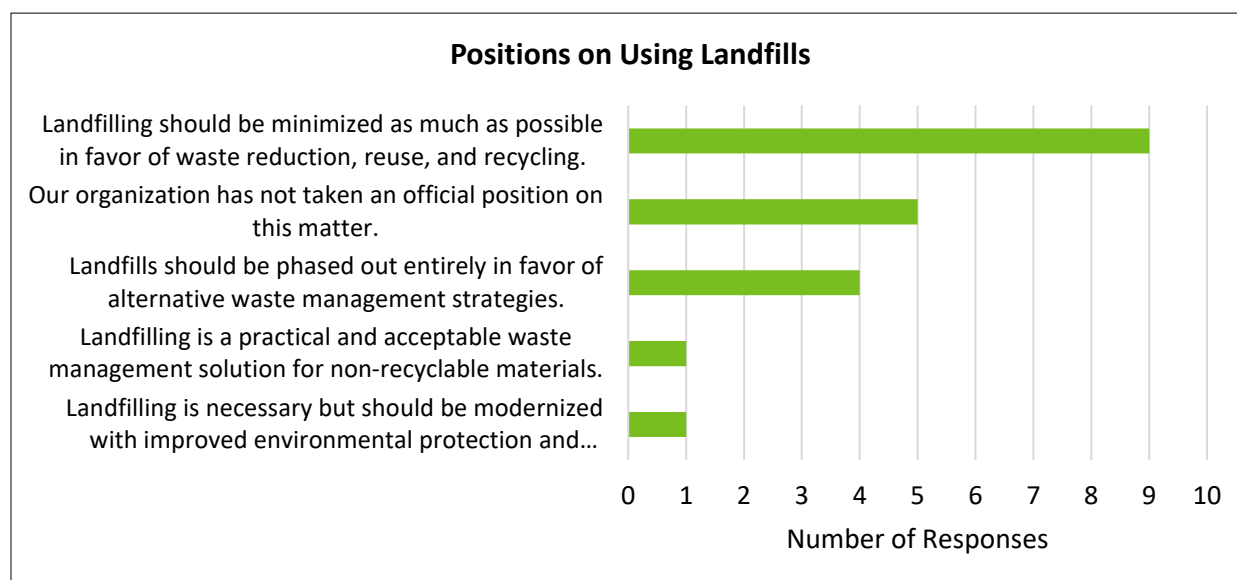
Respondents were asked to list up to three significant waste-related issues affecting the communities they serve. The top response was a lack of access to convenient recycling or composting options (12 respondents), followed by limited to no options or locations for reuse (9 respondents), as shown in Figure 89. In the text response given by “other” answers, respondents emphasized the need to prioritize waste prevention and reduction, particularly by addressing plastic production, health risks from microplastics, and the lack of scalable reuse systems for packaging and food ware. They also highlighted gaps in enforcement, standardized material ratings, and wasted food recovery programs.

Figure 89. Significant waste-related issues affecting respondents' communities served



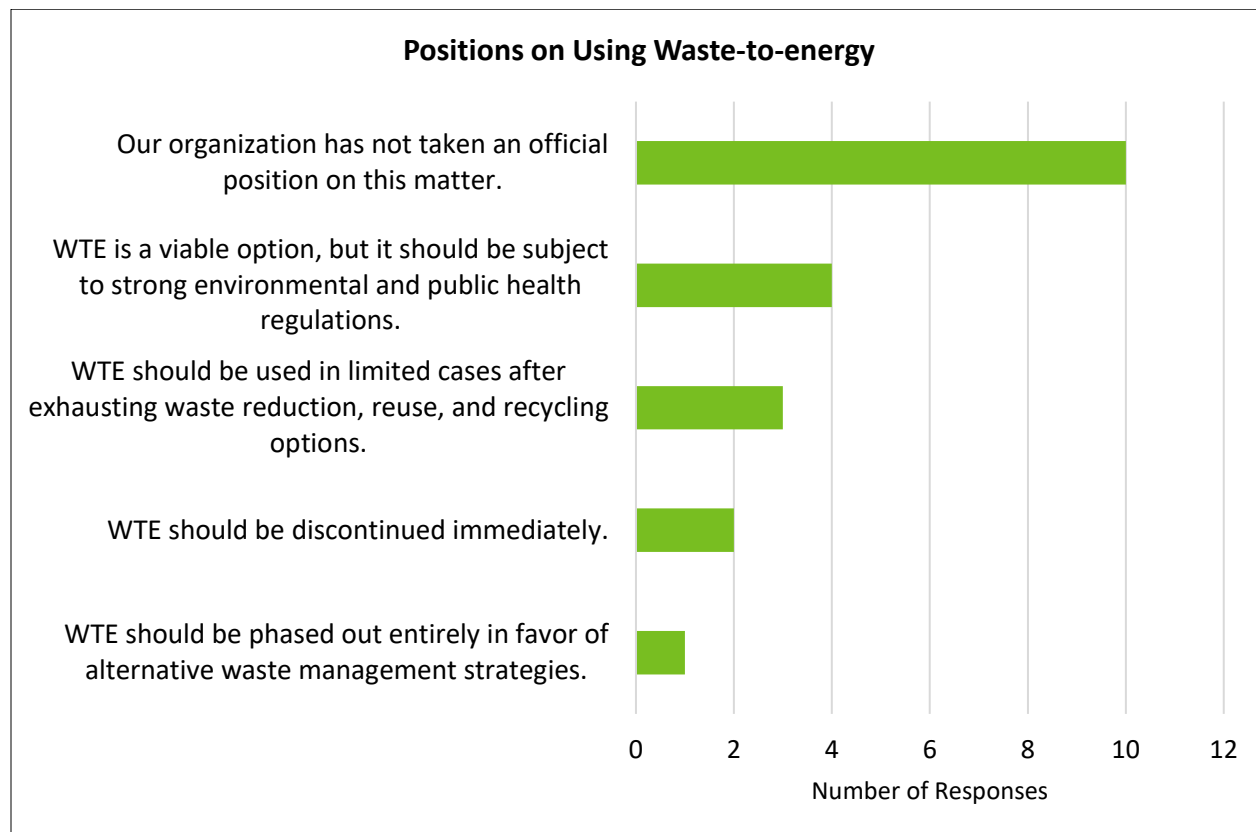
In the next two questions, respondents were asked to describe their organization's position of two specific waste management strategies: landfilling and waste-to-energy. Respondents were first asked to describe their organization's position on using landfills as a waste management strategy. The top position of respondents is that landfilling should be minimized as much as possible in favor of waste reduction, reuse, and recycling (9 respondents), as shown in Figure 90.

Figure 90. Positioning on using landfills as a waste management strategy



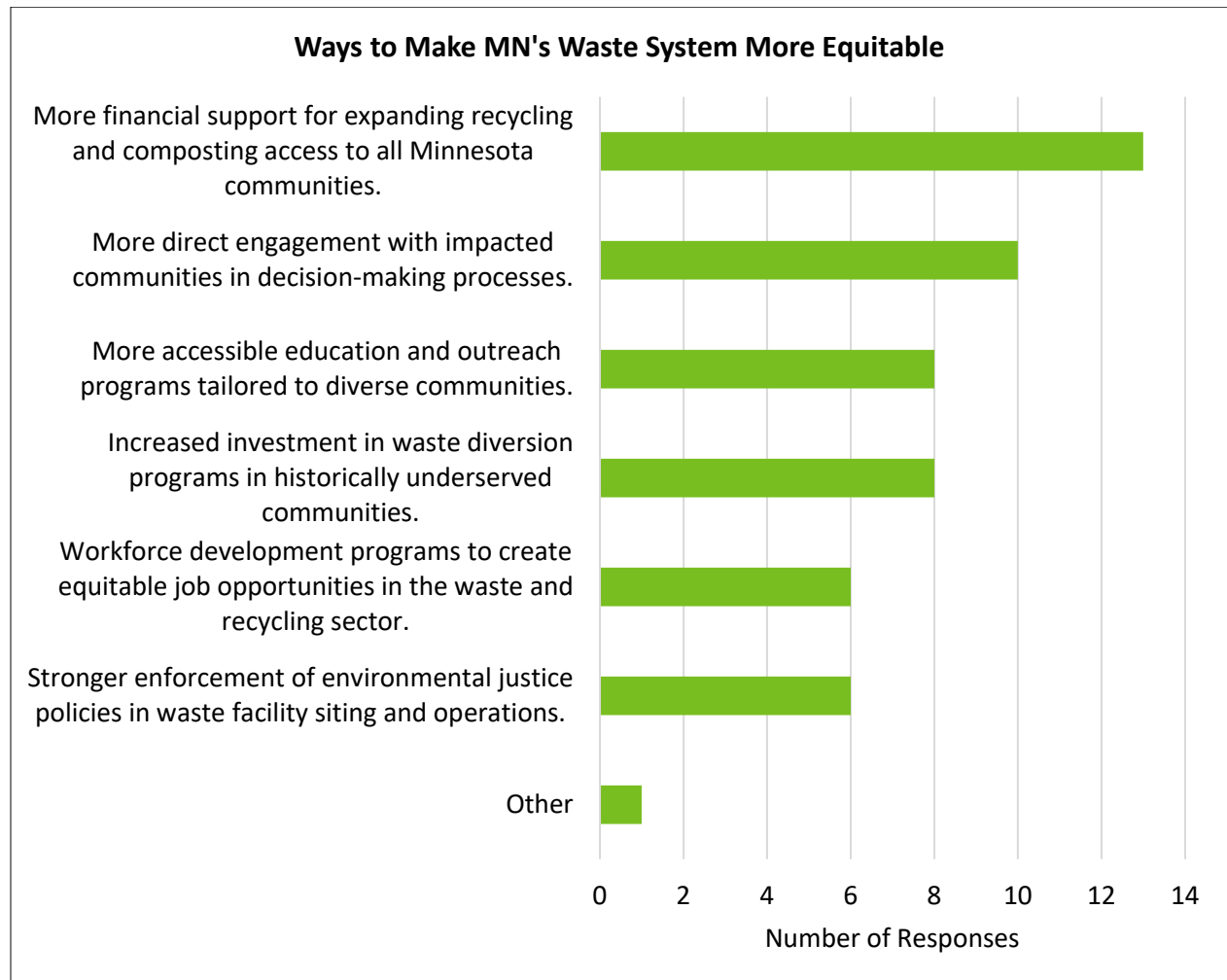
After that question, respondents were asked the same but on the use of waste-to-energy for managing waste. Most respondents indicated that their organization has not taken an official position (10 respondents), as shown in Figure 91.

Figure 91. Positioning on using waste-to-energy as a waste management strategy



Next, respondents were asked to select from provided ideas that would make Minnesota’s waste system more equitable. More financial support for expanding recycling and composting access to all Minnesota communities was the top choice (13 respondents), followed by more direct engagement with impacted communities in decision making processes (10 respondents). There was one “other” response which said, *“all of the above but with a focus on reuse systems instead of recycling - reuse creates more & safer jobs than recycling and waste management!”* The full distribution of responses is shown in Figure 92.

Figure 92. Ideas to improve equity in Minnesota's waste system

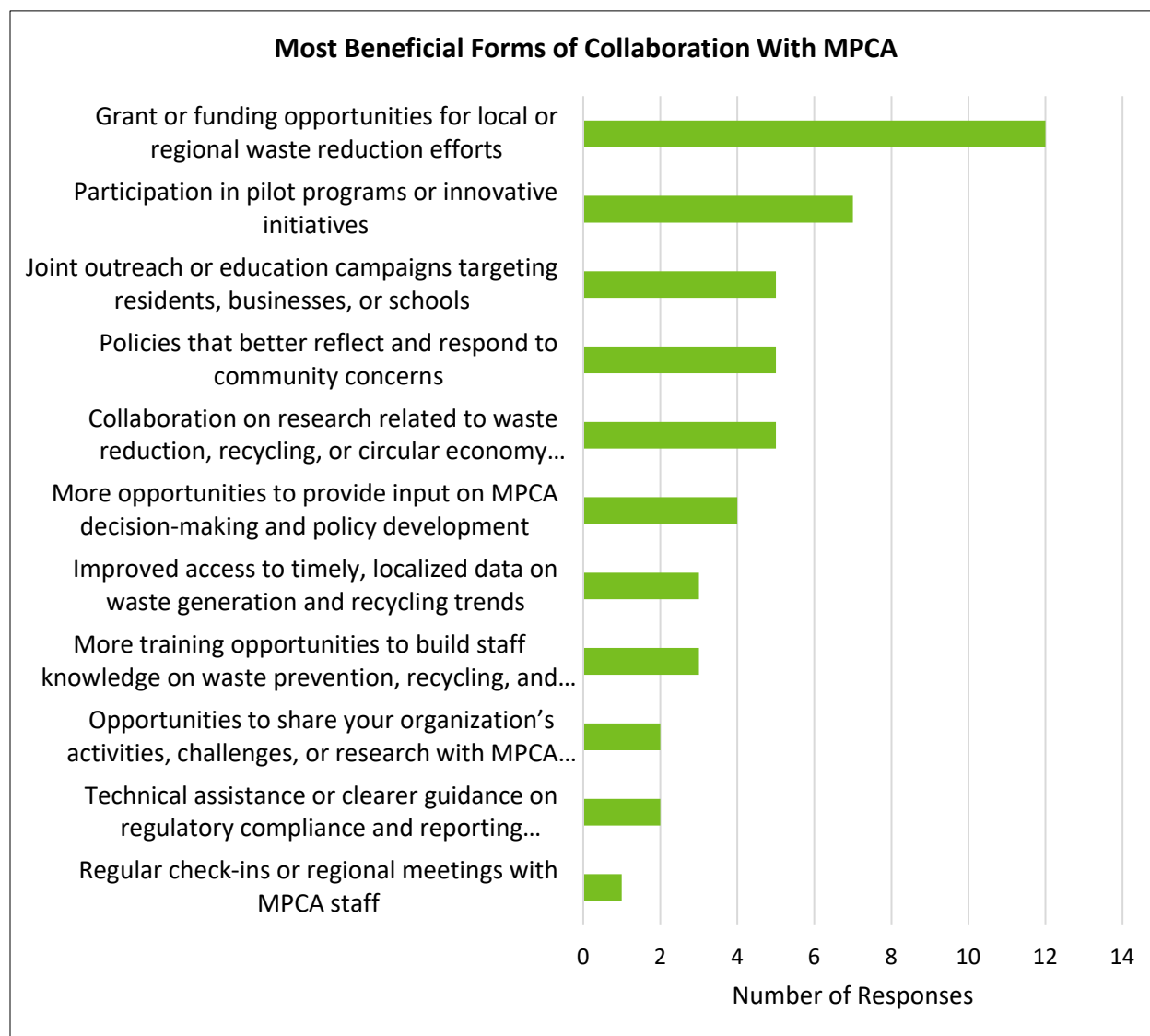


Then, environmental and social organization respondents were asked if they believe that certain communities in Minnesota are disproportionately impacted by current waste management practices. 11 respondents said “yes,” 7 said “no,” and 2 were unsure. If respondents answered “yes,” they were asked why they believed that in free response question. Respondents believe certain communities are more impacted due to systemic inequalities, including historic redlining, zoning, and the frequent siting of waste facilities in low-income and communities of color, while wealthier areas can resist such projects, with one respondent saying that, “*communities where residents are wealthier have resources to fight projects in their neighborhoods.*” Rural communities were also mentioned as facing challenges from limited or distant waste and recycling options, higher costs, and weaker infrastructure. The full list of responses to this question is in the Appendix C.2 – Environmental & Social Organizations.

Respondents were asked if there were any existing partnerships or networks that play a big role in their organization’s mission. 11 respondents said “yes,” 2 said “no,” and 6 said “none currently, but we are interested in future partnerships.” Respondents who answered “yes” were asked to specify. Respondents identified a wide range of key partners, including county environmental services, waste management departments, schools, local businesses, nonprofits, and state or regional organizations such as Reuse Minnesota, MN GreenStep Cities & Tribal Nations, and the League of MN Cities. They also highlighted coalitions and networks like the Zero Waste Coalition and MN EJ Table. The full list of responses to this question is in the Appendix C.2 – Environmental & Social Organizations.

The next question asked respondents to select forms of collaboration with MPCA that would be most beneficial to or of interest to their organization. The top response was accessing grant funding opportunities (12 respondents), followed by participation in pilot programs or innovative initiatives (7 respondents). The least selected response was regular check-ins or regional meetings with MPCA staff (1 respondent), as shown in Figure 93.

Figure 93. Most beneficial or interesting forms of collaboration with MPCA

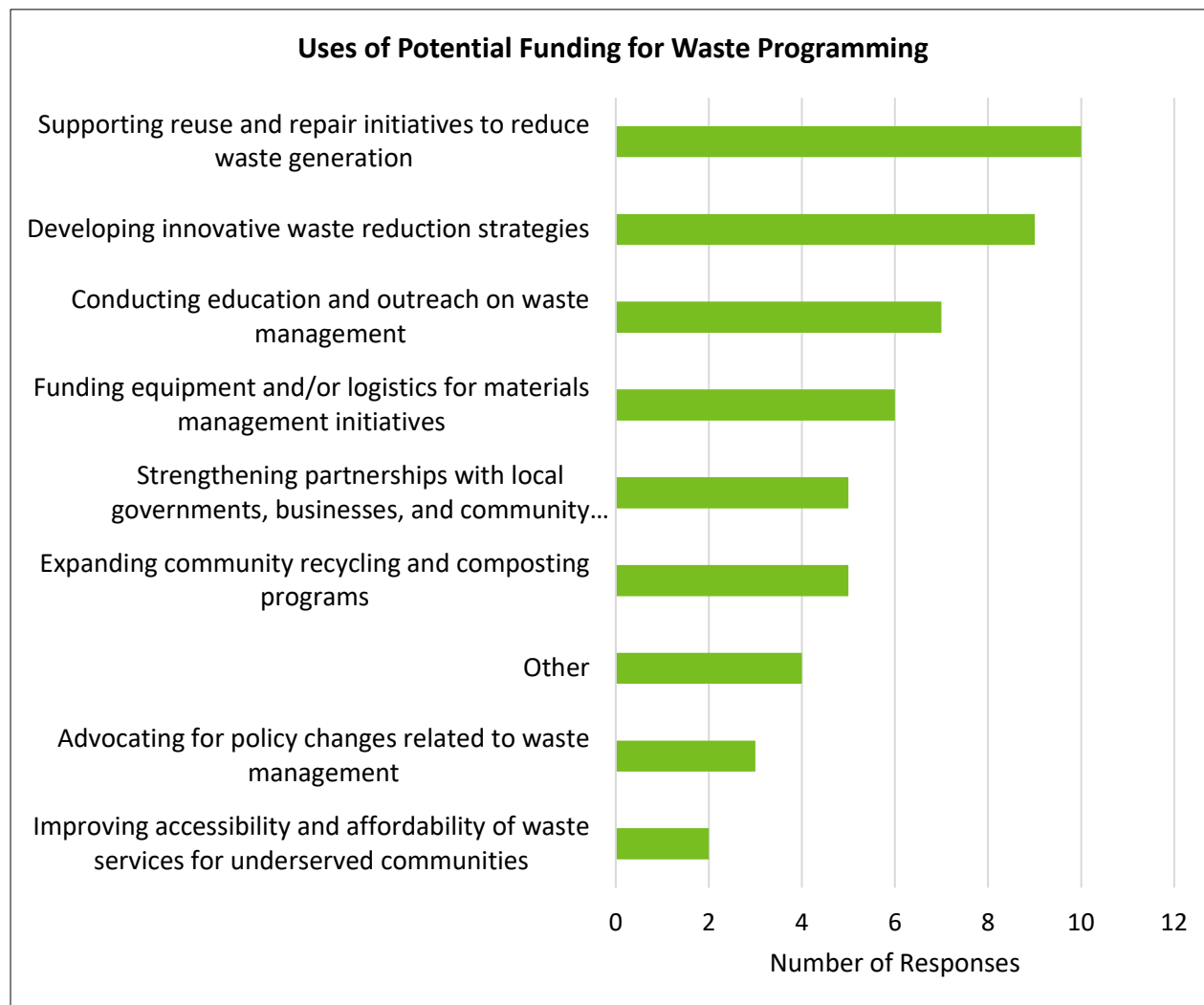


Additionally, respondents were asked if their organization could find the information it needs on waste management policies and programs through MPCA. Most said “somewhat, but it can be difficult to navigate or there is incomplete information” (14 respondents). Three respondents said “yes, the resources are accessible and helpful,” and 3 said that they do not seek information from MPCA.

The next question asked respondents to select ways they might use potential funding to improve waste management and recycling programs. The most selected uses were supporting reuse and repair initiatives (10 respondents), developing innovative waste reductions strategies (9 respondents), and conducting education and outreach (7 respondents), as shown in Figure 94. There were four “other” responses where respondents wrote in that they would focus on reuse systems or pilots, food recovery,

and deconstruction initiatives. The full responses are available in the Appendix C.2 – Environmental & Social Organizations

Figure 94. Potential uses of funding for waste and recycling programs (environmental and social organizations)



Then, respondents were asked to rate their organization’s level of trust in MPCA’s handling of waste and recycling policies. The majority said they have moderate trust (10 respondents). 6 respondents said they have high trust, and 1 said low trust. 3 respondents were unsure.

Appendix C.10 Tribal Government Responses

There were 3 finished responses for the Tribal Governments audience segment. Findings for this audience should be interpreted cautiously due to low response numbers. The results are included here for completeness but should not be considered representative of this audience. The full set of responses are listed below in Table 91.

Table 91. Tribal government respondents’ full set of responses

Question	Respondent A	Respondent B	Respondent C
Does your Tribe currently track waste, recycling, or organic waste data?	No, we do not currently track waste and recycling data.	Yes, but data collection is inconsistent or limited.	Yes, we collect detailed data regularly.

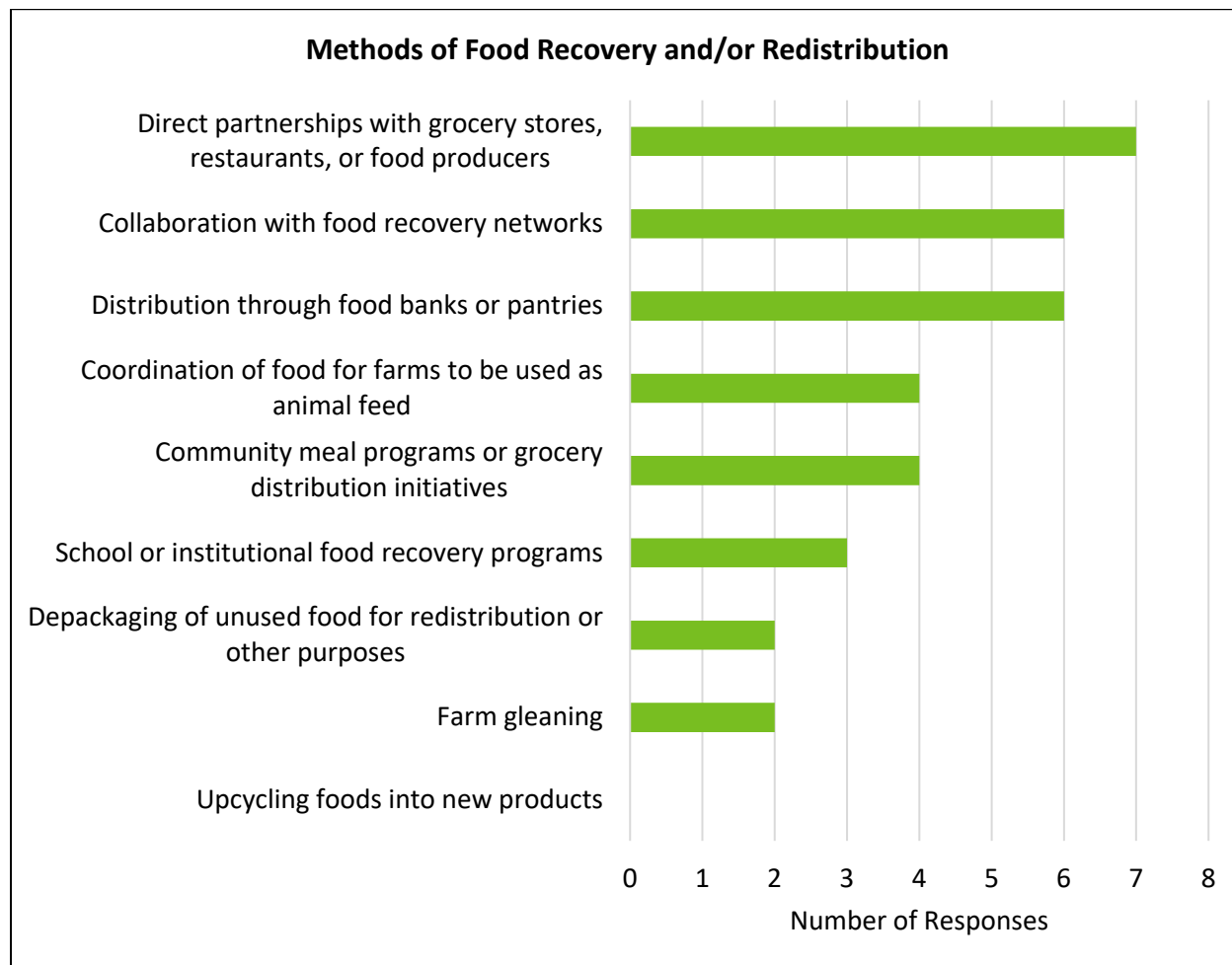
Question	Respondent A	Respondent B	Respondent C
How does your Tribe collect data on waste, recycling, or organic waste?		Tonnage reports from haulers	Audits of waste streams Data from our own facilities
What types of waste materials are most commonly generated within your community?	Household trash Recycling Hazardous waste E-waste Bulky waste Wood waste Tires Other (Plastic boat wrap)	Household trash Recycling Organic waste Construction and demolition debris Hazardous waste E-waste Bulky waste Household medical waste Scrap metal Plastics not accepted in curbside recycling Used oil or motor fluids Tires	Household trash Recycling Organic waste Hazardous waste E-waste Bulky waste Scrap metal Used oil or motor fluids Tires
Does your Tribe have its own residential recycling hauling or recycling drop-off sites?	No, we have a contract to use non-Tribal entities for recycling.	No, we have a contract to use non-Tribal entities for recycling.	No, we have a contract to use non-Tribal entities for recycling.
Where does most of the waste generated on your Tribal lands currently go?	Transfer station Regional or municipal recycling center	Direct to landfill Transfer station Regional or municipal recycling center Tribal-operated recycling/composting facility	Transfer station Regional or municipal recycling center Tribal-operated recycling/composting facility
Do you face any of the following cost-related challenges in your Tribe's waste management operations? Which of the following are the most significant?	Equipment and infrastructure needs Labor costs for waste management staff Costs associated with educating the community about waste management	Hauling and transportation expenses Equipment and infrastructure needs Labor costs for waste management staff	The question was not answered.
Does your Tribe face any of the following operational challenges in Tribal waste management operations? Which of the following are the most significant?	Limited staffing and technical expertise Lack of or limited local recycling or composting infrastructure Lack of adequate data on waste generation or diversion rates	High transportation costs for waste and recyclables Lack of or limited local recycling or composting infrastructure Insufficient funding or grant opportunities for operational improvements	Illegal dumping on Tribal lands Limited staffing and technical expertise Limited public awareness or participation in waste management programs
Does your Tribe operate or participate in any of the following programs?	Community composting programs Recycling or household hazardous waste collection events	Community composting programs Recycling or household hazardous waste collection events Selective tree harvesting	Reuse and initiatives Community composting programs

Question	Respondent A	Respondent B	Respondent C
	Selective tree harvesting E-waste recycling programs Green energy initiatives Indigenous knowledge-sharing on sustainable land or waste management practices Traditional food preservation and waste reduction programs Community clean-up or beautification programs Education and outreach on sustainability and waste reduction	Full utilization of hunted animal and fishing harvests E-waste recycling programs Green energy initiatives	Recycling or household hazardous waste collection events Selective tree harvesting Green energy initiatives Traditional food preservation and waste reduction programs Education and outreach on sustainability and waste reduction
Does your Tribe currently have partnerships with community organizations, schools, or businesses to promote waste reduction and recycling?	No, we do not have formal partnerships.	No, we do not have formal partnerships.	The question was not answered.

Appendix C.11 Food Recovery Organization Responses

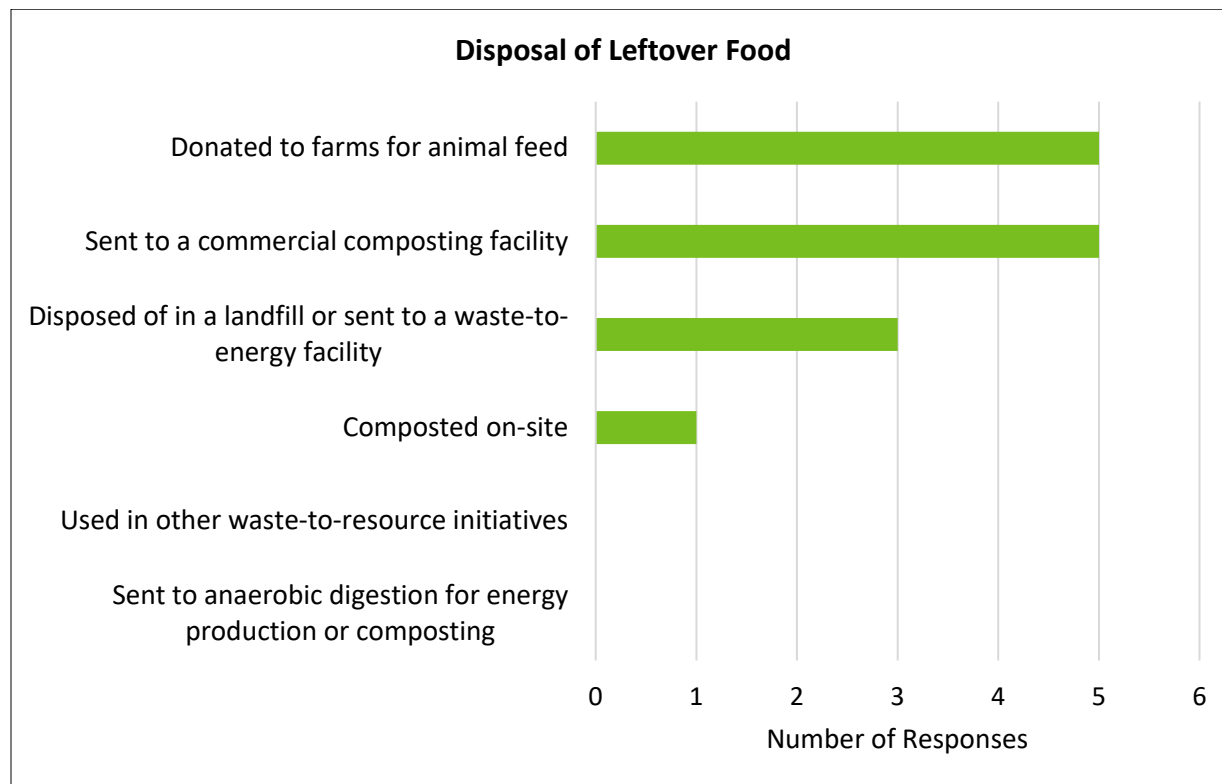
There were 8 complete responses from food recovery organizations. The main type of food recovery or redistribution of food for respondents was from direct partnerships with grocery stores, restaurants, or food producers (7 respondents). Respondents also reported working with food recovery networks and distributing through food banks or pantries, as shown in Figure 95.

Figure 95. Methods of food recovery/redistribution for food recovery organizations



Then, respondents were asked what happens to leftover food that cannot be recovered or redistributed. The top two solutions for leftover food were donations to farms for animal feed (5 respondents) and to send to a commercial composting facility (5 respondents), as shown in Figure 96.

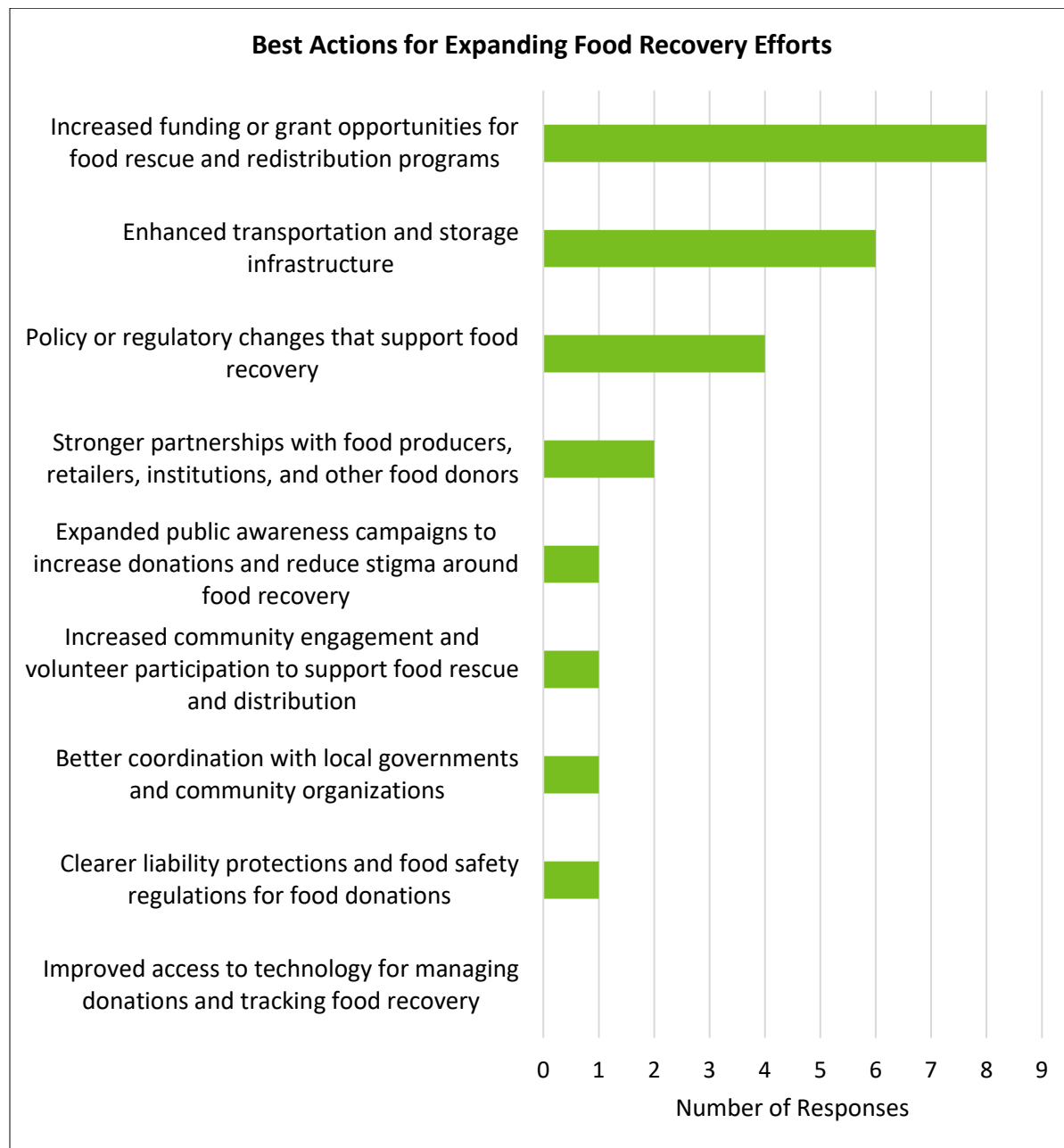
Figure 96. Reported disposal methods of leftover or unrecoverable food



Next, food recovery respondents were asked if they experience any barriers to recovering and distributing food. The main two barriers noted were insufficient funding or resources and transportation and logistics (7 respondents each). Maintaining donor relationships or securing reliable sources of food and storage limitations both had 2 respondents each, and 1 respondent noted that labor shortages or volunteer availability was a challenge.

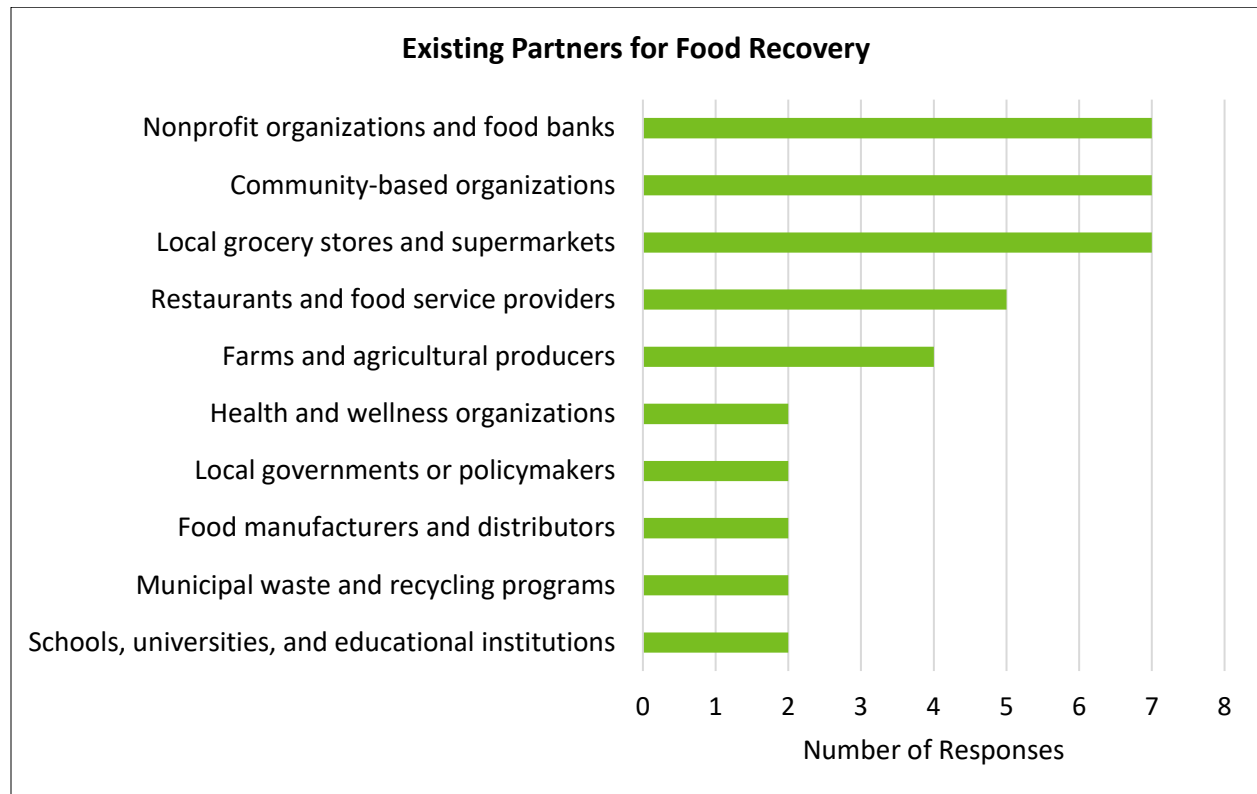
Respondents were then asked what would be the the most helpful actions for expanding food recovery efforts. The number one choice was increased funding or grant opportunities (8 respondents), followed by enhanced transportation and storage infrastructure (6 respondents), as shown in Figure 97.

Figure 97. Desired methods of expanding food recovery



Subsequently, food recovery organization respondents were asked who their primary partners were. The main three partners identified were nonprofits and food banks, community-based organizations, and local grocery stores and supermarkets (7 respondents each). The full distribution of partners is shown below in Figure 98.

Figure 98. Primary partners of food recovery organizations



The next question asked if respondents currently track the amount of food their organization diverts from waste. All 8 respondents reported that they track and regularly report their data.

After that, respondents were asked to select resources that could help their food recovery efforts. Improved access to refrigerated storage space and transportation options was the top choice (7 respondents), followed by funding or grants for expanding food recovery operations (6 respondents) and partnerships with local food recovery networks or coalitions (4 respondents). Volunteer recruitment, better tracking and reporting tools, and public education campaigns to reduce wasted food each had one 1 respondent.

Appendix C.12 Resident Responses

There were 349 complete resident responses. As mentioned previously, the survey was also available in Spanish and Hmong for resident respondents; however, there were no respondents in that language. 209 residents provided their zip code. There was a large distribution of zip codes; however, the top ten zip codes are show, and full list of zip codes can be found in the Appendix C.3 – Residents. The top ten zip codes represent the following cities or regions:

- Minneapolis
- Andover
- Anoka
- Ham Lake
- Nowthen
- Oak Grove

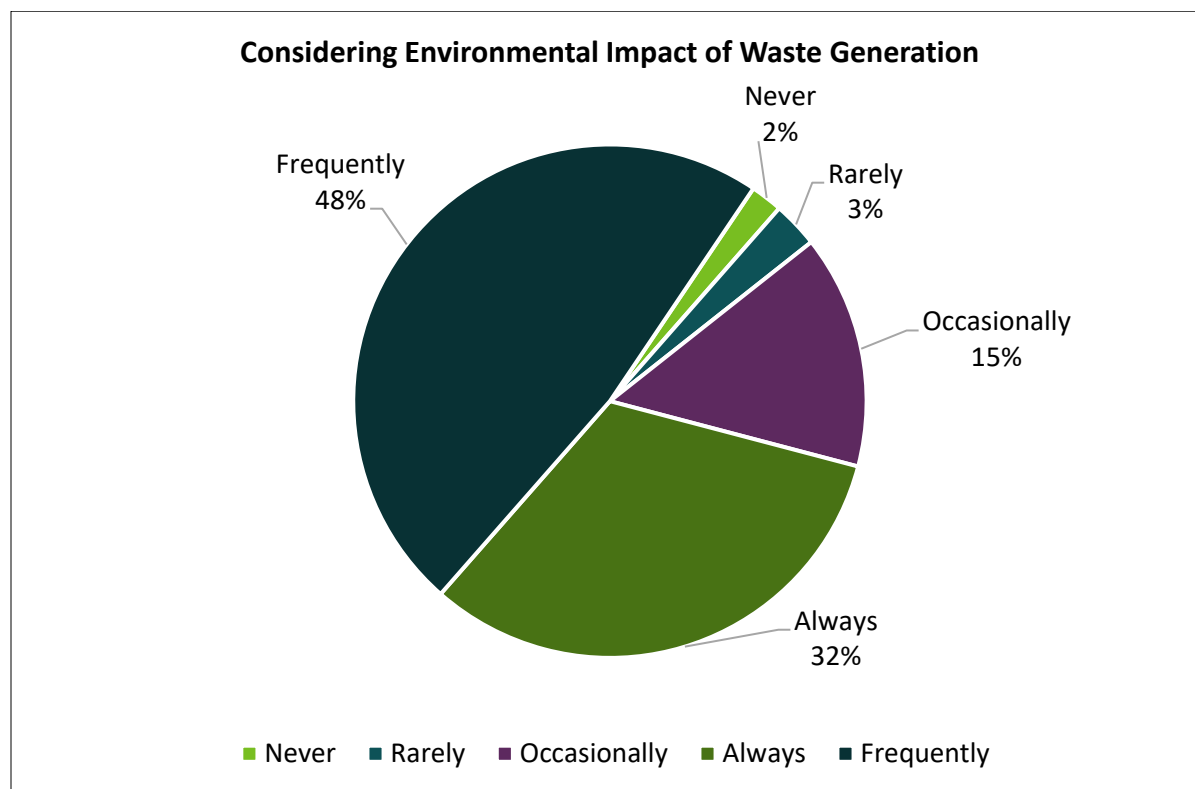
- Ramsey
- Saint Paul
- Rochester
- Blaine
- Saint Anthony
- Falcon Heights
- Lauderdale
- Little Canada
- Roseville
- Pine River
- Jenkins

Table 92. Top 10 self-reported resident respondent zip codes

Zip codes	Count
55411	7
55304	5
55303	5
55105	5
55901	4
55449	4
55418	4
55113	4
56474	3
55448	3

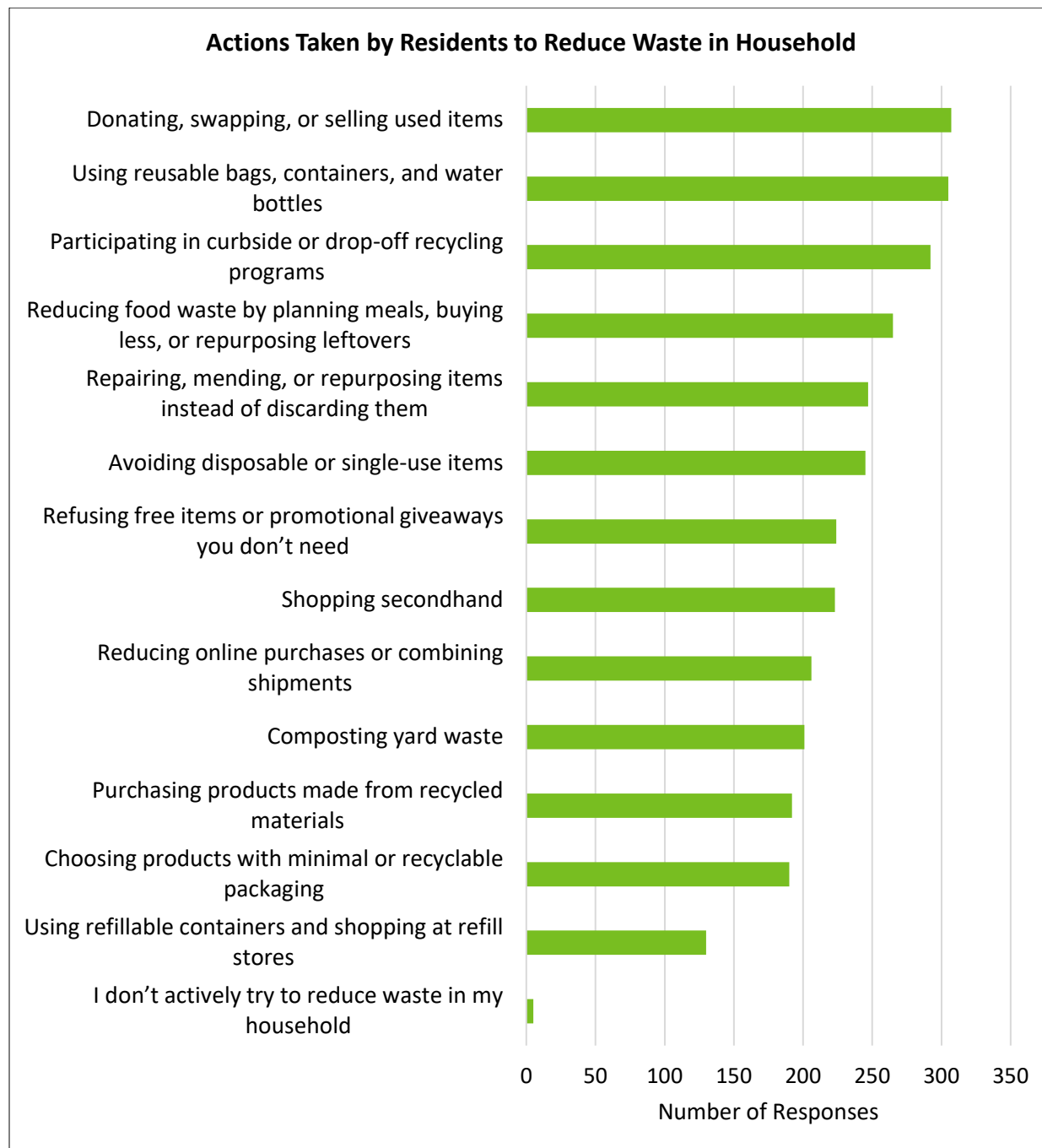
The first question asked resident respondents how often they consider the environmental impact of the waste generated from the items they purchase. 48% of respondents said they do it frequently. Only 2% and 3% indicated they never or rarely consider these impacts, as shown in Figure 99.

Figure 99. Frequency of residents considering the environmental impact of their purchases



Similarly, residents were asked to select the kinds of activities they do to reduce waste in their household. The responses for this answer were fairly distributed, but the top two responses were donating, swapping, or selling used items (88% of respondents), using reusable bags, containers, and water bottles (88% of respondents), and participating in curbside or drop-off recycling programs (84% of respondents). The least selected action was using refillable containers and shopping at refill stores (37% of respondents). All ranked actions are shown below in Figure 100.

Figure 100. Actions resident respondents take to reduce waste



Next, respondents were asked about their access to recycling and where they get information on what to recycle. 84% of respondents reported having access to curbside recycling and 13% reported having access but only to drop-off recycling. 97% of the residential respondents of this survey reported having some form of access to recycling, and 3% noted explicitly they do not have access (Figure 101). Those who responded that they have some form of access were asked to select where they get information on how to recycle properly. A city or county website was selected by 70% of respondents. 50% of respondents said they have existing knowledge. Only 22% of respondents reported getting information from word of mouth. All responses can be seen below in Figure 102. There were several “other” responses where respondents reported getting recycling information from a mix of official sources such as city and county mailings, hauler websites and apps, MPCA, and brochures. Some reported having

more firsthand knowledge, learning recycling information from recycling ambassador trainings, facility tours, and professional experience. All “other” responses can be found in the Appendix C.3 – Residents.

Figure 101. Self-reported residential access to recycling

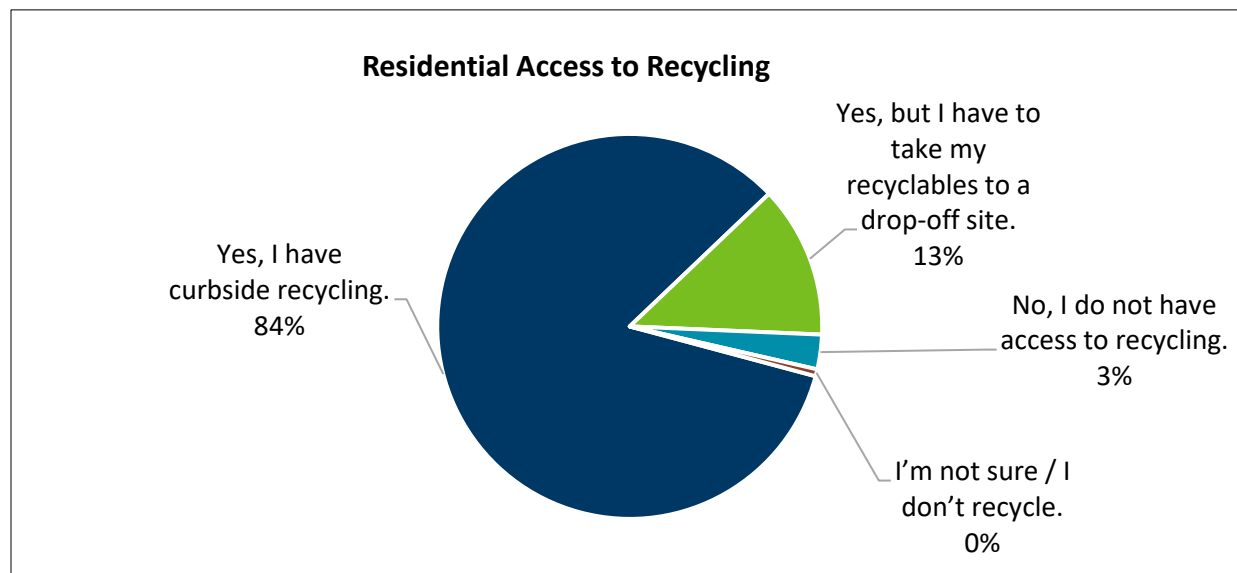
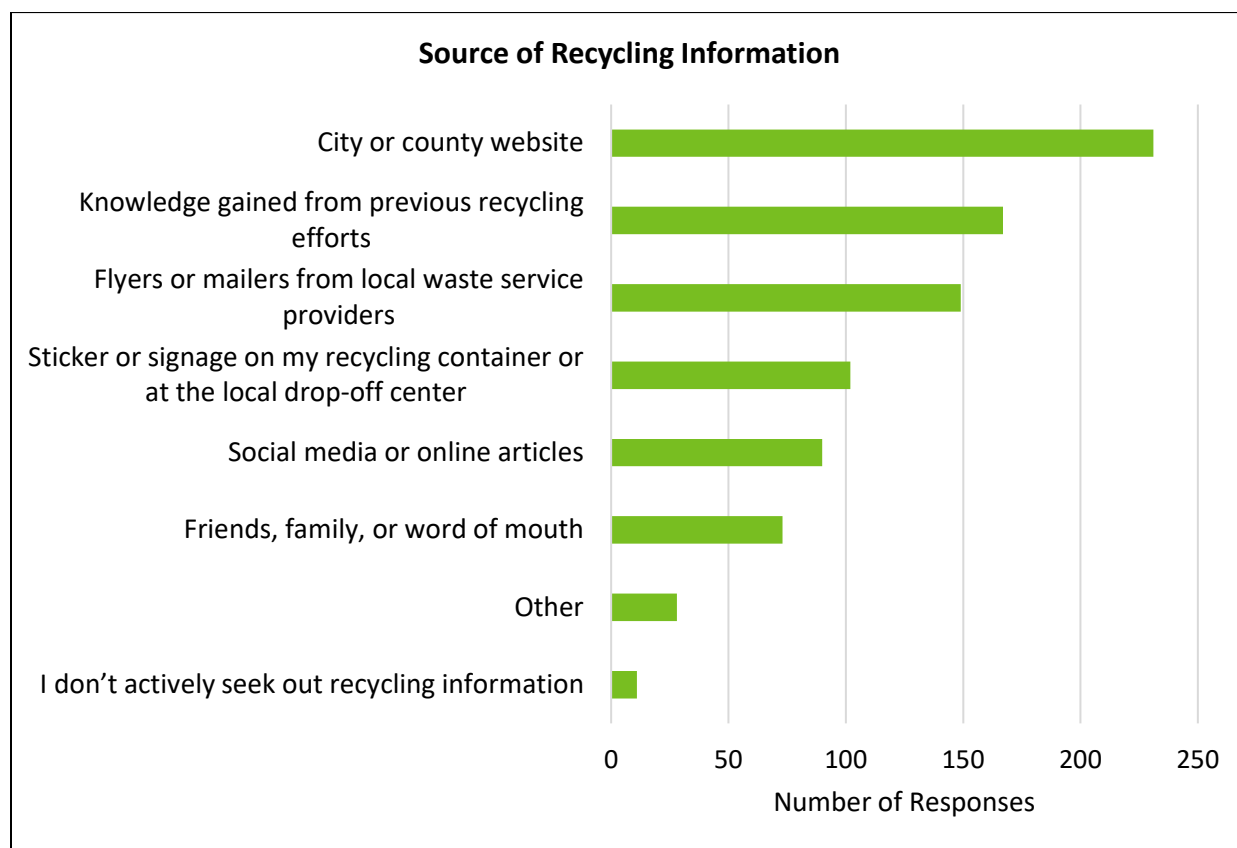


Figure 102. Reported sources of recycling information for residents

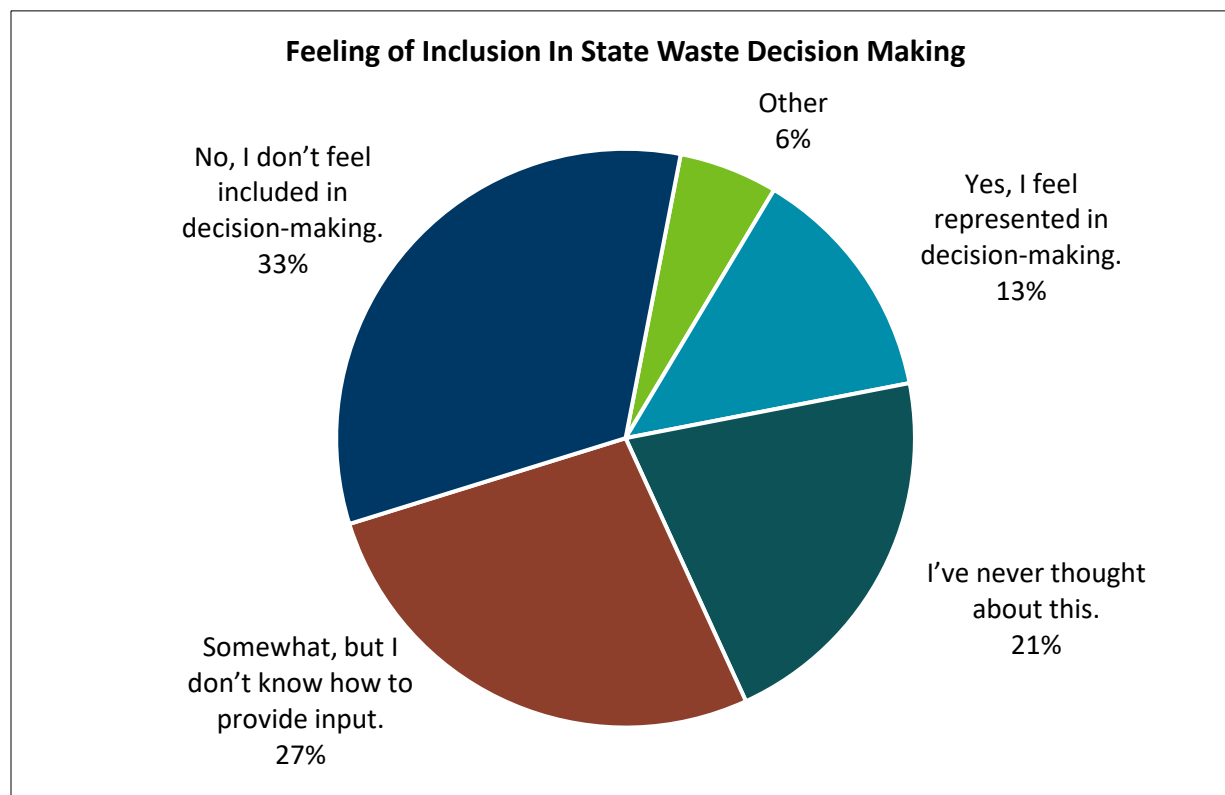


After that, residents were asked their opinion on how they would feel if their local government required resident to sort food scraps into a separate curbside collection bin. 45% of respondents said they would fully support this as they already compost, and 31% said they would support this if the process was easy,

convenient, and well-explained. Only 9% of respondents said they would oppose this change, and 16% said they would have concerns about the cost, convenience, or potential odor.

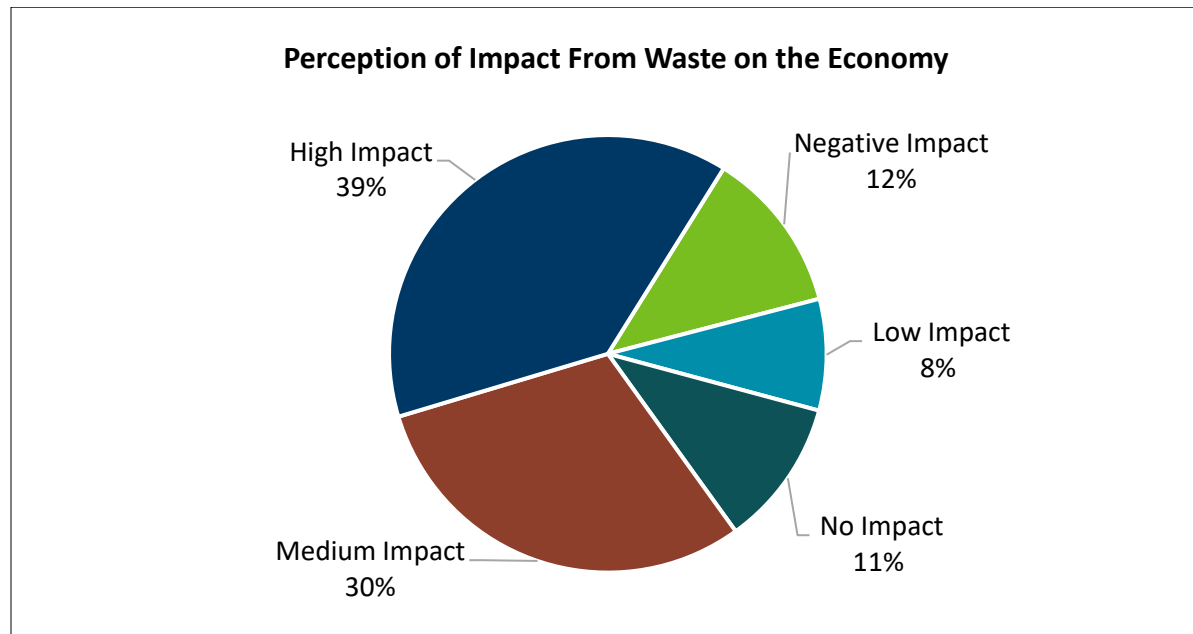
The next question asked if respondents feel as if their concerns about waste and recycling are heard by decision-makers. 33% of respondents said that they do not feel included in decision-making and only 13% of respondents saying that they feel represented in decision-making, as shown below in Figure 103. There were some “other” responses where respondents expressed mixed opinions about inclusion in decision-making. Some felt informed or empowered through their professional roles, direct outreach to officials, or opportunities like this survey, while others felt excluded, unheard, or skeptical about whether feedback influences outcomes. Several noted frustration with specific policies, a lack of transparency or understanding among decision makers, and concerns that community voices are not considered. All “other” responses are found in the Appendix C.3 – Residents.

Figure 103. Perceived level of resident representation in state waste decision-making



Respondents were asked about their perception of how managing waste affects the economy, meaning impacts from revenue from material sales, supporting local jobs, etc. The rank was from negative impact (managing waste costs more money than it provides), low impact, no impact (the economic benefits equal out), medium impact, or high impact (managing waste creates jobs and economic opportunities). 39% of respondents said that managing waste has a high impact on the economy, and 30% said that it has a medium impact (Figure 104).

Figure 104. Resident perceptions of economic impacts from waste management



After that, respondents were asked if they knew where to bring hard-to-recycle materials like mattresses, household hazardous waste, or tires. 45% of respondents said they know exactly where to take them and 45% said they have a general idea but would need to look it up. 9% said they don't know where to dispose of those items, and only 1% said they usually trash these items or leave them at the curb.

Finally, the last question prompted residents to share ideas they have for improving waste reduction and recycling in the state, or if there are specific programs, policies, or resources they think would make a difference. There were over 200 responses to this question. Each response was reviewed and characterized broadly for ease of analysis. Generally, the following themes arose in the respondents' ideas and comments: behavior, collection, education, funding, infrastructure, policy, and reuse. Below, each theme summarizes some of the ideas provided by respondents. The full list of responses is found in Appendix C.3 – Residents.

Behavior

Respondents emphasized that changing individual and community behaviors is important to improving waste management. A common theme was the desire for incentives or rewards that encourage households to reduce their waste, with some pointing out that families who already minimize trash output feel their efforts go unrecognized. Many expressed frustrations with the prevalence of plastic, particularly single-use bags and excessive packaging, noting that consumers often have little choice in avoiding it. Concerns also surfaced about improper use of recycling systems, with residents observing trash mixed into recycling bins and noting the need for clearer signage, more durable labels, or measure to prevent contamination at drop-off sites. Community driven events, such as "amnesty days," were mentioned by a respondent who wrote that these are helpful events where residents can responsibly dispose of a variety of items and help reduce improper disposal or dumping. Some respondents felt that fees for disposing of large items can discourage responsible behavior. Another respondent suggested that recycling and composting education should be more visible in public spaces, such as the state fair, to normalize participation and reach more people.

Collection

Several respondents highlighted frustrations with the mismatch between waste volumes and the frequency of collection services. A common challenge was overflowing recycling bins due to bi-weekly pickup services, with one person explaining, *“My recycling bin...is always overflowing, and Minneapolis only offers bi-weekly pickups. I manage to pack it all in and I refuse to put recyclables in the trash. However, I can imagine there are a lot of other residents who might give up and put recyclables in the trash when they run out of room.”* By contrast, some described trash carts as too large, with respondents noting that they only produce one or two bags per week and struggle to fill even the smallest bin sizes offered. As one put it, *“The smallest size offered here my family cannot fill in four months. Everyone everywhere has massive garbage cans that are overflowing every week.”* Some expressed that less frequent trash collection would be sufficient and could encourage organics diversion, particularly since wasted food is what typically causes odor issues.

This tension extended to broader observations about access and efficiency. Some respondents described wanting more flexibility to reduce their service levels, such as smaller bins or less frequent trash collection, but noted that haulers often refused such requests. Others shared experiences of informally adapting around the system, such as neighbors sharing garbage bins or household canceling trash service entirely while relying on organics and recycling programs. A few also drew attention to inefficiencies in rural or semi-rural areas, where multiple haulers serve the same route each week despite relatively small volume of waste. Overall, the comments point to a clear divide: recycling pickup was often seen as insufficient in frequency while trash and organics collection were viewed as more frequent or bins being bigger than necessary.

Education

Education In Schools and Youth Engagement

A strong theme was the importance of starting waste education early, particularly with children in schools. Some respondents felt this is the stage where habits can best be instilled and where students can influence their families. One person emphasized that schools are the *“only time when people are a captive audience before adults.”* Other respondents suggested making waste education interactive through projects, challenges, or even leadership opportunities that reward student engagement. One respondent also highlighted the value of including Indigenous knowledge and cultural practices in teaching approaches.

Clarity, Consistency, And Accessibility of Information

Many respondents expressed confusion about what can and cannot be recycled, with one saying that they’re a seasoned recycler and still struggle to stay updated. Residents noted that information is often inconsistent across haulers, cities, or counties, which undermines confidence. A couple of respondents reported a lack of signage or communication in multi-family buildings despite the density of people and materials. Suggestions for improvement included clearer bin labeling, more frequent multilingual mailers, and accessible, centralized resources such as a statewide website or app. Others stressed that information must be easy to find and digest to reach the widest audience.

Misinformation On Recycling

Several comments pointed out the prevalence of misinformation about recycling, especially plastics, as barrier to trust. Respondents described hearing national or global stories about plastics ending up overseas or in the ocean and some even expressed doubts about what really happens in Minnesota. As one explained, *“I have doubts about the value of plastics recycling... I’d welcome some reassurance that plastics recycling is beneficial.”* Others urged state and local agencies to take a more active role in combating misleading information and being more transparent about recycling and where materials end up.

Promoting Reduction and Reuse, Not Just Recycling

While recycling education was viewed as important, many respondents said that messaging focuses too heavily on recycling at the expense of waste prevention. Calls were made to shift emphasis toward reducing consumption, reusing materials, and supporting reuse and repair businesses. One comment summed it up, *“I feel like a lot of people focus on recycling but don’t think as much about wanting to promote reduction and reuse as a way to meet zero waste goals.”*

Broad and Inclusive Outreach

Respondents wanted more education to reach a larger range of audiences through several channels: schools, media campaigns, signage, mailers, and community events. There was particular concern for reaching residents outside the metro, within immigrant communities, renters, and those who may not have internet access. A few mentioned the need for ongoing, community-based engagement, such as expanding Recycling Ambassador programs, offering public tours or events, or even running contests to spark creativity around waste reduction.

Infrastructure

Expansion of Organics Infrastructure and Composting

Several respondents noted a desire for expanded or new organics processing, including curbside compost collection, anaerobic digesters, and neighborhood-level facilities. Respondents emphasized the need for curbside pickup of food scraps and yard waste, mentioning that this reduces the barrier to participation. Suggestions included providing compost bins to residents, offering drop-off options in rural areas, educating residents on home-based composting methods, and creating systems where processed compost could be returned to residents or local farms. Some participants also noted that multi-family buildings and large events could benefit from organized composting, ideally supported with educational staff or clear labeling to encourage proper use.

Improved Recycling Access and Convenience

Many comments focused on increasing access to curbside recycling and public recycling locations. Respondents called for more bins in neighborhoods, public spaces, gas stations, and parks. Accessibility in rural areas was highlighted as a significant challenge, with suggestions for multiple, conveniently located drop-off points and extended hours of operation. One respondent said, *“Greater MN needs access to curbside recycling in the rural communities, if we had it, people would use it.”* Equitable access was repeatedly mentioned. Respondents highlighted disparities between urban and rural areas, single-family homes and apartments, and wealthier versus lower-income communities. They recommended universal curbside collection where feasible, ensuring services are available to all residents and providing free or low-cost bins.

Hard-To-Recycle and Bulky Items

A recurring concern was the lack of convenient options for bulky, hazardous, or specialty items. Respondents mentioned electronics, batteries, Styrofoam, mattresses, concrete, and industrial waste as items that are difficult to dispose of and often end up in landfills or illegally dumped. One respondent commented that bulky item disposal can be inaccessible and suggest that *“it’d be nice if we were offered a time or two in the year for big pick ups... Not everyone has the means or vehicle to haul big items to recycling locations, especially when recycling locations are usually not open on the weekends and operate during regular business hours.”*

Policy

Extended Producer Responsibility and Manufacturer Accountability

A dominant theme in the responses around policy was the desire to shift the responsibility for waste management from consumers to manufacturers. Respondents repeatedly emphasized that companies

should be required to design products and packaging for reuse, recyclability, or compostability. Suggestions included mandatory take-back programs and end of life disposal plans. One respondent said, *“There should be a plastic/recycling/hazardous waste tax built in to the cost of production and recycling burden should not be an end result responsibility placed on to the consumer.”*

Plastic and Single-Use Material Reduction

Respondents advocated for broad bans or restrictions on single-use plastics, including bags, straws, Styrofoam, and disposable food ware. Policies such as state-wide fees for plastic bags, reusable to-go packaging, and regulations requiring items to be compostable were also highlighted. One respondent strongly noted, *“Enforce the damn plastic ban already!”* Other responses suggested using labeling requirements for disposables.

Encouraging Behavior Change

Many comments called for policies that provide financial incentives for sustainable behavior and disincentives for waste. Ideas included refundable deposits on electronics, furniture, appliances, and beverage containers. There was also recognition that waste reduction often requires time or upfront investment, and economic security measures such as guaranteed income, paid leave, and rebates for repair could enable individuals to adopt more sustainable practices. Increased landfill disposal fees and higher costs for non-recyclable packaging were suggested as mechanisms to shift behavior toward waste reduction.

Standardized Infrastructure and Education

Some respondents highlighted the need to strengthen infrastructure and provide clearer guidance to residents. A number of respondents stressed that recycling and organics systems in Minnesota are inconsistent and confusing, even within the same city. One respondent said, *“Most people like a convenient method of managing waste and it’s difficult when you have to look up every thing from where compost goes, where do battery’s go, where do large items go, and each place is different.”* Others pointed out that signage, labeling, and accepted materials vary widely between municipalities, haulers, and drop-off sites. Many emphasized that residents should not bear the burden of complex recycling systems.

Right To Repair, Product Stewardship, And Legislative Alignment

There were repeated comments encouraging right-to-repair laws, improving product stewardship requirements, and ensuring upcoming packaging legislation is upheld and not weakened. They suggested aligning multiple policies so there is coordinated enforcement, consistent standards, and integration of economic and educational measures.

Reuse

The responses related to reuse called for expanding access to repair, redistribution, and refill options, as well as education and cultural shifts around fixing and reusing items, as summarized by one respondent, *“More right to repair laws...More CLASSES! Teach people (for free) how to fix things, make it part of the culture.”* Other respondents mentioned the barriers they face in donating or repurposing items, noting that thrift stores often cannot accept larger or slightly damaged goods, and repair services are often unavailable. One person suggested using centralized facilities or public programs for swapping, refurbishing, and redistributing usable items. Refillable goods and bulk shopping were also a priority, with one respondent noting the frustration of having *“no alternative...so I have to buy all the plastic I have to buy because there’s no where to simply buy the goods using a refillable container.”* Education and workshops were also included as ways to support reuse.

Appendix D – Survey Responses

Appendix D.1 - County & City/Town Representatives

What is the most significant barrier to increasing recycling rates in your service area? - Other (please specify):

Responses relate to organics recycling, recovery rates for traditional recyclables have stagnated-which we are working to address with a new county SW ordinance.

education and engagement

Language and cultural barriers

We would be more effective if extended producer responsibility was more developed in Minnesota

Low volume

High renter turnover and no method of being informed when new renters move in

Lack of hauler requirements and outdated solid waste ordinances (with lack of specified requirements).

State contracted collectors that are out of state. (Ewaste and Empty Pesticide Containers) Increasing mandates to understaffed County SW Depts.

There is no volume to residential recycling

lack of organized/mandatory rural MSW collection. This leads to high contamination rates for recycling efforts.

Inconsistency in reporting, policy gap in making it a stronger requirement (there's no consequences for not recycling)

Small rural population spread over a large geographic area.

The most significant barrier to increasing recycling rates in our service area is a combination of confusion about what materials are recyclable, a lack of motivation or care among some residents, and skepticism about whether recycling is actually effective. Many people are unsure about which items belong in the recycling bin, while others feel discouraged by economic challenges or concerns that recyclables may not truly be recycled.

Money

While data suggests participation rates in recycling programs and services are reasonably high, even among participating households there is a wide variety of full diversion of recyclable materials for a host of reasons—awareness, commitment, competing priorities in residents’ lives, confusion about recyclability of some materials. This dynamic of uneven recycling diversion is even more pronounced with commercial entities, despite years of technical assistance and grant funding provided to this sector, as well as a significant incentive to divert waste from disposal with a 53% County Environmental Charge added to the cost of commercial trash services. Also, one area where the recycling infrastructure—and thus convenient access to recycling opportunities—as well as the economics of disposal versus recycling remains a significant challenge is the diversion of bulky items for reuse and recycling (e.g. mattresses, furniture and the like).

cost for businesses, residents not caring

Please list any key partnerships and describe their role in supporting waste and recycling initiatives.

Response	County
The county contracts with Minnesota Waste Wise to conduct technical assistance and help business apply for grant funding through our commercial entity grant program.	Anoka County
Multi-family recycling program, Business recycling program, School recycling program are all run through the county with city support as needed	Dakota County
Community Solid Waste Abatement Program (SCORE funding to cities) School recycling program Business recycling grant program Multi-family recycling grant program	Dakota County
Ramsey/Washington R & E Center offers a Biz Recycling Program for commercial and multi-family units. I think Washington County partners with a School Advisory Committee.	Washington County
A local school collects lunch waste for farmer.	Washington County
Second Chance Recycling--Mattress Collection, Washington County Public Health & Environment-Recycling Grants1	Washington County
Local schools. Active recycling programs in-house.	Clearwater County
Owatonna Community Education - Partner for Day Trips for Residents & The Enviro Show for County & Statewide attendees to attend! Vendors come from far and wide sharing their sustainable initiatives.	Steele County
Tri County Solid Waste City of St. Cloud ISD 742	Stearns County
We provide tours to 5th grade students and presentations for multiple classes throughout the year.	Olmsted County
schools, medical institutions, cities, and regional partnerships with other counties	Otter Tail County
Bemidji State University	Beltrami County
Triton School District - we go 2-3 times per year to a HS classroom for a presentation.	Dodge County
Hennepin County is a major partner in supporting waste and recycling initiatives via educational materials, convening of other organizations, and sharing information on the most up to date policies and procedures.	Hennepin County
Contact Hennepin County - question specifies 'does the county have'...	Hennepin County
ReuseMN partnership to set up fix-it clinics/swap events.	Douglas County, Pope County
Schools	Houston County
Collaborate household hazardous waste collections with surrounding counties	Wabasha County
Tri-County Solid Waste	Stearns County
We contract with a recycling contractor who is responsible for developing and maintaining those partnerships	NA
Local nature center provides recycling education to schools.	Jackson County
The County works with businesses to provide recycling containers thru our recycling contract and subsidizes 50% of the cost	Lincoln County
Creekside Soils-reciprocal support for composting & recycling/HW education. District Schools-we fund their recycling collection services & provide education & technical assistance when requested. Dem Con Recycling-recycling messaging and contamination updates.	McLeod County
Second Chance Recycling	Washington County

Response	County
Municipalities, schools, community groups, Ramsey/Washington Recycling and Energy, Partnership on Waste & Energy	Washington County
mcneilus, Restore, Furnishing Hope	Dodge County
The County partners with the City of Cologne, City of Mayer, and the City of Norwood to offer recycling drop-off sites in the rural areas of Carver County. The County also offers grant funding for a wide variety of waste-related initiatives to schools, businesses, and non-profit organizations.	Carver County
Sustainable Stillwater, Biz Recycling	Washington County
Scott County has a partnership with CLIMB Theater to provide recycling education to schools who in turn are a partner in the recycling education of students in the County. We also have a contract with Dem-Con and their Green Grades Program who provides recycling education to residents and schools. We also contract with MN Waste Wise to provide recycling education to businesses and multi-family in Scott County. We also provide funding to cities and solid waste facilities to host organics collection sites throughout the County.	Scott County
Our Green Partners grants program has multiple partners as does our Plastics Free Challenge, Salvage Crawl, Choose to Reuse, Trash or Cash, Business Waste Reduction Grants and the Food Waste Challenge	Hennepin County
BizRecycling - recycling help for businesses, Ramsey County Food Scraps - food scraps dumpster	Ramsey County
schools food waste	Otter Tail County
We train and work with Recycling Ambassador volunteers to implement waste reduction/recycling in community and help educate. partner and provide funding to all our suburban cities to improve recycling, and have partnerships with our schools, multi-unit residential properties and businesses for waste reduction and recycling infrastructure improvements and to provide education to residents/employees/students. Our county ordinance makes it illegal for residents, schools, businesses, and government entities to throw designated materials (paper, cardboard, cartons, metal cans and bottles, plastic containers and jugs 1,2 and 5) in the trash, and haulers must collect the designated list of recyclables. Having a basic standardized list of recyclables has simplified messaging across our communities and reduced confusion about what can be recycled. We have MANY other partnerships - described in our annual report to the MPCA.	Dakota County
• Ramsey/Washington Recycling & Energy--coordination of many activities and programs through joint powers authority with Washington County to meet both counties' solid waste management plan goals and objectives, including: technical assistance and grant programs for businesses, non-profit organizations, farmers markets and other entities; public education and outreach; collection services; partnerships with a wide range of community and business organizations and municipalities to reduce, reuse, recycle and compost materials generated by both residents and non-residential entities; processing of MSW from all generators in both counties to recover energy, recyclables and organics. Some details can be seen in R&E's Annual Report for 2024 at https://recyclingandenergy.org/2024-annual-report/. • Partnership on Waste and Energy--Hennepin, Ramsey and Washington counties collaborate in areas of waste and energy management, including legislation and policy development, communication and outreach, planning and evaluation of waste processing technologies. • Partnerships with all municipalities in the county on a variety of waste reduction, reuse, recycling and public education efforts and a pass-through of nearly all county SCORE grant funding to municipalities for these purposes, and, with several municipalities, partnerships to provide food scraps drop-off services. • Partnerships with several public school districts and public charter schools on technical	Ramsey County

Response	County
assistance and grants for equipment, supplies and other resources to reduce and recycle waste. Partnerships with a wide variety of community, neighborhood, religious and service organizations reaching a diverse range of audiences through presentations, event tabling and other outreach efforts, some involving community members trained through the county's Recycling Ambassadors program to provide peer-to-peer information to community members.	

If there are other methods of support that would be helpful for you regarding waste and recycling operations in your jurisdiction, share your thoughts here.

Response	County
We need to have a better understanding of the types of waste generated at commercial entities vs. the residential sector. We have estimates on how many tons of organics remain in the waste stream to capture; however, we do not have a good handle on which sector is generating organics in the largest quantities. Having that information would help us target limited staff resources.	Anoka County
Guidance for cities considering a switch to organized collection	Dakota County
Establishing incentives for residents to want to recycle. Reduce collection costs, make it easier. . .	Washington County
Increase the SCORE funding so that we can afford the recycling were are doing now. Distance and small population make recycling very difficult in our area. It just costs so much that it really hurts.	Pennington County
Funding is needed more than technical assistance. Information is out there but having resources (time & \$\$) to implement is the biggest challenge. 100% of SW tax needs to go back to SW programs as a starting point.	Rice County
The most helpful implementation that could be provided (in no particular order) would be: 1) Provide consistent markets for and transparency on recyclable materials, to help assure the public that effort spent to divert materials from landfills or WTE are worthwhile. 2) Invest in local capacity for sortation, separation, and education. We can only get the recycling rate so high through education alone, especially with increasingly complex and varied products that require management at specialized facilities. 3) Establish consistent guidelines for front-end product development, labeling, and product stewardship, to ensure that engagement with more beneficial end of life management strategies (reuse, recycling) is simple and well-supported in the long-term.	Blue Earth County
More funding to support local city operated recycling drop off centers.	Anoka County
Statewide education efforts to improve overall public knowledge/attitudes/practices in the home (people are stupid - they need to be trained).	Clearwater County
Low staff = less ability do support waste and recycling programs.	Steele County
All the SCORE money.	Olmsted County
Advocating for extended producer responsibility. Also, when appropriate, trusting local units of government to do the best thing for their community.	Otter Tail County
improving rural recycling infrastructure. increased curbside pickup opportunities. Reduce burdens on new commercial compost sites to allow rural and underfunded communities to start composting operations without spending millions on site development and engineering.	
We have haulers that don't really want to offer recycling at the western parts of the county because it is not economical for them to run 2 trucks in the rural areas. We do	Dodge County

Response	County
have recycling bins at each of the township halls but we do get more contamination that way also.	
This survey was confusing. Unsure if intended for residential, commercial, both; unsure if 'recycling access' referred to single-sort or drop-off, etc.	Hennepin County
county needs to open compost site asap	Washington County
More grants for Counties to start large scale composting and campus like transfer stations.	Itasca County
The State doesn't seem to do a very good job at supporting recycling collectors within the State. This often means options for recycling items that aren't collected in the single-sort containers are few and far between. For example, in Jackson Co, there is a lot of agricultural plastic which goes unrecycled due to no collectors serving our area.	Jackson County
I think guidance or assistance or a statewide campaign that counties can tap into with education, as I am one person department, its very tough to do all. I think developing a statewide campaign would be very beneficial with education, outreach and provide those materials to counties to use. I think having workshops or classes on how to reach out to businesses for year end reporting for SCORE.	Wright County
Statewide consistent messaging for single-sort programs (residential recycling services) should be the first step. Having haulers report for the previous year-when local licensures are required for that reporting year, puts the counties at a disadvantage. We discover unlicensed haulers after the fact and have to chase down their business contacts during the busy reporting window. If the MPCA wants to track haulers in Re-Trac, then they should have to enter their business info and known counties of collection origin, during the first quarter of the new year, to then complete and adjust during the reporting window at the beginning of the following year.	McLeod County
Stronger policy on recycling requirements	Washington County
Better knowledge of end markets and how do smaller hauling companies compete with larger quantity haulers when trying to market products.	Chippewa County
More recycling education recourses for LGUs developed corroboratively between counties and the state, specifically for regions, like the TCMA who may be ahead of outstate MN with regards to recycling infrastructure and opportunities.	Scott County
More communication programs on reducing consumption to reduce waste. Package-free alternatives.	Ramsey County
Help with recycling items that are not accepted through curbside or drop site locations such as bulky plastics	Lyon County, Yellow Medicine County
More SCORE and other state funding to offset large county funding sources used to support required local recycling education and programs. Helpful if MPCA would help improve the quality of the ReTrac data (improve accuracy by comparing facility and hauler reports, etc.) which is used for policy decisions. More frequent state outreach to combat misinformation that "recycling is broke" that has been in the media for years.	Dakota County
• Advocacy at the legislature for more SCORE and other grant funding to counties, cities and community organizations for reduction, reuse, recycling and organics diversion. • Improvements to recycling data collection systems and methodologies, including enforcement of state law requiring hauler/facility reporting (115A.93), and greater assistance to reporting entities on measurement and reporting methodologies. • MPCA enforcement of state law on business recycling requirements (115A.151). • Implement Packaging Waste and Cost Reduction Act (EPR for packaging/paper products law, 115A.144 etc.) with strong goals and requirements on producers, and enforce the requirement for packaging to be reusable, recyclable or compostable by 2032 with minimal exemptions.	Ramsey County

Response	County
• Develop regulatory approaches and protocols that facilitate non-mechanical recycling solutions for materials that are not easily recycled through traditional mechanical recycling processes, and support legislative action to support development of those solutions. • Support development of incentives for recycling, motivation of recycling behaviors, confidence in recycling systems and understanding of the value of recycling to our environment and the economy. • Implement incentives (or perhaps regulations) for larger firms, particularly in manufacturing, to enter into resource management contracts that go beyond traditional waste and recycling collection services and incent service providers to maximize waste reduction, reuse and recycling while creating disincentives for service providers to manage a customer's solid waste through waste-to-energy or especially landfilling.	

Appendix D.2 – Environmental & Social Organizations

Why do you believe some communities are more impacted than others?

Location of facilities and access
Waste management is expensive!
Waste facilities are almost always cited in lower-income areas. You won't see them wedged into many suburbs, at least not close to housing. Redlining led to communities of colors only being able to buy or live in certain areas that had industrial facilities. Its legacy remains to this day.
Many rural communities do not have municipal waste or recycling options at all. County facilities offer drop off but are often 20 or more miles away.
this is largely true throughout the world and the US so I see no reason it would not be true in MN
A combination of factors, including pre-existing vulnerabilities and poor infrastructure, location, and systemic inequalities.
Some people know how to keep their areas neat.
Rural communities across Minnesota do not have reliable and economical access to recycling, reuse, and composting options. In addition, they may be located far from a waste disposal site which increases their costs.
not all communities have access to composting and recycling, especially for larger amounts
Most are sited in low-income and communities of color.
Communities where residents are wealthier have resources to fight projects in their neighborhoods.
urban poor
Historic zoning targeting low-income and/or communities of color.
n/a
Costs, lack of education, lack of care for minorities
That's the nature of this - it's a NIMBY and yet it has to be located in someone's backyard. Whether that's transfer stations, recycling centers, landfills, composting, etc. Rural communities also have less access and potentially less beneficial tactics to dealing with their waste (burn, litter, wishcycle, etc).

Are there any existing partnerships or networks that play a big role in your organization's mission? - Yes (please specify):

Trade associations
Reuse MN
County Environmental Services and Waste Management Departments, Schools, Local Businesses & non-profit organizations
Trump
MN GreenStep Cities & Tribal Nations, MN Technical Assistance Collaborative, League of MN Cities, Association of MN Counties, Regional Development Orgs
MN EJ Table
support from Dakota County recycling program
zero waste coalition
County governments (due to their role in solid waste management), Developers
Other local and state government
Our partners in the waste reduction landscape are: Waste Partners, Cass Co. Environmental Services, ReUseMN, REC, and more local partners depending on the project, program, etc.

If your organization received funding to improve waste management and recycling programs, how would it be used? (Select up to 3) - Other (please specify):

all of this focused on REUSE. equipment & logistics are needed to build reuse systems; policy changes are needed to support reuse
helping other organizations reduce food waste by leaning into food recovery
Advocate for reuse/refill pilot.
Policy-wise, it would be focused on helping local municipalities develop a robust enough deconstruction ecosystem to made a deconstruction ordinance/incentive program realistic.

Appendix D.3 – Residents

Zip Codes	Count
55411	7
55304	5
55303	5
55105	5
55901	4
55449	4
55418	4
55113	4
56474	3
55448	3
55413	3
55408	3
55407	3
55406	3
55347	3
55112	3
55082	3
56601	2
56401	2
56007	2
55811	2
55806	2
55779	2
55744	2
55446	2
55433	2
55426	2
55417	2
55410	2
55404	2
55364	2
55320	2
55319	2
55309	2
55129	2
55119	2
55117	2
55116	2
55110	2
55016	2

Zip Codes	Count
55007	2
85284*	1
56572	1
56554	1
56537	1
56501	1
56482	1
56472	1
56470	1
56468	1
56467	1
56448	1
56437	1
56433	1
56347	1
56342	1
56332	1
56241	1
56201	1
56175	1
56142	1
56071	1
56057	1
56031	1
55991	1
55963	1
55952	1
55923	1
55912	1
55906	1
55904	1
55805	1
55804	1
55760	1
55750	1
55731	1
55616	1
55612	1
55447	1
55443	1
55442	1
55439	1

Zip Codes	Count
55432	1
55429	1
55428	1
55427	1
55426-3851	1
55421	1
55419	1
55414	1
55412	1
55409	1
55403	1
55398	1
55391	1
55386	1
55379	1
55373	1
55372	1
55369	1
55360	1
55356	1
55352	1
55349	1
55344	1
55343	1
55322	1
55316	1
55308	1
55306	1
55130	1
55128	1
55127	1
55126	1
55125	1
55118	1
55115	1
55109	1
55107	1
55106	1
55104	1
55092	1
55077	1
55076	1

Zip Codes	Count
55073	1
55070	1
55068	1
55066	1
55057	1
55051	1
55047	1
55045	1
55025	1
55024	1
55014	1
55008	1
55005	1

**Note: this zip code is located outside of Minnesota. While this may indicate that the respondent lives elsewhere or entered an alternate location, the response has been retained to account for the possibility of temporary residents or intentional miscoding rather than exclusion of a response (as the question was optional).*

Where do you typically get information about how to recycle properly? (Select that all apply) - Other (please specify):

I work in the industry as a consultant

I'm an EHS Specialist

When I moved into this house recently, I received a very helpful brochure from the city of Minneapolis on what can and can't go in the recycling, organics, etc. I keep that handy and reference it regularly. I also joined the Minneapolis Recycles facebook page. And I recently booked a tour to the Eureka Recycling facility.

Hauler website

How2Recycle labels, my hauler

Profession

state

Recycling ambassador class

Waste service/recycling app

Public radio

Waste Provider Website

In person community educators

MN Pollution Agency

Library

City & County mailed info

Annual guidance booklet from my city recycling program

Tour of Eureka Recycling sort facility.

Betterbin App for my county

Community Recycling Ambassador program

Reliable online information; not social media

I learned a lot during my Recycling Ambassador training

City paper mail

Teachers at school

Park Pages column , BP HRG app

Hauler

I am a Recycling Ambassador

RAM, MNCC, US Composting council

Do you feel like your concerns about waste and recycling are heard by decision-makers? - Other (please specify):

I have contacted my elected officials on waste management issues. I realize that all my representatives are well versed in waste issues but still sent them emails on issues I care about just to give them something to think about.

This is the first time I've been asked for feedback, and I only know this survey exists because I went out of my way to sign up for MPCA emails.

I work in the recycling industry (my org is responding separately) so I feel much more informed and capable than most, but I also live in a multi-family building and at home I feel like there's little I can do to change how my building recycles.

share the decision making

I think the decision makers in Minnesota do whatever they want, regardless of what anyone else thinks or needs.

They now charge everyone for organics even if you do your own. Not right

I'm new to Minnesota and haven't been here long enough to know.

Survey gives us an opportunity.

I believe the human waste climate change agenda is a hoax and no

I think it's ridiculous that residents are being charged for Organics Recycling. Only 1 person on our whole street is doing it. People don't have time to deal with that. People talk about keeping the bags in the freezer in a coffee can. Not happening.

just "somewhat"

Not included, never asked, and never listened to.

Somewhat but I have not spent a lot of time influencing decision makers.

I think some local political decision makers don't understand waste management and make decisions that are not fully understood and may have more negative environmental consequences.

I don't think decision makers are focused enough on stopping the flow of plastics into our environment

I don't think those making the decisions are thinking about it.

Resident but work for City - resident's will probably answer this as no - but they don't understand timelines from receiving feedback to implementing / developing new programs/projects.

The people selling there products don't use the wright recycling numbers 1,2&5

I think we are too loose and much of recycling gets burned anyway as sometimes the transportation costs are too high. We should make changes before we are forced to by our garbage centers filling up too fast.

What ideas do you have for improving waste reduction and recycling in our state? Are there specific programs, policies, or resources you think would make a difference?

Response	County
Ensuring that every business has sustainability employees	Ramsey County
Fund programs that make waste reduction and recycling easy - not opt in	Ramsey County Washington County
Education needs to start in schools with kids. Incorporating recycling into education instills lifelong skills that can be practiced in all aspects of life. Only time when people are a captive audience before adults.	Dakota County
I feel like a lot of people focus on recycling but don't think as much about wanting to promote reduction and reuse as a way to meet zero waste goals	Ramsey County Washington County
Increase the number of compost and anaerobic digester facilities. Reduce the amount of red tape that impedes these efforts	Scott County
Make used goods tax free like clothing and food! There is immense value in landfill abatement that may come close to negating or exceeding the tax base loss from used goods. Expand and support rebates for repair.	Hennepin County
compost at large events, like Vikings games. Have staffers there to educate people at every trash bin and compost bin	Hennepin County
I am glad to know that the Waste Packaging and Cost Reduction Act passed the Minnesota legislature. We need to have the manufactures of food packaging to take an active role in managing the end of life of these materials and not externalize the costs of managing their waste. Also I hope the expanded e-waste bill in this legislation (2025) passes for the same reason as they need to take active role in managing e-waste at the end of life.	Dakota County
Compost collection should be offered. Information should be made more accessible to the public.	Olmsted County
Focus more on waste reduction efforts!	Ramsey County
1) Economic policies such as guaranteed income, paid leave, and other programs that provide economic security for people would go a long way towards providing people the time/capacity to do things that are less wasteful but require more time and energy. Reducing waste can sometimes align with cheaper options (e.g. mending clothes instead of buying new clothes). But oftentimes, reducing waste is something that necessitates more time//planning/money (e.g. investing in reusable containers that you bring to the store with you; making a specific trip to a specialty bulk store; buying raw bulk ingredients that will require preparation instead of a ready to eat meal). 2) Disposable servingware should be required to be labeled as plastic or compostable as applicable; there is so much stuff that is hard to identify and will end up getting "wish-composted" (think wish-cycling) if composting options become more prevalent without additional education and regulation to manage it.	Hennepin County
More, and more accessible, reuse centers. More state laws like EPR aimed at reducing waste	Ramsey County

Response	County
expanded organics collection would drastically increase the amount of organics being collected. Currently, my county does not offer this and I cannot wait for the day that they do. Also doing more education on how recycling works (because I know it does but there is SO MUCH misinformation and skepticism out there) I think would greatly help increase the amount of people participating.	Dakota County
Continue to focus on optimizing the handling and management of the waste generated by businesses, restaurants, cafeterias, etc. as a first priority as compared to efforts to address individual household waste management.	Hennepin County
Continue to build upon right to repair legislation, product stewardship requirements, packaging laws, bag bans, etc.	Ramsey County
Lower the bar for participation. Have drop off bins for textile recycling, plastic wrap/bag recycling, composting, etc.	Scott County
More advertisement of it, how to, what is recyclable, what are the benefits, ect.	Benton County
	Mille Lacs County
	Sherburne County
I have a Mill food recycler at home, and we use it to manage 100% of our food waste. It makes the chore easy and not smelly, and I'm more conscious about wasting less. Because the device dehydrates my food, my organics bin is barely full and not smelly... and I could definitely live with less frequent collection (monthly would be sufficient). If everybody could get access to a device like this, I think the city would see a tremendous increase in organics recycling participation. But the device is expensive, and so I would love to see state rebates offered to make it more accessible... similar to how the state offered eBike rebates last year. My recycling bin, on the other hand, is always overflowing, and Minneapolis only offers bi-weekly pickups. I manage to pack it all in and I refuse to put recyclables in the trash. However, I can imagine there are a lot of other residents who might give up and put recyclables in the trash when they run out of room. Regarding trash, my trash can has only one or two bags in it weekly (and I have 2 kids in diapers!). My trash bin is huge (we used to live in a city out of state where everybody had a 15-gallon trash cart and it was totally manageable). We could definitely live with every-other-week collection of our current large trash cart... and it would probably incentivize residents to start diverting their organics (which make the trash smelly in the first place). Lastly, I subscribe to Ridwell for soft plastics and fabric recycling. Their service has been wonderful, and helps to significantly reduce the volume of trash. I bet Ridwell also helps drive reduced plastic film contamination in the Minneapolis recycling stream. Again, it would be great if the city of Minneapolis more formally endorsed or subsidized a program like Ridwell for lower income families who might not otherwise be able to afford it.	Hennepin County
Allowing for less pick up of curbside trash and organics (recycling is bi-weekly but trash/organics have no option for less frequency). More labeling of the environmental harm that products have. More affordable and accessible options	Hennepin County

Response	County
for buying bulk and reuse - and widely communicating this. Bans on packaging/requirement for recyclable or compostable packaging on all products.	
I just recently learned about a place that deconstructs mattresses. While I feel like I look up how to dispose of products, it can be difficult to find better ways to dispose of items. Since this information is always changing, it is difficult to know if the information on the various websites is last updated. It would be great if there was a 1 stop shop - I know there are a couple resources out there, but I feel like when I reach out to some of the places on these lists, the information I got from the initial website isn't always updated.	Hennepin County
Composting yard and food waste is a big miss. Challenging in rural areas like mine, because bears and raccoons will get into any food waste bin on the street waiting for pickup. My neighbors all burn everything. We try to dispose of waste appropriately but it seems like a lot of services are designed just for city-dwellers. Have to drive 16 miles to Forest Lake to dispose of hazardous waste or nonstandard recyclables like molded styrofoam (the stuff insulin is shipped in). I'd like to see a statewide plan that accommodates rural needs as well as urban, and recognizes that they are not the same and need different tools and policies.	Washington County
Make disposal of furniture, electronics and appliances free or by refundable deposit. SO PEOPLE DON'T DUMP THEM IN THE RURAL AREA WHERE WE LIVE. THIS REALLY PISSES ME OFF.	Kandiyohi County
Greater MN needs access to curbside recycling in the rural communities, if we had it, people would use it. I think food waste is not a needed item in rural MN as many of us compost/utilize chickens or hogs for disposal of those items.	Todd County Wadena County
Curbside composting pickup in my area would be fantastic. I know it's available, but it hasn't expanded to my zip code yet. Also, what about curbside battery recycling. I think a lot of household batteries end up in the garbage. Possibly more or better communication that LED lamps should be recycled due to the small, printed circuit board inside of them. I work in the industry and most employees have no idea about their contents. I'm sure the general homeowner doesn't know either. Energy efficiency is promoted, but not how to manage them afterwards.	Ramsey County
I vermicompost inside my house for vegetable scraps and such. Perhaps, this is another alternative for some people that haven't heard of it.	Anoka County
Can't wait for curbside organics collection to be everywhere in Ramsey County. Looking forward to it coming to my city. I did a drop-off program for a while, but it got to be a lot with other family, work and home responsibilities.	Ramsey County
I think the messaging needs to scare people who don't believe in climate change (like the old cigarette commercials). Scare people about rising insurance costs, cancer risks, heating days, etc. People need to wake up!	Dakota County
I know from my work that a lot is being done to make recycling info available and accessible for residents, although it's a lot easier in the metro area than in the rest of the state. I think national ad campaigns (like that irritating Plastic Recycling Is A Myth billboard) and news stories are the most visible form of recycling information to many residents, and that info is often not accurate to what we are doing locally	Hennepin County

Response	County
and how recycling works in our state. State and local governments are not flashy - they are not built to combat this type of misinformation, which is high-profile, targeted, and memorable even when it is wrong. I would support budget being spent on using similar tactics to combat misinformation. Anti-litter and environmental ad campaigns have been successful in the past (e.g., give a hoot, don't pollute); they could be again!	
I believe that with the costs of recycling electronics the state should implement a fee on a purchase of new electronics that can be refunded when brought back to the store or origin. much like automotive batteries.	Wadena County
Greater Minnesota is underrepresented in state policies; just because there are lower quantities, it does not mean that material can't be recycled or reused or that the waste material has less contaminants. Also, type of waste varies significantly by geographic areas that is not properly considered in developing programs and policies. In addition, without state support, there are no incentives, financially or otherwise, to divert waste from land disposal in greater Minnesota.	Sherburne County
More Waste to energy facilities to reduce the amount of waste going into landfills.	Sherburne County
incentize behaviors, circular solutions and markets for waste locally.	Washington County
It's hard to get a smaller garbage can. The default is something my family cannot fill in a year. The smallest size offered here my family cannot fill in four months. Everyone everywhere has massive garbage cans that are overflowing every week. If the default was a small size, I think people would realize massive amounts of waste isn't the norm or something to strive for.	Washington County
Expand to multi-family housing, mandate organized collection	Hennepin County
Neighborhood anaerobic digesters for methane generation - keep natural gas in the ground. Expanded recycling of multi-layer plastic and plastic film instead of for-profit companies like Ridwell.	Hennepin County
Not pre-maturely closing the HERC, which is an effective way to handle city waste if permitted properly and fitted with adequate emission control equipment. Sending all of the municipal trash/solid waste to a landfill instead is not a good alternative or long-term solution.	Hennepin County
improve the infrastructure for processing organics waste, especially in areas with smaller population	Ramsey County
Continue to expand the collection of FOOD WASTE to divert from landfill, with the use of certified compostable products.	Anoka County
Education, training, legislation, community outreach, promote reuse & repair businesses, promote manufacturer's responsibility in product life cycles and disposal.	Ramsey County
Put cameras at recycling drop off sites to discourage abuse.	Otter Tail County
More programs like Ridwell to help reduce packing waste, smaller options for garbage if you signed up for curbside organics	Hennepin County

Response	County
Curbside composting everywhere and better access for multi-family bldgs.	Hennepin County
I just want to know we're doing something about plastic waste	Hennepin County
A new governor would help as a start.	Blue Earth County
Allow storage of garbage and recycling bins outside without screening.	Hennepin County
Bottle deposits	Washington County
Making organic recycling available in more locations.	Anoka County
Weekly recycling pickup. We frequently put recyclables in with garbage as the recycle bin is full.	Crow Wing County
Curbside Organics would be great.	Ramsey County
Use less plastic, especially the plastic bags.	Wright County
More consistent coverage via general media about the impact, benefits, and small things each resident can do to reduce waste. It still boggles my mind when I see people toss an aluminum can into the garbage. Some people are uninformed or don't care - they need to!	Hennepin County
A residential yard waste service would be welcomed.	Olmsted County
I think we need to do a better job of managing the data collected within the state and use that to drive policy and decisions about how to manage waste within the state.	Ramsey County
I think the biggest benefit would be statewide policies that cut down on single-use plastics. Other states have made the use of plastic bags in grocery stores illegal OR have required stores to charge for each bag. It massively cuts down on the consumption of single-use plastic bags.	Nicollet County
More information on what to recycle and ways to reduce waste in written form, online(not just Facebook), and commercials.	St. Louis County
I think disposing of tech items, furniture, etc. is too expensive. Our city cleanup days require ME to unload items. I can't. Assistance for seniors.	Rice County
For years I repeatedly asked our garbage company if we could change to an every other week garbage pick-up. I was always told, "no, they only offer weekly". Over 1 year ago we cancelled our garbage service completely and we don't miss it. 90% of our waste is compostable and we participate in the organics recycling program provided by the City of Plymouth. Our small amount of "true garbage" is collected over a 2+ week period. We share our neighbor's garbage bin when our bag is full and needs to be collected by the garbage company. Everything else is placed in our mixed recycling container which gets picked up every other week. It would be great if everyone could reduce their true garbage waste and then have someone create a garbage sharing program for each street or neighborhood.	Hennepin County
Forcing organics recycling is the worst policy you could pursue. Many counties and cities already have drop sites for the most hardcore believers in it.	Benton County Chisago County
Don't let the big trash industry capture you. Use common sense.	Isanti County

Response	County
	Kanabec County Kandiyohi County McLeod County Meeker County Mille Lacs Band of Ojibwe Mille Lacs County Pine County Renville County Sherburne County Stearns County Wright County
I live in an apartment complex that has recycling pickup. I have no say in who picks things up, and there is little information conveyed about the entire process. If I ask a "recycling representative" a question, I often hear that it's different from provider to provider. I don't know what can or can't be recycled, especially related to updates or changes. I wish I knew of a reliable, current source of information.	Hennepin County
Stop picking up items in recycling bins that are clearly garbage/non-recyclable... otherwise it negates the efforts others put in to doing it correctly. Do much more to educate on do's and don't's. Curbside composting is very easy.	Hennepin County
Get regulations up to speed so all packaging identifies if item is recyclable or easy way to let people know.	Hennepin County
Better communication to ALL MN Residents by ALL forms of Media	Hennepin County
As a Sherburne county resident, 10 minutes from St. Cloud, there isn't super accessible recycling drop off centers. I know I have way more recycle than trash and curbside pickup for my recycle is only every other week which leaves a lot of recycling just sitting around (we are a household of 7). If I had somewhere to load up and take it, easily, I would. I moved here from Kansas City, MO and there are recycle centers and drop offs everywhere and free. The one place I've found in St. Cloud charges to drop off, though just a few dollars, but honestly I'm sure that deters a lot of people from doing it, leading to more recyclables being trashed instead. I know it deters me because I came from a place where I could just recycle for free. So if there were bins in parking lots or multiple bins in unused city lots to create a free resource. Glass drop off bins and cardboard drop off bins in grocery store parking lots were abundant in the KC metro area.	Sherburne County
More info on plastic and styrofoam recycling programs. What can be included, what is not recycled in the state, etc	Scott County
Curbside pickup of compostable material	Ramsey County
For people who 'home' compost you should give a credit towards their trash/recycling bill. Also, do like Michigan and Oregon and others and offer 5-10 cents per aluminum can.	Hennepin County

Response	County
Charge a fee for plastic bags.	Washington County
I'd love to hear more about opportunities for recycling clothing. I'd love to take a mending class. I'd love to learn more about where I can donate used clothing over and above Goodwill and other price gouging resellers....or being able to redistribute directly to others in need.	Ramsey County
Single sort recycling	Washington County
Make laws governing plastic single use items. Support bulk purchasing and reusable containers for take out food	Hennepin County
I wish the single use plastic containers would be banned - keurig coffee cups, yogurt cups, soup cups, etc	Washington County
Just making available many opportunities to inform people of how important waste reduction and recycling is to good health of the community. I dont know any specific programs or opportunities for education myself, but everyone needs exposure to the why and how of this....from citizens to immigrant communities, young and old alike. And this is not offered as any kind of political viewpoint.	Scott County
Since my waste collection service doesn't pick up my recyclables, I would like the drop off sites to have more convenient hours of operation. I can't recall a specific recycling idea at this moment, but there have been a few recently that I read online.	Carver County
In Rochester/Olmsted County there is a voluntary organic compost program which has a bit of expense to it but they take nearly all organic waste, including meat, fish and dairy products. It seems to be worth it and working well for us although to be effective here and elsewhere, more drop sites or curb-side pick up is needed.	Olmsted County
There should be some kind of tax on companies that do not think about the packaging that gets thrown away because it is not recyclable.	Anoka County
Better incentives.	Ramsey County
More detail regarding how plastic waste is recycled would be helpful to me as a resident. The news is full of stories of plastic piling up in other countries, or floating in the ocean. I honestly don't know how plastics are recycled in Minnesota.	Hennepin County
Greater transparency about where it goes and how it's used	Hennepin County
Our waste hauler no longer accepts the paper recycling bags for yard waste. Isn't that what they were invented/used/meant for? Ridiculous rules that keep changing while prices keep increasing.	Anoka County
let there be local stores that accept donated items and give those donated items away yo whoever wants them	Otter Tail County
Statewide convenient electronic recycling. Convenient battery disposal. Better education and outreach. Ban Styrofoam egg cartons.	Lake County
Need a way to recycle batteries like AA, D, etc.	Stearns County

Response	County
	Wright County
I need more specifics about what can be recycled. I also have doubts about the value of plastics recycling as I've read that most plastic that is collected never gets recycled or it goes to poor countries where it can harm workers because regulation is lacking. I'd welcome some reassurance that plastics recycling is beneficial.	Rice County
Figure out how to clean recycling material at the recycling plant instead of rejecting the load to the dump.	Chisago County
partnering with Mill for a pilot program of some sort would be incredible - and could also recruit local farms to pickup the food grounds to use at their organic farms	Hennepin County
We need far more recycling containers in public places, like gas stations, parking lots, businesses, etc. I'm always disappointed when I see the number of places that don't offer any recycling. We have been composting for five years and we enjoy it. It really does contribute. The facilities are generally pretty easy to locate and use. I wish more people composted, but I don't know how to encourage it, other than talking about it with my neighbors.	Dakota County
only concern is if I do more recycling and still get increases on weekly garbage pickup rates while garbage decreases only have I bag per week on garbage now and prices increase	McLeod County
More recycling locations are needed for convenience. I think more people would recycle, especially in our area.	Crow Wing County
Stores charging for bags.	Washington County
(Simple) Lock some of the recycle cans at drop off sites. I bring my recycling to a nearby park and people toss trash in the recycling cans at random as they don't care/didn't realize. Paint the accepted plastic numbers on the can, the label guides wear away and are barely visible on the cans I use, but the plastic is the easiest to know. Advertise community recycling/compost availability or the volume of MN waste more at the state fair; a walking exhibit through the streets would have way more people see than would go into the environmental building	Hennepin County
I would like the grocery stores near me to carry products in bulk like rice, beans, candies like WinCo does. I would like everyone to receive recycling bins, and regular newsletters reporting about recycling efforts.	Mower County
Just moved to Rochester from St Paul. Glad to see Rochester doing some food composting. Hope more people will use it soon. Wish we could do something more with natural woody material in the Rochester area. We could leave it at the Ramsey County place for organics, but I think we have to throw away woody material in Rochester.	Olmsted County
More Bins places, especially gas stations, public places, all over	Crow Wing County
Neighborhood composting	Crow Wing County

Response	County
Yes! More education/outreach. Make incentives for businesses to reduce waste. Make wasteful businesses accept their trash back from customer. Enforce the damn plastic ban already!. Make recycling or compostable packaging options cheaper than plastic, and required for at least the wealthy producers!!! Curbside compost pickup. More annual free dump day pick up sites/ at home pickups. Stop plastic producers from destroying our Earth. Fees on fast food/fast fashion/single use producers. Waste-free festivals. End planned obsolescence practices and require production of quality products. Get rid of dollar stores. TAX THE RICH.	St. Louis County
All State, county and city entities should lead the way by example. Not telling people what to do and then they get to do whatever works easiest for them.	Ramsey County
I live in Gnesen and we do not have a recycling facility nor does our waste hauler pick it up so we drive to wlssd site but most of our neighbors don't because it is inconvenient. We pay a great deal for waste removal and the company should provide that service, it should be required.	St. Louis County
I don't know how to improve the process without legislation which creates a huge bureaucracy. I think more experiential field trips for high schoolers might help. Online information is not available to everyone.	Winona County
I have noticed many businesses do not recycle even easy things like cans and water bottles. More education needs to be done.	Washington County
We need curbside recycling companies to start taking packaging foam and styrofoam. People are putting it in the trash instead of taking the time to bring it to a recycling center. Every trash pick up day, the neighborhood seems to be littered with it.	Anoka County
A reuse program would be great if people had a place to bring items that could be used by someone else, to one location. So many use again bins have had to be removed because people dump so much stuff, especially when they have to move and can't take it with them. If the rich paid their fair share of taxes so much could be accomplished.	Anoka County
I wish there were options for small electrical repairs. It kills me to throw something away because I don't know how to fix it.	Hennepin County
Educate more people to become Recycling Ambassadors. I'm one but, we need more people with environmental training.	Dakota County
Make people aware of what a scam it is. Zero impact with higher costs	Wright County
E recycling needs to broaden education on what and how to properly recycle our RE minerals	Isanti County
Town amnesty days cleans up a good amount of and has people available that recycle all items. Win win	Wright County
If the sanitation company I pay for garbage pickup could offer recycling pick up as well	Becker County
More signs and advertisements, it took me six years before I found a close recycling bin...	

Response	County
Have the recycling companies be more specific about what they recycle	Sherburne County
Buying a large bottle of something vs more small bottles of the same thing.	Washington County
Elect a different governor	Hubbard County
Keep up the good work providing education, information & resources.	Ramsey County
More curbside recycling efforts, more recycling drop-off points, more communications regarding what can be recycled and where & how to dispose of toxic materials	Kanabec County
Pressure manufacturers to avoid materials that are not reusable/recyclable. I know we have a packaging law that was passed but much more work is needed.	Hennepin County
I would like to see recycling containers placed around our town, along the walking paths and bike trails, the campground, parks and picnic areas. I would like to see one night a week where the recycling center is open later for those that work later than 3:00. Being able to recycle fuel canisters would be a big bonus.	Lake County
I question where the recycled material is really going and how it's being used. I know local waste companies sell it off and it's often shipped over seas but does it make it there?	St. Louis County
Recycling has become to complex and confusing for folks. Easier materials in the hands of more people is key. The state is doing alot but forcing municipalities to engage with the programs through legislation is how you take the effective next step. Such as having municipalities require landlords to provide materials to every new tenant. Bolstering city infrastructure to have their own municipal recycling program and pushing out green washing super corporations like Waste Management is essential too. Introduction of bottle recycling and can recycling pay out like we see in Canada or Europe. It would cost alot of money obviously to implement all of these but to get political and lobbyists involved on some of these issues is how you move the needle for systemic waste management change.	St. Louis County
Production with natural materials seems like it would cut down on waste.	Cook County
Compost and recycling bins around the city, instead of just trash cans	Hennepin County Ramsey County
we are just starting a compost site as we recently moved to an area that doesn't offer curbside recycling	Kanabec County
Stop using plastic bags. packaging material needs to be recyclable.	Otter Tail County
Landscape materials recycling - somewhere to drop off concrete/pavers/blocks. Local places charge over \$50 for a small amount of concrete waste. Everyone is just throwing it in their garbage cans.	Anoka County
A public education blitz would help. Incentives for businesses to recycle as well. More public organic, recycling, waste containers.	Hennepin County

Response	County
I think new ideas should always be listened to, summarized for the public, and presented in many ways for the public to add their input.	Olmsted County
Start strong with the Youth programs. Kids will encourage the adults better than contemporary marketing does. Turn it into a homework assignment to learn more and teach their families or communities. Offer an incentive to get stated. Provide a Leadership qualification for those that excel or go above & beyond to share the knowledge. Have students, families, & communities share inspiring pictures & stories of ways they are being successful or thriving. Create yard signs with engaging wise words. Find ways to highlight the hardest workers and strongest participants. Turn it into a game or challenge. Give thanks and praise to keep the momentum going. Create good vibes & good energy! Find ways to include & uplift Traditional Ecological Knowledge (TEK). Indigenous wisdom is the key wise solution to moving forward in a good way. ❤️	Mille Lacs Band of Ojibwe Mille Lacs County
Needs to be more requirements to provide curbside recycling unless really remote northern county. More emphasis on reducing waste in manufacturing, retail and institutions.	Goodhue County
Stop manufacturers from using plastic packaging.	Itasca County
Help facilitate organized collection to reduce truck traffic and environmental impacts from inefficient collection routes. Organics should be focused on food scraps. Both recycling and food scrap collection need both paid and volunteer boots on the ground engaging residents since these are unregulated parties that don't understand the impact of contamination on the systems in various waste or commodity streams. The consequences for residents sorting recycling or organics are negligible if at all, but the impacts on our waste systems is significant. For example, people in general don't understand food scraps or electronics going in their garbage can may impact the end disposal site such as a landfill or an incinerator and in different ways for those facilities. Policies need to lean in on Product Stewardship to leverage manufacturers and hold them accountable to reduce the amount and complexity and lack of recyclability of products at end of life. Residents should not bear the burden for those manufacturers' decisions and costs.	Hennepin County
Duluth/Cloquet has no stores/businesses that cater to refillable goods so even though I have the desire to avoid single use packaging - I have no alternative. It's very frustrating to have to buy the all the plastic I have to buy because there's no where to simply buy the goods using a refillable container.	St. Louis County
All items should include the cost of proper disposal at the time of purchase. This is especially true for hazardous or hard to recycle items. When a cost is imposed in the individual trying to dispose of something properly, it creates a barrier and incentive to cheat. Separately, there should be regulation and potentially state level market participation for materials potentially recyclable when private industry is not doing so	Rice County
• Extended Producer Responsibility (EPR) • Packaging Waste Reduction Legislation • Increased Landfill Disposal Fees • GreenStep Cities Program • Waste Wise Program	Hubbard County

Response	County
• BizRecycling Grants • Home Composting • Recycling Education • Promotion of Reusable Products • Home Recycling Bins • Compost Bins • Reusable Bags and Containers	
Have cities provide free yard waste pick up.	Ramsey County
Ban single use plastics, force companies to do take back programs or circular economy initiatives & push the burden onto companies who create things like vape pens but don't have any desire to help keep them from being littered on our streets or tossed in the trash where they cause harm	Anoka County
Cardboard and plastic containers separated	Rice County
one single website resource for all residents of MN for all waste resources (drop sites, haulers, recycling, etc) by item/type	Hennepin County
The(Anoka) county site could be much better, it is vague and hard to navigate or find what I need. It needs to be basic, clear and to the point. Videos and attention grabbing pics should be part of it. People don't like to read a book to find one answer. Also, keep the mailer type documents coming, and again make it to the point and direct to online resources, not just to "call the county office for more info". All this should be laid out like a child's picture book(with a little more wording)...not kidding, this is how it needs to be. If I could draw you a picture I would :) :) :) Thanks for doing this survey!!	Anoka County
Bottle deposit law. State-wide education campaign to include common signage for waste - recycle - compost. Public school campaign. Prohibit disposable foodware in favor of reusable or recyclable/compostable at sporting and music-type events, including the State Fair. I don't like the word Organics for Compost because it gets confused with the term Certified Organic.	Hennepin County
state led guidance and resources for consistency.	Scott County
Convenient options for recycling hazardous waste; esp computers, electronics, batteries	Mille Lacs County
where I live the table crap bins would just be an attractant for bears and other animals	Morrison County
I'm unclear as to when recycling started, the collector paid the city because they were profitable... And our bill goes up and up and up now and I don't understand that	Hennepin County
We live 6 miles out of town and three different garbage companies come by every week. There should be a more efficient way to do this.	Douglas County
n/a	Hennepin County
Provide paper, plastic, and steel curbside receptacles	Aitkin County
An education about chemical waste would be good. Too many residential fertilizers and paint is not recycled.	Hennepin County

Response	County
None that I can think of at this time	Hennepin County
Unfortunately I don't know/have any ideas for input	Hennepin County
I would love to see curbside compost pick up	St. Louis County
I would like to see the county take more items for recycling...Like more # of plastic.	Hubbard County
more right to repair laws (I had a lawn mower that broke, brought it to a fix it clinic, and they figured out that the broken piece I needed to replace was not sold anywhere so I had to trash the whole thing.), increased sharing opportunities - I know we have the tool library but you have to pay to use it, could we get this for more items like sewing machines, yard games, cooking equipment, etc. More CLASSES! Teach people (for free) how to fix things, make it part of the culture, not just fix things but fix their homes as well, teach us how to do it and not just with options during the day when we are at work. Make it a requirement for people to sort out food waste at the curb, I am the only one on my block that has opted in for the curbside organics program. I work in recycling/reuse on the state level and we need these resources in the seven county metro but some areas in Greater MN don't even have curbside recycling, we need to create more equity in our waste systems like yesterday.	Anoka County Carver County Dakota County Hennepin County Ramsey County Scott County Washington County
Pick up every week, I have more recycling than garbage design garbage cans to be secure...neighbors put their garbage in our cans	Hennepin County
I'm really inspired by companies like Ridwell—promoting things like that where specific hard-to-recycle items are collected for specific companies that can recycle them I think could have a big impact and provide an incentive for people to start small recycling companies. Overall though I'm really impressed with all that Minneapolis does, every time I learn more I'm more amazed by what a good job they're doing and how they're so far ahead of the average! Thank you!	Hennepin County
in Minneapolis, we have the green organics bin. In the summer, it's important that it's picked up weekly. In the cooler weather, I would like to see that only picked up every other week. I can't imagine anybody is actually feeling that Ben and it would save on hauling impact.	Hennepin County
One of the most urgent needs in Minnesota is source reduction. Our economy is built around the idea that goods are disposable—that we can simply throw things away and buy new ones. We need to shift toward a system that prioritizes durable, repairable products and minimizes waste from the start. As a former renter, I saw firsthand how hard it can be to access organics recycling in multi-family housing, even though these buildings offer the benefit of density. Our systems for recycling and reuse need to be much stronger in these settings. Everyone should have equal access to high-quality recycling and reuse options, regardless of where they live. I'm encouraged by Minnesota's new Extended Producer Responsibility (EPR) law—it's a critical step toward source reduction. But we need to go further. I'd like to see more material bans backed by strong enforcement. Right now, when	Hennepin County

Response	County
items are expensive to dispose of, they often end up dumped illegally—especially on side streets along highways in places like Minneapolis. We should be holding manufacturers responsible for end-of-life management and building the true cost of disposal into the purchase price. Public education is also essential—starting in early childhood classrooms and continuing through adulthood—so people understand the environmental and economic consequences of throwing everything in the trash. I also support proven policies like right to repair and pay-as-you-throw, along with strong monitoring and enforcement of businesses and haulers to ensure accountability. And finally, local governments must do more to ensure consistent collection systems and messaging, so residents can participate in waste reduction and recycling efforts with confidence and clarity.	
To spread the word to more residents about the need to reduce trash and increase recycling, I suggest that the MPCA do a contest to collect ideas from everyone in the state on ways to avoid and reduce waste. The focus is usually on how to increase recycling. This contest would help educate people that we need to address waste and focus on the top of the hierarchy. People could send in any idea they had and be entered in a drawing for prizes. First Bank did something similar with all employees to generate ideas on how to be more efficient. They got lots of creative ideas and implemented many, saving thousands of dollars. It also instilled in employees the need to be on the lookout for ways to make things more efficient and that leadership welcomed suggestions. This would work for reducing waste also. I think most people don't think about trash and aren't aware of the need to reduce. Create a simple website for people to enter their idea along with their email address. You could share the contest through county communications. It could be a fun way to engage people in the metro and greater Minnesota and could result in some new, creative solutions.	Ramsey County
better consistency between haulers and end processors about what items are recyclable	Scott County Shakopee Mdewakanton Sioux Community
Statewide Green to Go law. Law allowing straws, single-use utensils and condiments to only be provided upon request. Change State building code to increase building design volume for recycling capacity and require reuse spaces in multi-unit building projects. State food code changes to support expansion of reusable to-go packaging. Maintain integrity of EPR law as designed - don't let it be watered down.	Hennepin County
Spoke and wheel system of environmental/reuse centers that have: - Amnesty dumping area (accepts all waste) - Industrial washing machines for reuse programs - Library of items that not every house needs (snowblowers, tools, etc.) - Educational area	Hennepin County
I think residents should be "rewarded" for a reduction in their waste. For example, my family of 4 only needs to put out curbside recycling and trash 1-2 a months. Could there be incentive for this active reduction? Work with HOAs to promote better/proper recycling. Eliminate all use of plastic bags in grocery stores.	Washington County

Response	County
Everything sold, every product and its packaging should have a mandatory method of recycling and end of life manufacturer take-back. All product packaging should be taxed; There should be a plastic/recycling/hazardous waste tax built in to the cost of production and recycling burden should not be an end result responsibility placed on to the consumer.	Hennepin County
Ban plastic bags, ban plastic straws, ban Styrofoam, make waste disposal more expensive and incentivize recycling, require restaurants, grocery stores, etc. to compost food waste - so many other countries and some of our states have good programs that we can learn from	Anoka County
explain the fact of contamination in recycling, how this affects the amount of recyclable items	Anoka County
Curbside Collection Of ALL Items	Anoka County
providing more options to dispose of bulky or hard-to-recycle items. Too many are dumped on local roads.	Sherburne County
Ongoing education might help but no idea how to deliver it.	Hennepin County
Start with children--educate them on the impact of waste in this country. It's really hard to get adults to stop "wish cycling". Someone needs to come up with a creative way to get people to think more about what they buy and discard	Ramsey County
Zero waste classes/workshops, charge for shopping bags at the store, more ways/locations to purchase bulk products from refill stations using own containers, Buy Nothing FB groups are awesome but would love for it to be a free public operated service through the city/county instead of through FB	Ramsey County
I think it should be more convenient/less costly for rural residents-- Additionally, I think there should be a site that people can both drop compostable/organic waste (and after an appropriate time) people can TAKE the "Black Dirt" for gardening, etc for a donation... A number of the empty rock quarries could be used as the site/sites across the state (would be HUGELY BENEFICIAL in rural areas)... If all goes well, the same could be done for wood chips/logging waste, Pot-Ash from the annual fires, etc (those with Farms/Hobby Farms/Agriculture could REALLY benefit)!!! It would create jobs, get rid of organic waste and aid in community sustainability!!! As things evolve, we could even offer to DELIVER (for a fee)!!!	St. Louis County
Why are brown paper bags sold for collecting leaves, when the compost sites don't even want them. Wouldn't a collapsable reusable bin be better for raking leaves into? It is evil marketing. Help take away from evil marketing.	Ramsey County
I think it's just fine the way it is.	St. Louis County
More signage and information at apartment buildings. Apartment-specific ways to get rid of furniture upon move out. A seamless food recovery program that organizations and individuals could use if they have leftover perishable food to distribute.	Ramsey County
More grant funding for waste reduction programming.	Ramsey County

Response	County
More county funded dropoff facilities that can be accessed more frequently than 1x per month	Anoka County
What happen to free recycling bins and pick up? I live in Anoka Co and we have to pay for recycling. I don't remember this when I was a child growing up in St. Paul. Also having multiple bins made it more fun to designate a bin (glass, cans, paper, etc) for recyclable item when it came to sorting vs one now where I just toss everything into one big bin. I also would like and think it'd be nice if we were offered a time or two in the year for big pick ups (mattress, tv, hazardous waste) that would be nice. Not everyone has the means or vehicle to haul big items to recycling locations, especially when recycling locations are usually not open on the weekends and operate during regular business hours.	Anoka County
Provide options to people for creating their own compost at home. This would also reduce the need for curbside pickup.	Cass County
It's extremely hard to buy groceries without it being in plastic and while understandable with some food not so much with others. Consumers can only do so much before breaking the bank	Ramsey County
Hennepin County requires curbside organics collection but our container does not have a sticker to show what is acceptable to put in it, and the city I live in has not done a good job of explaining it either. Most of my neighbors are unaware that they are even paying for it and don't participate	Hennepin County
There should be curbside (animal proof) food scrap bins that residents can use. These food scraps and compost then could go to Minnesota farmers to reduce artificial fertilizers.	St. Louis County
More resources and emphasis on waste reduction. Building materials, used furniture, small appliances, clothing that needs some mending, instruments (particularly pianos) and larger household goods are not accepted by many thrift stores due to space, upholstery is soiled or they can't sell the item. With furniture, possibly they simply need some cleaning and then someone else could use the item. I would love to run a large warehouse where all these materials were taken in and refurbished for reuse. We need facilities like this all over the state. Small appliances might need a cleaning or a small part and they would be usable. Many overseas countries would love to have our discarded instruments. There are so many people in need of decent goods we should not be throwing them away.	Anoka County
Maybe an auto factory or equipment factory that utilizes our local resources, i.e. aluminum auto body parts for northern vehicles or equipment prone to rust. Surveying for scrap metals on residents properties for donation to our county to bring down taxes for land owner. 😊 Thank you. Have a great day!	Isanti County
More local drop off locations to take bulky items (furniture, mattresses, electronics, tires, etc) at a low cost. Provide incentives to residents to recycle rather than throw items in the trash.	Sherburne County
Provide a place to donate/swap items that are working (or may need minimal repairs from fixers). Like hazardous waste reuse store, except for blenders, vacuums, mixers, toasters, irons,...WHATEVER!!	Hennepin County Ramsey County

Response	County
If you force people to recycle, they are less likely to do it properly. Packaging needs to be more clearly labeled and reliable. Specific companies make incorrect claims about recyclability or compostability that consumers generally believe. Apartment complexes' recycling programs often differ from curbside programs, with more waste and frequently less informed consumers. The recycling programs are different at different apartment complexes. More standardization of recycling programs, at least regionally, would be preferable. Information about recycling isn't sent out in accessible formats for people with various print disabilities. For example, a publication like Ramsey Recycles could be given to State Services for the Blind to create accessible flyers. The use of pictures of what can be recycled would also be helpful. Where can I give additional feedback? In addition, this survey should be available in alternative formats.	Ramsey County
We need more reuse programming and support for more reuse businesses.	Ramsey County
Make recycling mandatory. I personally several residents in Sherburne county that brag about not recycling, there needs to be more education and more enforcement	Sherburne County
I would love a compost bin, but also want to support the local govs that sell them. However they frequently sell out quickly and they are a bit costly	Dakota County
Compost bins provided to residents. Education provided to residents or more promotion of recycling events. Make it fee for residents to drop off hard to recycle items instead of charging money.	Sherburne County
None at this time.	Anoka County
I think the biggest challenge I see is lack of clarity on what can be recycled. I use the city of Minneapolis mailer they send out to double check myself but even I mess up sometimes and I'm generally pretty knowledgeable about recycling. If there was some way to put stickers on the city or county-issued bins, or send out more frequent mailers in multiple languages; post flyers in apartment buildings; educate landlords, etc. that might help people feel more confident about recycling vs. trash.	Anoka County Hennepin County
I would love to have curbside pickup of kitchen food scraps but am concerned about additional costs. As it is our household has very little trash each week and we have the smallest can available. My county and city have drop-off options for kitchen waste for free. I just think if there was a curbside option at no additional cost more food waste would be diverted from landfills.	Anoka County
Yes, I wish the city would allow you to bring big items to landfill without charging you. It would be nice if they did not charge to take a mattress and other big things to the dump or allow you one trip a year to go there. Or have one day a year where you could bring those things free of charge as long as you were a resident. They can put the cost to repurpose and dispose those items in the cost of paying for garbage. I think that would encourage more people to do it over throwing it away inappropriately.	Wright County
I would like to see curbside organics pick up offered by all waste haulers/companies. In many areas people need to compost in their own yard or bring it to a drop off site. More people might separate organics if there was curbside pick up available.	Anoka County

Response	County
not sure	Anoka County
Stop producing unnecessary packaging Use compostable material to package food items Set reimbursable fees no purchased items, to be reimbursed when reyclable material is returned	Ramsey County
More requirements for manufacturers. More take-back program options.	Hennepin County
There needs to be more Producer Responsibility laws-responsibilities shouldn't fall on the consumers and communities to manage and host landfills for materials that should have been designed for waste reduction, reuse or recycling in the first place-polluting our air, water and land while businesses make millions. Design our products better-we used to get milk delivered in reusable glass containers. Make all take-out containers reusable, make all packaging reusable to return to store. We have the knowledge and ideas-but the government needs to hold companies accountable to implement them.	Dakota County
Additional ordinances - we will not reach our recycling and waste reduction goals without more ordinances for people to follow	Hennepin County
I think that recycling and industrial composting is less accessible in rural areas, and it's unclear how effective these programs are.	St. Louis County
Like most problems, start from the top down. Disinformative Ads. Company polices need direction from lawmakers. There are plenty of sustainable packaging companies these days. Include the real cost of everything on this planet. Stop ignoring facts.	
I already use the city compost curbside which began this year.	Hennepin County
I think a big issue is the lack of readily available information. Most people like a convenient method of managing waste and it's difficult when you have to look up every thing from where compost goes, where do battery's go, where do large items go, and each place is different. I think due to convenience, even just the convenience of finding the answers, most of us are not able to actively manage all our waste in the best way. I also thing another issue is how to learn how we can reduce our environmental impact. I think having city/state events surrounding instructional activities on how to compost easily or how to reuse your things would really help spread more awareness. Information access and convenience are key.	Washington County
I like the idea of food waste collections curbside. However, we have bears, coyotes, raccoons, etc. in the neighborhood already. They like it when my neighbors keep their food waste outdoors and put out birdfeeders. Can separate food waste collection be done without attracting wildlife scavengers?	St. Louis County
Promote waste incineration. HERC should not be shut down. Waste incineration should not be considered equal to or worse than landfilling.	Crow Wing County Morrison County
I think there needs to be policies that move public buildings, like schools and state agencies, eliminate single use products and switch to reusables. We didn't have single use products for centuries and we don't NEED them now. Single use products need to be aggressively discouraged. Maybe there could be a tax on single use products specifically. I think large waste producers should also have to	Washington County

Response	County
switch to reusables, like stadiums and festivals. These events create massive amounts of waste in very short amounts of time and have no requirements to reduce that waste. Reuse is the only way to address that properly.	
Requiring more retailers/manufacturers to be responsible for waste generated from new items purchased (mostly packaging) or at least offer customers a path to accepting waste.	Cass County
Copy Minneapolis solid waste/big item/hazardous pickup model. residents should not have to "drop off". 1 in 10 St Paul households have no car. Eliminate resident charges for responsible recycling of hazardous items. Divert usable and repairable items dropped off at "Service" centers. Volunteers are already available to teach recovery and repair. The Ramsey Co Environmental Service Center missed an opportunity. The Bloomington/Better Futures program is a start but we need to start to INSPECT AND DIVERT at metro drop off recycling centers. WLSSD and Hubbard Co can do it and the best we can do in Ramsey is build a multi-million dollar facility that made no noticeable improvement to the reuse rates. I read about ReTuna Återbruksgalleria and think about what a St Paul resident has to do with a broken microwave. I am embarrassed.	Anoka County Carver County Dakota County Hennepin County Ramsey County Scott County Washington County
Encourage more reuse at businesses, sporting venues, entertainment venues. Encourage or require the use of compostable foodservice items. Especially considering the 2030 requirement for curbside organics collection in the Twin Cities metro area.	Dakota County
I think expanding access to curbside recycling and composting would have a massive benefit! I lived somewhere I didn't have curbside compost, so it was more work to drop it off and on a few instances I had to throw food waste in the trash when, for example, I was leaving on vacation and ran out of time to drop composting. Now I have curbside pickup and I never have to throw away food scraps! All households in Minneapolis get a compost bin without needing to opt in, so there's a reduced barrier to entry and consumer behavior research consistently shows that this is more likely to result in residents using the bins. If the infrastructure could be put into place, a policy for all homes to have three separate bins for trash, recycling, and compost would make a huge difference! I also think the program would need to be marketed correctly. Not only would people need education on what to toss in which bins, but they'd need a compelling reason to put in the effort to learn. How do we promote how Minnesota uses recyclables and compost? Can we profile a small farmer that uses compost to improve their soil health? Or highlight a small business that partners with a recycling facility for recycled paper to make their notebooks? Tons of options!	Dakota County Hennepin County
I think being honest about the cradle-to-grave cycle of waste management is important. I am disillusioned by the notion that my wastes are made profitable for others, meaning I'm a cog in the disposal industry. It matters less to me to clean out a plastic takeout container when I consider that the recycling might get sent across the ocean for disposal or raw materials for other industry. What's the benefit of recycling if my energy just goes into making money for others?	Hennepin County
Regulate manufacturers so they are responsible for the end-of-use of their product; it's recycling, reuse, etc.	Hennepin County Ramsey County

Response	County
Transportation costs are a huge barrier; this is something that needs to be worked out logistically across our state and especially in rural areas. Too bad rail is so expensive because its network is everywhere.	Itasca County

Appendix E – Survey Questions

Appendix E.1 Introduction

Welcome to the Minnesota Statewide Waste & Materials Management Survey

The Minnesota Pollution Control Agency needs your help to shape the future of waste and materials management in our state. The goal of the survey is to better understand current waste management practices, challenges, and opportunities for improvement.

Your Opinions Matter

All Minnesota residents, local government representatives, Tribal representatives, waste and recycling professionals, environmental organizations, and all individuals and groups representing diverse views in Minnesota are invited to contribute. To ensure we accurately capture regional differences and operational considerations, we will ask for location details such as counties or service areas. Please provide the most relevant and accurate information based on your role. Please note that individual survey responses will be kept confidential. Please ensure only one representative per entity completes the survey.

This survey should take approximately **5 minutes** to complete, and the majority of questions are optional. Your responses will be used to inform policies, programs, and resources that support the future of materials management in Minnesota. If you would like to learn more about the Resource Management Report process, visit the link to the website at the end of the survey.

Let's Get Started!

By clicking the button below, you acknowledge that:

- Your participation in the survey is voluntary.
- You are at least 18 years of age.

Yes, I am ready to proceed.

Appendix E.2 Audience Segmentation & Location

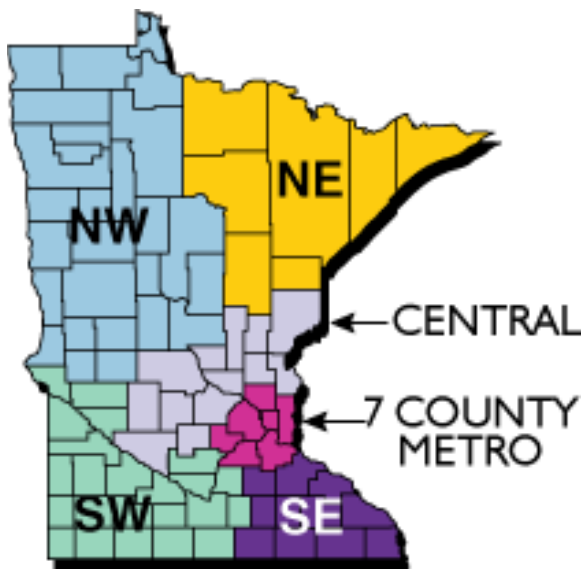
QX: In what capacity are you responding to this survey? If you are representing an entity (e.g., county, city, Tribe, organization, group), please collaborate internally to ensure only one representative submits the survey on behalf of your entity.

- County or city/town representative
- Tribal government representative
- Waste hauler representative
- Recycling facility representative
- Composting facility representative
- Anaerobic digestion facility representative
- Reuse and/or repair retail representative
- Food recovery organization representative
- Environmental or community-based organization representative
- Resident

Use the map below to help answer the next question.

QX: Which region(s) do you operate, reside, work, or advocate in? (Select all that apply)

Figure 105. Map of Minnesota with identified solid waste planning regions



- Central Minnesota
- Northeast Minnesota
- Northwest Minnesota
- Southeast Minnesota
- Southwest Minnesota
- Seven-County Twin Cities Metro Area
- Entire State

QX: In which county, counties, or Tribal nation within Central Minnesota? (Select all that apply)

- Benton County
- Chisago County
- Isanti County
- Kanabec County
- Kandiyohi County
- McLeod County
- Meeker County
- Mille Lacs Band of Ojibwe
- Mille Lacs County
- Pine County
- Renville County
- Sherburne County
- Stearns County
- Wright County

QX: In which county, counties, or Tribal nation within Northeast Minnesota? (Select all that apply)

- Aitkin County
- Bois Forte Band of Chippewa
- Carlton County
- Cook County
- Fond du Lac Band of Lake Superior Chippewa
- Grand Portage Chippewa
- Itasca County
- Leech Lake Band of Ojibwe
- Koochiching County
- Lake County
- St. Louis County

QX: In which county, counties, or Tribal nation within Northwest Minnesota? (Select all that apply)

- Becker County
- Beltrami County
- Cass County
- Clay County
- Clearwater County
- Crow Wing County
- Douglas County
- Grant County
- Hubbard County
- Kittson County
- Lake of the Woods County
- Leech Lake Band of Ojibwe

- Mahnomen County
- Marshall County
- Morrison County
- Norman County
- Otter Tail County
- Pennington County
- Polk County
- Pope County
- Red Lake Band of Chippewa
- Red Lake County
- Roseau County
- Stevens County
- Todd County
- Traverse County
- Wadena County
- White Earth Nation
- Wilkin County

QX: In which county, counties, or Tribal nation within Southeast Minnesota? (Select all that apply)

- Dodge County
- Fillmore County
- Freeborn County
- Goodhue County
- Houston County
- Mower County
- Olmsted County
- Prairie Island Indian Community
- Rice County
- Steele County
- Wabasha County
- Winona County

QX: In which county, counties, or Tribal nation within Southwest Minnesota? (Select all that apply)

- Big Stone County
- Blue Earth County
- Brown County
- Chippewa County
- Cottonwood County
- Faribault County
- Jackson County
- Lac qui Parle County
- Le Sueur County
- Lincoln County

- Lower Sioux Indian Community
- Lyon County
- Martin County
- Murray County
- Nicollet County
- Nobles County
- Pipestone County
- Redwood County
- Rock County
- Sibley County
- Swift County
- Upper Sioux Community
- Waseca County
- Watonwan County
- Yellow Medicine County

QX: In which county, counties, or Tribal nation within the Seven County Metro Area? (Select all that apply)

- Anoka County
- Carver County
- Dakota County
- Hennepin County
- Ramsey County
- Scott County
- Shakopee Mdewakanton Sioux Community
- Washington County

Appendix E.3 Audience-Specific Questions

County & city/town Representatives

QX: Do you represent a county or a city/town?

- County
- City/Town

QXa: What kind of hauling system does your jurisdiction operate?

- Open - Residents individually choose their own hauler.
- Open system with some self-organized areas – Most areas are open, but some neighborhoods or HOAs coordinate service.
- Organized – Multiple haulers serve different zones under contract or license.
- Organized - Single hauler contracted by the municipality for all service.

QX: How does your jurisdiction collect data on waste and recycling? (Select all that apply)

- Reports submitted by haulers
- Audits or assessments of waste and recycling streams
- Surveys or self-reported data from businesses/residents
- Reports from transfer stations, MRFs, or disposal facilities
- Reports required through permits, contracts, or franchise agreements
- We do not collect this information

QX: Are there gaps in recycling infrastructure within your city or county's jurisdiction? If so, what is the approximate distance (miles) to the nearest recycling facility or drop-off location for underserved areas?

- Yes - Major gaps (more than 10 miles away)
- Yes - Moderate gaps (5 to 10 miles away)
- Yes - Minor gaps (1 to 5 miles away)
- No - Little to no gaps (less than 1 mile away)
- Unsure

QXa: What challenges related to recycling access, participation, or infrastructure are present in your area? (Select all that apply)

- Minimal recycling access in rural areas
- Limits in access for multi-family housing (e.g., apartments, townhouses)
- Funding constraints for expanding services
- Funding limitations for continuing existing services
- Limited or insufficient hauling or processing infrastructure
- Insufficient staff capacity to manage or expand recycling programs
- Lack of public participation or interest in recycling
- Limited availability of recycling education and outreach resources
- Challenges in monitoring and managing drop-off sites (e.g., contamination, illegal dumping)
- Other (please specify):

QX: What is the most significant barrier to increasing recycling rates in your service area? (Select up to 3)

- Low public participation and/or awareness
- High contamination rates in recycling streams
- Limited local or regional processing capacity
- Insufficient collection infrastructure (e.g., limited curbside service, few drop-off locations)
- Weak end markets for recycled materials
- Cheap or more convenient alternative disposal options (landfill, waste-to-energy, etc.)
- Unsure
- Other (please specify):

QX: Does your county currently have partnerships with community organizations, schools, or businesses to promote waste reduction and recycling?

- Yes, 4 or more partnerships
- Yes, 1-3 partnerships
- No formal partnerships

QXa: Please list any key partnerships and describe their role in supporting waste and recycling initiatives. (Open ended)

QX: If your county had additional funding for outreach and education, which of the following would be the most impactful? Please rank the activities by potential level of impact for your jurisdiction.

- Developing multilingual and culturally tailored outreach materials
- Expanding school-based waste reduction and recycling education programs
- Hosting community workshops, events, or hands-on training
- Hiring or expanding dedicated outreach and educational staff
- Creating toolkits or best practices for businesses and institutions
- Launching targeted campaigns to reduce contamination in recycling
- Providing outreach specific to multi-family housing or underserved communities
- Strengthening partnerships with local organizations to reach priority populations
- Updating digital platforms or tools for public engagement (e.g., websites, apps, social media)

QX: Please rank the following types of technical assistance on how helpful they would be to improve waste and recycling operations in your jurisdiction. 1 being the least helpful, and 5 being extremely helpful.

- 1. Not at all helpful**
- 2. Not particularly helpful**
- 3. Neither helpful nor not helpful**
- 4. Somewhat helpful**
- 5. Extremely helpful**

- Improving data collection and reporting (e.g., assistance with MPCA reporting requirements, waste audits)
- Best practices for public outreach and community engagement
- Strategies to reduce contamination in recycling streams

- Updates on policy, regulations, and compliance requirements
- Support for grant writing and funding opportunities
- Guidance on optimizing collection, hauling, and processing efficiency
- Strategies for expanding recycling access in underserved areas
- Developing and implementing waste reduction programs

QX: If there are other methods of support that would be helpful for you regarding waste and recycling operations in your jurisdiction, share your thoughts here.

Reuse & Repair Retailers

QX: What materials or items does your organization prioritize for reuse or repair? (Select all that apply)

- Electronics, Physical Media, and Office Supplies
- Furniture, Home Improvement, and Construction Materials
- Clothing, Textiles, and Craft Supplies
- Vehicles, Bicycles, and Outdoor Equipment
- Containers, Packaging, and Household Items
- Specialty and Niche Items

QXa: Which specific electronics, physical media, or office supplies? (Select all that apply)

- Household electronics or appliances (e.g., computers, small kitchen appliances)
- Physical media (e.g., books, records, DVDs, video games, sheet music)
- Office and school supplies (e.g., binders, notebooks, desks, whiteboards)
- Other (please specify):

QXb: Which specific furniture, home improvement, or construction materials? (Select all that apply)

- Furniture (e.g., couches, tables, chairs, shelving)
- Construction and building materials (e.g., lumber, doors, windows, fixtures)
- Home improvement items (e.g., paint, hardware, tools)
- Other (please specify):

QXc: Which specific clothing, textiles, or craft supplies? (Select all that apply)

- Clothing or textiles (e.g., apparel, shoes, fabric scraps, linens)
- Textiles (e.g., fabric scraps, fabric)
- Arts and crafts materials (e.g., fabric, yarn, paints, frames)
- Other (please specify):

QXd: Which specific of vehicles, bicycles, or outdoor equipment? (Select all that apply)

- Vehicles or watercraft (e.g., cars, boats, trailers, RVs)
- Bicycles and related parts (e.g., helmets, bike frames, tires)
- Outdoor gear (e.g., camping equipment, skis, fishing gear)
- Other (please specify):

QXe: Which specific containers, packaging, and household items? (Select all that apply)

- Food containers and packaging (e.g., glass jars, takeout containers, reusable bags)
- Pet supplies (e.g., kennels, leashes, aquariums)

- Home kitchenware (e.g., plates, cups, cookware, utensils)
- Home décor (e.g., vases, candles, wall art)
- Storage and organization items (e.g., baskets, bins)
- Other (please specify):

QXf: Which specific specialty or niche items? (Select all that apply)

- Musical instruments and equipment (e.g., guitars, keyboards, amplifiers)
- Photography equipment (e.g., cameras, tripods, lighting)
- Fitness equipment (e.g., free weights, exercise machines, yoga mats)
- Medical equipment and supplies (e.g., crutches, wheelchairs, CPAP machines)
- Children's items (e.g., toys, baby gear, strollers, car seats)
- Collectibles and antiques (e.g., rare coins, vintage figurines)
- Other (please specify):

QX: What are the most significant infrastructure challenges your business faces, if any? (Select all that apply)

- Lack of sufficient storage space for incoming or processed items
- Transportation and logistics for moving items
- Processing or repair capabilities (e.g., lack of tools, skilled labor, or equipment)
- Limited access to retail or distribution locations (e.g., storefront limitations, zoning barriers)
- Lack of washing or sanitization infrastructure
- My business or organization does not currently face infrastructure challenges

QX: What are your top financial challenges with your business, if any? (Select up to 3)

- Limited access to grants or public funding opportunities
- Low consumer demand or awareness
- High operational costs (e.g. rent, labor, transportation, utilities)
- Competition with inexpensive new products
- Difficulty securing private investment or business loans
- My business does not currently face financial challenges

QX: What support would you need to scale or expand your business, if any? (Select up to 3)

- Policy changes to support reuse/repair businesses
- Skill and workforce development programs
- Business development programs
- New partnerships or collaborations with other businesses or governments
- Funding or financial support
- Consumer education and marketing support
- New facilities or equipment
- Access to affordable retail or warehouse space
- My business doesn't need anything to scale or expand at this time

QX: Does your organization currently track data on reuse operations (e.g., materials diverted, items repaired or resold, repair events held)?

- Yes, and the data is regularly updated.
- Yes, but the data is limited or inconsistent.
- No, we do not track reuse data at this time.

QXa: What types of reuse data are tracked? (Select all that apply)

- Materials diverted
- Weight/volume of materials
- Types of materials
- Items repaired
- Number of repair events
- Other (please specify):

QXb: How often is the data updated?

- Weekly
- Monthly
- Quarterly
- Annually
- Less than annually

QXc: What are main limitations or barriers to tracking data? (Select all that apply)

- Limited staff capacity
- No or limited access to technology or tools to collect data
- Lack of resources
- Limited time
- Not sure what to track
- Other (please specify):

QX: Would your organization benefit from support or tools to improve data tracking capabilities?

- Yes
- No
- Maybe, but more information is needed

QX: Does your business participate in any reuse-focused collaborations, networks, or shared infrastructure projects?

- Yes, we are part of a formal network/group (please specify):
- Yes, but informally with other businesses/organizations.
- No, but we would be interested in opportunities to collaborate.
- No, we operate independently.

QX: In your opinion, what factors most influence whether consumers choose to buy secondhand or reused products? (Select up to 3)

- Price compared to new products
- Perceived quality or durability of secondhand/reused items
- Availability of warranties or return policies
- Convenience of access (e.g., location, online options, ease of shopping)
- Social or environmental/waste reduction attitudes toward secondhand shopping/reuse retailers
- Unique or vintage appeal
- Trust in the source of the products
- Product selection variety

- Peer influence or recommendations (e.g., recommendations from friends, influencers, or social media)
- Brand reputation of the reuse business or store
- Desire to support local or small businesses

Recycling Facilities

QX: What are the most problematic contaminants in your facility's recycling stream? (Select up to 3)

- Plastic bags and film
- Food and liquid residue
- Non-recyclable plastics (e.g., black plastics, mixed-material items)
- Hazardous materials (e.g., propane tanks, sharps, chemicals)
- Lithium-ion batteries and electronics
- Clothing and textiles
- Toys and small household items (e.g., plastic toys, non-recyclable items)
- Styrofoam or polystyrene foam
- Glass contamination (e.g., broken glass or non-recyclable glass containers)
- Ceramics or cookware (e.g., broken dishes, non-recyclable cookware)
- Cords and wires (e.g., electrical cables, tangled wires)
- Other (please specify):

QX: Has your facility experienced any of the following in the past 5 years related to lithium-ion batteries? (Select all that apply)

- A minor fire or thermal event
- A major fire or explosion requiring emergency response
- Multiple incidents over time
- No incidents related to lithium-ion batteries
- Not sure

QXa: How was the fire detected?

- Smoke or flames visible
- Unusual smell or heat
- Alarm or sensor alert
- Other (please specify):

QXb: Which of the following fire detection or suppression tools are used at your facility? (Select all that apply)

- Thermal imaging or infrared camera systems
- Temperature threshold notification systems
- Type D fire extinguishers
- Suppression blankets or cell block materials (e.g., puffed glass)
- Staff fire safety training specific to lithium battery incidents
- None of the above
- Other (please specify):

QXc: What actions were taken to control the incident? (Select all that apply)

- Fire extinguisher used
- Load dumped to prevent spread
- Fire department called
- No immediate action was possible
- Other (please specify):

QXd: Did the incident result in any of the following? (Select all that apply)

- Minor property damage (e.g., container or equipment only)
- Major property damage (e.g., structural damage, vehicle loss)
- Minor injury (e.g., first aid only)
- Serious injury (e.g., hospitalization or lost work time)
- Temporary service disruption (less than 1 day)
- Extended service disruption (1 day or more)
- Emergency response required (fire dept, hazmat, etc.)
- Environmental impact (e.g., smoke release, leachate issues)
- Evacuation of personnel or public
- Negative media or public attention
- No significant impact
- Other (please specify):

QXe: If your facility had additional funding, which of the following would be a priority investment to reduce lithium battery fire risks? Please rank from most helpful to least helpful.

- Installation of thermal imaging or infrared detection systems
- Temperature alert systems for high-risk areas (e.g., flam sheds, bunkers)
- Purchase of suppression blankets or specialized extinguishers
- Enhanced staff training for lithium battery-related fires
- Public outreach and education to reduce improper battery disposal
- Battery-specific collection containers or sorting protocols
- Facility layout/design improvements to isolate high-risk materials

QX: What are the most significant safety risks that your staff face at your facility? (Select up to 3)

- Injuries from sorting or processing equipment (e.g., pinch points, moving belts, compactors)
- Slips, trips, or falls (e.g., from wet floors, uneven surfaces, climbing equipment)
- Manual handling injuries (e.g., lifting heavy materials, repetitive strain)
- Exposure to hazardous or unknown materials (e.g., chemicals, sharps, propane tanks)
- Fires from non-lithium materials (e.g., flammable liquids, pressurized containers)
- Vehicle-related incidents (e.g., truck or loader collisions, backing accidents)
- Poor ventilation or exposure to dust and airborne particles
- Inadequate personal protective equipment (PPE) or compliance
- Verbal abuse or threats from customers or site users

QX: How does contamination impact your facility's operations? Please rank each outcome by the most to least impact on your operations.

- Increased equipment downtime and repair costs (e.g., damage to sorting machinery, conveyor systems, or other equipment)

- Increased labor costs for sorting and handling (e.g., additional manual labor required to remove contaminants or sort materials)
- Increased rejection rates from end markets
- Lower market prices for contaminated materials
- Increased fire and worker safety hazards
- Slower processing speeds (e.g., bottlenecks or delays in sorting and processing due to contamination)
- Higher disposal costs (e.g., additional fees for disposing of contaminated materials that cannot be recycled)
- Reduced overall recycling efficiency (e.g., contamination reducing the effectiveness of the entire recycling process)

QX: What's your estimated contamination rate of the material coming into your facility?

- Under 10%
- 10-15%
- 16-20%
- 21-25%
- 26-30%
- Over 30%
- Unsure

QX: What are the biggest challenges your facility experiences? (Select up to 3)

- Inconsistent availability or supply of materials
- Poor material quality or high contamination levels
- Competition with other processors or manufacturers
- Regulatory, permitting, or compliance-related obstacles
- High transportation or logistics costs
- Fluctuating volumes or seasonal variability
- Market instability or unpredictable pricing
- Lack of long-term contracts or reliable supplier relationships
- Limited access to local or regional sorting/processing capacity

QX: What are the greatest challenges in securing end markets for recycled materials? (Select up to 3)

- Market volatility and fluctuating prices
- Lack of demand for certain recycled commodities
- Inconsistent material quality
- Competition with virgin materials
- Lack of infrastructure or processing capacity
- Changing regulatory or policy requirements
- Limited access to end buyers or markets
- Price sensitivity in buyer market

QX: What are your facility's biggest workforce challenges? (Select up to 3)

- Hiring and retaining skilled workers
- Lack of workforce training programs

- High turnover rates
- Workplace safety concerns
- Low employee engagement or morale
- Inadequate compensation or benefits
- Difficulty with seasonal or fluctuating workforce needs

QX: Which equipment investments would most improve your facility's efficiency? (Select up to 3)

- Advanced sorting technology (e.g., AI, robotics, or optical sorting systems)
- Better contamination detection and removal systems
- Upgraded conveyor systems or balers
- Fire suppression systems and workplace safety equipment
- Material handling equipment (e.g., forklifts, compactors, or automated stacking systems for more efficient material handling)
- Shredders or crushers
- Weight measurement or tracking systems
- Air quality control systems
- Recycling-specific software or data management systems (e.g., technology for tracking materials, optimizing operations, and improving reporting accuracy)

QX: What are the most significant barriers to increasing recycling rates in your service area? (Select up to 3)

- Lack of public participation and/or awareness
- High contamination rates
- Limited processing capacity
- Limited collection infrastructure
- Weak end markets for recycled materials
- Cheap or more convenient alternative disposal options (landfill, waste to energy, etc.)
- Lack of regulatory or policy support
- Financial constraints
- Lack of convenient or accessible recycling options
- Unsure

QX: What public education efforts would have the greatest impact on reducing contamination? (Select up to 3)

- Standardized statewide recycling guidelines
- More direct outreach to residents (e.g., mailers, social media)
- Retail-based education at point of purchase
- School and community-based education programs
- Public visits to recycling facilities
- Collaborations with waste haulers for better communication
- Use of digital tools or apps to guide residents
- Incentive programs to encourage recycling

Composting Facilities

QX: What are the most common contaminants in the organic waste stream at your facility/site? (Select all that apply)

- Plastic bags and packaging
- Non-compostable foodware (e.g., bioplastics, coated paper , or compostable products that do not break down properly in the composting process)
- Glass, metals, or other non-organic materials
- Household hazardous waste (e.g., chemicals, pesticides, cleaning products, or other potentially harmful materials)
- Non-organic waste (e.g., electronic waste, batteries, or items that should not be in compostable material)
- Medical or personal care items (e.g., diapers, sanitary products, or pharmaceuticals)
- Food contamination (e.g., food containers with excessive residue or non-compostable food items such as oils or liquids)

QX: How does contamination most impact your facility/site's operations? (Select up to 3)

- Increased labor for contaminant removal
- Equipment damage or downtime
- Reduced quality of finished compost
- Increased disposal costs for rejected material
- Decreased processing efficiency
- Regulatory or compliance challenges
- Increased operational costs
- Reduced consumer confidence or demand

QX: Which equipment investments would most improve your facility's efficiency? (Select up to 3)

- Improved screening and contamination removal systems
- More advanced aeration or composting technology
- Better odor control and emissions management equipment
- Upgraded processing capacity (e.g., larger or more efficient grinders, windrow turners, or mixers to handle higher material volumes or improve processing time)
- Improved facility monitoring and data tracking systems

QX: What's your estimated contamination rate at your facility?

- Under 5%
- 6-10%
- 11-15%
- 15-20%
- Over 20%
- Unsure

QX: What are the most significant barriers to increasing composting rates at your facility/site? (Select up to 3)

- Lack of public participation and/or awareness
- Low feedstock/supply
- High contamination rates
- Limited composting infrastructure or facility capacity
- Weak end markets for finished compost
- Regulatory or policy barriers
- Operational cost constraints

QX: What public education efforts would have the greatest impact on reducing contamination in composting? (Select up to 3)

- Standardized statewide composting guidelines
- More direct outreach to residents (e.g., mailers, social media)
- Retail-based education at point of purchase
- School and community-based education programs
- Public visits to composting facilities
- Multilingual outreach materials
- Partnerships with local businesses and waste haulers

Anaerobic Digestion Facilities

QX: What are the most common contaminants in the organic waste stream at your facility? (Select all that apply)

- Plastic bags and packaging
- Non-compostable foodware (e.g., bioplastics, coated paper)
- Glass, metals, or other non-organic materials
- Household hazardous waste (e.g., chemicals, pesticides)
- Other (please specify):

QX: How does contamination most impact your facility/site's operations? (Select up to 3)

- Increased labor for sorting/contaminant removal
- Equipment damage or downtime
- Reduced efficiency in biogas production
- Increased disposal costs for rejected material
- Reduced quality of finished compost or biogas
- Increased regulatory or compliance challenges
- Other (please specify):

QX: What's your estimated contamination rate at your facility?

- Under 5%
- 6-10%
- 11-15%
- 15-20%
- Over 20%

- Unsure

QX: Which equipment investments would most improve your facility's efficiency? (Select up to 3)

- Pre-treatment and contamination removal technology
- More advanced digestion and gas capture systems
- Upgraded storage or dewatering equipment for digestate
- Safety systems (e.g., equipment to monitor and ensure worker safety, such as gas detection systems or fire suppression equipment)
- Odor control systems (e.g., air filtration, biofilters, or other technologies to reduce odor emissions from the facility)
- Monitoring and automation technology
- Energy recovery or conversion systems (e.g., equipment to convert excess biogas into usable energy or other byproducts)
- Other (please specify):

Waste & Recycling Haulers

QX: What types of material do you haul? (Select all that apply)

- Residential MMSW
- Commercial MMSW
- Single-Stream Recycling/Other Recyclable Materials
- Yard Waste
- Organic Waste (Food & Compostable Materials)
- Industrial Waste
- Hazardous Waste
- E-Waste
- Biomedical Waste
- Sludge & Biosolids
- Construction & Demolition
- Specialty Material/Other

QXa-2: What is the most common contaminant in your recycling stream that you know of? (Select up to 3)

- Plastic bags or bagged recyclables
- Soiled paper or cardboard
- Non-recyclable plastics (e.g., black plastics, mixed-material items)
- Lithium-ion batteries and hazardous materials (e.g., propane tanks, chemicals, sharps)
- Food scraps and liquids in recycling loads
- Electronics or small appliances
- Glass in non-glass recycling streams
- Textiles and clothing
- Yard waste or organic material in trash/recycling
- Bulky items (e.g., furniture, large rigid plastics)
- Scrap metal in non-metal streams

- Construction and demolition debris
- Medical or biohazardous waste
- Other (please specify):

QX: Have you experienced fire or safety hazards related to hazardous materials (e.g., lithium-ion batteries, propane tanks) in the waste stream?

- Yes
- No

QXa: Where did the fire or safety incident occur? (Select all that apply)

- Inside a collection truck
- At a transfer station or MRF
- At a landfill
- Other (please specify):

QXb: What material(s) do you believe caused or contributed to the fire/hazard? (Select all that apply)

- Lithium-ion battery
- Propane tank (full or empty)
- Aerosol can
- Pool or household chemicals
- Other (please specify):

QXc: How was the fire/hazard detected?

- Smoke or flames visible
- Unusual smell or heat
- Alarm or sensor alert
- Other (please specify):

QXd: What actions were taken to control the incident? (Select all that apply)

- Fire extinguisher used
- Load dumped to prevent spread
- Fire department called
- No immediate action was possible
- Other (please specify):

QXe: Did the incident result in any of the following? (Select all that apply)

- Property damage
- Injury to workers
- Service disruption
- No significant impact

QXf: If you had additional funding, which of the following would be a priority investment to reduce lithium battery fire risks? Please rank from most helpful to least helpful.

- Installation of thermal imaging or infrared detection systems
- Temperature alert systems
- Purchase of suppression blankets or specialized extinguishers
- Enhanced staff training for lithium battery-related fires

- Public outreach and education to reduce improper battery disposal
- Battery-specific collection containers or sorting protocols

QX: Which of the following would help you improve route efficiency in your service area? (Select up to 3)

- Route optimization software and/or technology (e.g., GPS tracking, AI-powered route planning)
- Increased customer education to reduce contamination and rejected loads
- Better coordination with processing facilities
- Better coordination of new residential or commercial service locations
- Newer collection infrastructure to increase collection times (e.g., automated trucks)
- Route efficiency does not need to be improved

QX: Do you experience any of the following regulatory or operational barriers that impact your business? (Select up to 3)

- Permitting and zoning restrictions
- Inconsistent or conflicting local policies and regulations
- Cost of compliance with state and local regulations
- Limited infrastructure (e.g., transfer stations, composting facilities, dirty MRFs)
- Difficulty accessing or securing contracts for services
- Challenges with enforcement or regulatory uncertainty
- I do not experience regulatory or operational barriers at this time

QX: Do you currently provide education to your customers on proper disposal or recycling best practices?

- Yes
- No
- Unsure

QXa: Which kinds of promotional materials or education do you provide?

Promotional Material	More Than Once per Year	Once per Year	Less Than Once per Year	Never
Direct feedback (e.g., email, portal, mail)				
Flyers/pamphlets/brochures/guides				
Calendars				
Magnets				
Public events (e.g., classroom presentations, recycling drives)				

Notices or cart tagging				
Utility inserts				
Mailer				

Environmental & Community-Based Organizations

QX: What type of organization do you represent? (Select all that apply)

- Environmental justice
- Climate action/climate justice
- Tribal nonprofit or Indigenous-led initiative
- Reuse and waste reduction
- Zero waste advocacy
- Pollution prevention and toxics reduction
- Circular economy/sustainable business
- Housing, tenants' rights, or community development
- Public health and environmental health
- Youth engagement and education
- Mutual aid or grassroots organization
- Other (please specify):

QX: What are the most significant waste-related issues affecting the communities you serve? (Select up to 3)

- Lack of access to convenient recycling or composting options
- Limited or no options/locations for reuse (e.g., refilleries, repair shops, tool libraries, thrift stores)
- Higher exposure to air pollution or environmental hazards from waste facilities
- Illegal dumping or littering
- Rising costs for waste disposal and recycling programs
- Limited availability of take-back programs for hard-to-recycle items (e.g., electronics, mattresses, hazardous waste)
- Limited education and outreach on proper waste management practices
- Disparities in waste services and infrastructure across different communities
- Other (please specify):

QX: What best describes your organization's position on using landfills as a waste management strategy?

- Landfilling is a practical and acceptable waste management solution for non-recyclable materials.
- Landfilling is necessary but should be modernized with improved environmental protection and diversion efforts.

- Landfilling should be minimized as much as possible in favor of waste reduction, reuse, and recycling.
- Landfills should be phased out entirely in favor of alternative waste management strategies (e.g., waste-to-energy, advanced recycling technologies, composting).
- Landfills should be discontinued immediately.
- Our organization has not taken an official position on this matter.

QX: What best describes your organization’s position on using waste-to-energy (WTE) as a waste management strategy?

- WTE is necessary for managing non-recyclable materials and recovering energy.
- WTE is a viable option, but it should be subject to strong environmental and public health regulations.
- WTE should be used in limited cases after exhausting waste reduction, reuse, and recycling options.
- WTE should be phased out entirely in favor of alternative waste management strategies (e.g., landfilling, advanced recycling technologies, composting).
- WTE should be discontinued immediately.
- Our organization has not taken an official position on this matter.

QX: What are the most important ways to make Minnesota’s waste system more equitable? (Select up to 3)

- Increased investment in waste diversion programs in historically underserved communities.
- More financial support for expanding recycling and composting access to all Minnesota communities, particularly in rural and low-income areas.
- Stronger enforcement of environmental justice policies in waste facility siting and operations.
- More direct engagement with impacted communities in decision-making processes.
- Workforce development programs to create equitable job opportunities in the waste and recycling sector.
- More accessible education and outreach programs tailored to diverse communities.
- Other (please specify):

QX: Do you believe that certain communities in Minnesota are disproportionately impacted by current waste management practices?

- Yes, significantly
- Yes, somewhat
- No, impacts are generally equal across communities
- Unsure

QXa: Why do you believe some communities are more impacted than others?

QX: Are there any existing partnerships or networks that play a big role in your organization’s mission?

- Yes (please specify):
- None currently
- None currently, but we are interested in future partnerships

QX: What forms of collaboration with MPCA would be most beneficial or of interest to your organization? (Select up to 3)

- More training opportunities to build staff knowledge on waste prevention, recycling, and compliance
- Technical assistance or clearer guidance on regulatory compliance and reporting requirements
- Opportunities to share your organization's activities, challenges, or research with MPCA staff
- Participation in pilot programs or innovative initiatives
- Collaboration on research related to waste reduction, recycling, or circular economy strategies
- Policies that better reflect and respond to community concerns (e.g., environmental justice, local impacts)
- Joint outreach or education campaigns targeting residents, businesses, or schools
- Improved access to timely, localized data on waste generation and recycling trends
- More opportunities to provide input on MPCA decision-making and policy development
- Grant or funding opportunities for local or regional waste reduction efforts
- Regular check-ins or regional meetings with MPCA staff

QX: Can your organization find the information it needs on waste management policies and programs through MPCA?

- Yes, the resources are accessible and helpful.
- Somewhat, but it can be difficult to navigate or there is incomplete information.
- No, it is challenging to find necessary information.
- We do not seek information from MPCA.

QX: If your organization received funding to improve waste management and recycling programs, how would it be used? (Select up to 3)

- Expanding community recycling and composting programs
- Conducting education and outreach on waste management
- Advocating for policy changes related to waste management
- Strengthening partnerships with local governments, businesses, and community organizations
- Funding equipment and/or logistics for materials management initiatives
- Improving accessibility and affordability of waste services for underserved communities
- Supporting reuse and repair initiatives to reduce waste generation
- Developing innovative waste reduction strategies (e.g., circular economy initiatives, extended producer responsibility programs)
- Other (please specify):

QX: How would you broadly rate your organization's level of trust in MPCA's handling of waste and recycling policies?

- High trust - MPCA is transparent and responsive.
- Moderate trust - MPCA generally does a good job but could improve.
- Low trust - MPCA does not effectively address community concerns.
- Unsure

Tribal Representatives

QX: Does your Tribe currently track waste, recycling, or organic waste data (e.g., tonnages, material types, diversion rates)?

- Yes, we collect detailed data regularly.
- Yes, but data collection is inconsistent or limited.
- No, we do not currently track waste and recycling data.

QXa: How does your Tribe collect data on waste, recycling, or organic waste? (Select all that apply)

- Tonnage reports from haulers
- Audits of waste streams
- Surveys or self-reported data from businesses/residents
- Data from our own facilities
- Other (please specify):

QX: What types of waste materials are most commonly generated within your community? (Select all that apply)

- Household trash
- Recycling (mixed paper, plastics, metals)
- Organic waste (food scraps, yard clippings)
- Construction and demolition debris
- Hazardous waste (batteries, paints, chemicals)
- E-waste (electronics, appliances, TVs)
- Bulky waste (furniture, mattresses, large items)
- Textiles (clothing, linens, fabric waste)
- Household medical waste (e.g., sharps, medications)
- Pharmaceutical waste
- Agricultural waste (e.g., manure, crop residues)
- Scrap metal
- Plastics not accepted in curbside recycling (e.g., plastic bags, straws)
- Wood waste (e.g., untreated wood, lumber, pallets)
- Used oil or motor fluids
- Tires
- Other (please specify):

QXa: Does your Tribe have its own residential recycling hauling or recycling drop-off sites?

- Yes, we have a residential recycling hauling program operated by the tribe.
- Yes, we have recycling drop-off sites managed by the tribe.
- Yes, we have recycling hauling and drop-off sites operated by the tribe.
- No, we do not have either program.
- No, we have a contract to use non-Tribal entities for recycling.

QX: Where does most of the waste generated on your Tribal lands currently go? (Select all that apply)

- Direct to landfill
- Transfer station
- Waste-to-energy facility
- Regional or municipal recycling center
- Tribal-operated recycling/composting facility
- Other (please specify):

QX: Do you face any of the following cost-related challenges in your Tribe's waste management operations? Which of the following are the most significant? (Select up to 3)

- Hauling and transportation expenses
- Disposal fees at landfills or transfer stations
- Costs of maintaining/expanding recycling or composting programs
- Costs of waste reduction and diversion programs
- Equipment and infrastructure needs
- Labor costs for waste management staff
- Costs associated with educating the community about waste management
- Costs of maintaining or upgrading waste facilities
- Regulatory compliance costs
- Costs for hazardous waste disposal
- Challenges with funding or accessing grants for waste programs
- No major cost challenges currently
- Other (please specify):

QX: Does your Tribe face any of the following operational challenges in Tribal waste management operations? Which of the following are the most significant? (Select up to 3)

- Limited staffing and technical expertise
- High transportation costs for waste and recyclables
- Lack of or limited local recycling or composting infrastructure
- Contamination in recycling or compost streams
- Difficult enforcing waste management policies
- Open burning of waste
- Illegal dumping on Tribal lands
- Limited access to or lack of waste diversion programs
- Challenges with managing hazardous waste
- Limited public awareness or participation in waste management programs
- Insufficient funding or grant opportunities for operational improvements
- Unreliable or inadequate waste disposal services
- Aging or inefficient waste management equipment
- Lack of adequate data on waste generation or diversion rates
- Other (please specify):

QX: Does your Tribe operate or participate in any of the following programs? (Select all that apply)

- Mobile waste collection programs for remote areas
- Reuse and initiatives (thrift stores, tool libraries/sharing, item distribution/sharing, etc.)
- Repair initiatives (repurposing garments, mending/weaving, etc.)
- Community composting programs (backyard bins, worm composting, community gardens)
- Recycling or household hazardous waste collection events
- Selective tree harvesting
- Full utilization of hunted animal and fishing harvests
- E-waste recycling programs
- Electronics repair or refurbishment programs
- Green energy initiatives (solar, wind, etc.)
- Waste-to-energy or biogas production programs
- Indigenous knowledge-sharing on sustainable land or waste management practices
- Traditional food preservation and waste reduction programs
- Zero-waste initiatives or events
- Community clean-up or beautification programs
- Education and outreach on sustainability and waste reduction
- Other (please specify):

QX: Does your Tribe currently have partnerships with community organizations, schools, or businesses to promote waste reduction and recycling? (Select all that apply)

- Yes, with multiple partners.
- Yes, but limited partnerships.
- No, we do not have formal partnerships.

QXa: Please list any key partnerships and describe their role in supporting waste and recycling initiatives.

QX: Are there other waste management solutions that your Tribe has implemented that could serve as a model for others?

Food Recovery Organizations

QX: How does your organization primarily recover and redistribute food? (Select all that apply)

- Direct partnerships with grocery stores, restaurants, or food producers
- Distribution through food banks or pantries
- Community meal programs or grocery distribution initiatives
- Farm gleanings (collecting surplus crops after harvest)
- School or institutional food recovery programs
- Upcycling foods into new products (e.g., transforming surplus ingredients into prepared meals or other food products)
- Coordination of food for farms to be used as animal feed
- Depackaging of unused food for redistribution or other purposes
- Collaboration with food recovery networks (e.g., food rescue organizations)

QX: What happens to food that cannot be redistributed? (Select all that apply)

- Composted on-site
- Sent to a commercial composting facility
- Donated to farms for animal feed
- Sent to anaerobic digestion for energy production or composting
- Disposed of in a landfill or sent to a waste-to-energy facility
- Used in other waste-to-resource initiatives (e.g., bio-based products, soil amendment)

QX: What are the biggest barriers your organization faces in recovering and distributing food? (Select up to 3)

- Transportation and logistics (e.g., lack of refrigerated vehicles, limited certified drivers)
- Insufficient funding or resources
- Storage limitations (e.g., refrigeration, warehouse space)
- Strict food safety regulations or liability concerns
- Difficulty connecting food to people who need it
- Public misconceptions about food recovery
- Labor shortages or volunteer availability
- Lack of infrastructure or technology to manage donations
- Challenges with maintaining donor relationships or securing reliable sources of food

QX: What would most help your organization expand food recovery efforts? (Select up to 3)

- Enhanced transportation and storage infrastructure (e.g., refrigerated vehicles, larger storage facilities)
- Clearer liability protections and food safety regulations for food donations
- Stronger partnerships with food producers, retailers, institutions, and other food donors
- Better coordination with local governments and community organizations (e.g., sharing logistics, recipient connections, space)
- Increased community engagement and volunteer participation to support food rescue and distribution
- Expanded public awareness campaigns to increase donations and reduce stigma around food recovery
- Increased funding or grant opportunities for food rescue and redistribution programs
- Policy or regulatory changes that support food recovery (e.g., tax incentives, donation requirements)
- Improved access to technology for managing donations and tracking food recovery

QX: Who are your primary partners in food recovery efforts? (Select all that apply)

- Local grocery stores and supermarkets
- Restaurants and food service providers
- Farms and agricultural producers
- Schools, universities, and educational institutions
- Municipal waste and recycling programs
- Community-based organizations (e.g., food pantries, shelters)
- Nonprofit organizations and food banks
- Food manufacturers and distributors

- Local governments or policymakers
- Health and wellness organizations

QX: Do you currently track the amount of food your organization diverts from waste?

- Yes, we track and report regularly.
- Yes, but tracking is not consistent.
- No, we do not currently track diversion.

QX: What resources would help your organization better manage food recovery efforts? (Select up to 3)

- Training on food safety and donation best practices
- Public education campaigns to reduce food waste
- Better tracking and reporting tools for food diversion
- Policy guidance on food donation laws and protections
- Funding or grants for expanding food recovery operations
- Partnerships with local food recovery networks or coalitions
- Improved access to refrigerated storage and transportation options
- Research on new technologies for food waste reduction and recovery
- Volunteer recruitment and management resources

Residents

QX: What is your zip code?

QX: How often do you consider the environmental impact of the waste generated from the items you purchase?

- Always
- Frequently
- Occasionally
- Rarely
- Never

QX: Which of the following actions do you take to reduce waste in your household? (Select all that apply)

- Purchasing products made from recycled materials
- Reducing food waste by planning meals, buying less, or repurposing leftovers
- Choosing products with minimal or recyclable packaging
- Composting yard waste
- Using refillable containers and shopping at refill stores
- Using reusable bags, containers, and water bottles
- Repairing, mending, or repurposing items instead of discarding them
- Donating, swapping, or selling used items
- Reducing online purchases or combining shipments
- Shopping secondhand (e.g., clothing, furniture, electronics)
- Avoiding disposable or single-use items (e.g., plates, cups, utensils)
- Participating in curbside or drop-off recycling programs

- Refusing free items or promotional giveaways you don't need
- I don't actively try to reduce waste in my household

QX: Do you have access to recycling at home or where you live?

- Yes, I have curbside recycling.
- Yes, but I have to take my recyclables to a drop-off site.
- No, I do not have access to recycling.
- I'm not sure / I don't recycle.

QXa: Where do you typically get information about how to recycle properly? (Select that all apply)

- City or county website
- Social media or online articles
- Sticker or signage on my recycling container or at the local drop-off center
- Flyers or mailers from local waste service providers
- Friends, family, or word of mouth
- Knowledge gained from previous recycling efforts
- I don't actively seek out recycling information
- Other (please specify):

QX: How would you feel if your local government required residents to sort food scraps into a separate curbside collection bin?

- I would fully support this, as I already compost.
- I would support this if the process was easy, convenient, and well-explained.
- I would have concerns about cost, convenience, or potential odor.
- I would oppose this change.

QX: Do you feel like your concerns about waste and recycling are heard by decision-makers?

- Yes, I feel represented in decision-making.
- Somewhat, but I don't know how to provide input.
- No, I don't feel included in decision-making.
- I've never thought about this.
- Other (please specify):

QX: How much of a positive impact do you think waste has on Minnesota's economy? Economic impacts could include revenue from material sales, supporting local jobs, etc.

- 1 – Negative Impact – Managing waste costs more money than it provides
- 2 – Low Impact
- 3 – No Impact – The economic benefits equal out
- 4 – Medium Impact
- 5 – High Impact – Managing waste creates jobs and economic opportunities

QX: Do you know where to bring hard-to-recycle materials like mattresses, household hazardous waste, or tires?

- Yes, I know exactly where to take them.

- I have a general idea but would need to look it up.
- No, I don't know where to dispose of these items.
- No, I usually trash these items or leave them at the curb.

QX: What ideas do you have for improving waste reduction and recycling in our state? Are there specific programs, policies, or resources you think would make a difference?

Appendix E.4 Closing

Click the arrow below to finish the survey.

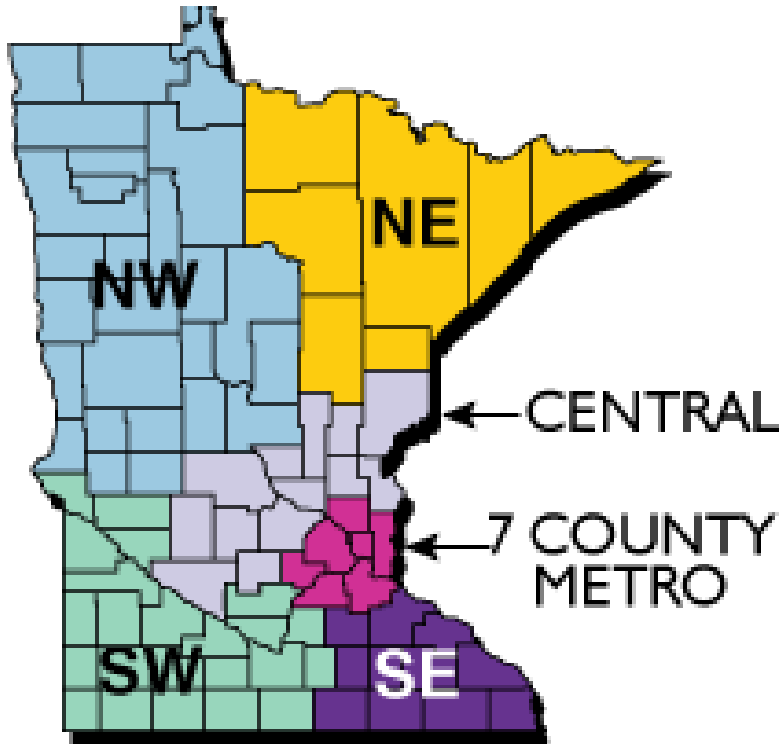
Thank you for your time and for sharing your thoughts! If you'd like to stay engaged in the future of materials management in the state, visit [the Resource Management Report website](#). If you are interested in providing more in-depth feedback, you can sign up for a phone interview on the [website](#).

Reach out to info@mnresourcemanagementreport.org if you have any further questions or comments.

Appendix F – Regional Map

Minnesota Regional Map used for the survey. The map is sourced from the [MN Department of Employment and Economic Development](#).

Figure 106. Map of Minnesota with identified solid waste planning regions



Glossary

Aerated Static Pile (ASP): A composting method in which organic materials are piled and aerated using a system of perforated pipes or blowers, without the need for turning.

Artificial Intelligence (AI): The field of computer science focused on creating systems that can perform tasks typically requiring human intelligence, such as learning, reasoning, problem solving, and understanding language. AI can be used in MRF operations to help sort material.

Anaerobic Digestion (AD): Anaerobic Digestion is a process in which microorganisms break down organic material in an environment without oxygen. During the digestion process, microorganisms produce biogas (methane) which can be converted to natural gas as a renewable source of energy.

Commercial, Industrial, and Institutional (CII) Waste: Waste generated by businesses, institutions, and industrial facilities.

Construction and Demolition (C&D): Waste generated during the construction, renovation, repair, and demolition of buildings, roads, and other structures.

Density Separator: Density separation systems sort materials using the difference in specific gravity of materials, which are suspended in a medium such as water, sand, or air. Less dense materials float to the top of the medium, while more dense materials sink to the bottom.

Deposit Return Systems (DRS): Programs where consumers pay a deposit on beverage containers and receive a refund when they return the container for recycling.

Drum Separator: Drum separators use a combination of high-speed conveyors, fans, and a rotating drum to separate materials based on weight and density.

Eco-modulation: A fee structure within Extended Producer Responsibility (EPR) that incentivizes using materials and design attributes that reduce the environmental and human health impacts of materials.

Eddy Current Separator: A type of sorting equipment that uses magnetic rotors to create a force called an eddy current that separates non-ferrous metals such as aluminum, die-cast metal, and copper, from non-metallic materials like paper or plastic.

Extended Producer Responsibility (EPR): An environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of that product's life cycle.

GHG Emissions: Greenhouse gas emissions, including carbon dioxide, methane, and other gases that contribute to climate change.

Household Hazardous Waste (HHW): Wastes generated that are dangerous or potentially harmful to human health or the environment.

IMPLAN: A widely used economic modeling system that estimates the economic impacts of industries, policies, or projects, including jobs, output, and taxes.

In-Vessel Composting: A controlled composting process where organic materials are enclosed in a vessel, drum, or container to optimize decomposition and control temperature, moisture, and odor.

Materials Recovery Facility (MRF): A solid waste plant that sorts and processes materials to prepare them for recycling. MRFs may accept dual-stream or source-separated recyclables where materials such as paper have been sorted by individuals before collection, commingled recyclable material, or mixed streams that contain both solid waste and recyclable material. The sorting equipment and technology integrated into a MRF depends on what type of material stream it is designed to accept.

Mixed Waste Processing (MWP): A facility or system that receives unsorted municipal solid waste and separates it into recyclable, compostable, and residual waste streams using mechanical and/or manual methods.

Multi-Family Units: Residential buildings containing multiple separate housing units, such as apartments, condos, or townhomes.

Municipal Solid Waste (MSW) – MSW refers to household waste, commercial waste, waste generated by other nonindustrial locations, waste with characteristics similar to that generated at a household or commercial business, or any combination thereof. MSW does not include municipal wastewater treatment sludges, industrial process wastes, automobile bodies, combustion ash, or C&D debris.

NAICS Codes: Standardized codes from the North American Industry Classification System used to classify business establishments by industry.

Near-infrared (NIR) Image Recognition: A technology that uses sensors to detect and analyze materials based on how they reflect near-infrared light

Single-Stream Recycling (Onsite Recycling SSR) : The practice of collecting, sorting, and processing recyclable materials at the same location where they are generated, such as a business, institution, or construction site, rather than transporting them to an offsite facility.

Optical Sorting: Optical sorting systems are a technology that includes advanced cameras and sensors to identify waste and use jets of air to move and sort materials into categories.

Organic Separation Press (OSP): An Organic Separation Press employs a compression auger and a hydraulic door which squeezes nutrient-rich liquid from organic material, which is collected in tanks and processed via composting or anaerobic digestion.

PFAS (Per- and Polyfluoroalkyl Substances): A group of human-made chemicals used in a wide range of products for their water-, grease-, and stain-resistant properties.

Post-Consumer Recycled (PCR): Materials recovered from products that have been used and discarded by consumers, then reprocessed into new products.

Recycled Content: The proportion of a product made from recovered materials rather than virgin materials.

Recycling Shredders: Shredding machines cut materials into smaller, more uniform pieces for further processing. Shredding also reduces material volumes which makes it easier to manage and transport. Shredding machinery can be used on a wide variety of materials, including metal, plastic, paper, wood, and electronics.

Reuse Facility: A dedicated site where used goods and materials are collected, sorted, and made available for redistribution, remanufacturing, resale, or donation, extending their useful life and diverting them from disposal.

SCORE Funding: State or local grants (often from recycling or waste programs) provided to support waste reduction, recycling, or organics management initiatives.

Screens: Screening equipment is a common type of machinery in MRFs that separate materials. For example, ballistic screens separate containers from flat materials. Elliptical screens may be designed so that lighter materials like paper run over the screen, heavier materials like containers bounce backwards from the screen, and small materials like broken glass fall through holes that remove them from the stream.

Single-family/Single-family Units: Residential buildings designed to house one family, typically a standalone home with its own entrance and utilities.

Source-Separated Organics (SSO) Facilities: Specialized facilities that receive and process organic materials (such as food scraps, yard trimmings, and soiled paper) that have been separated from other waste streams at the point of generation.

Static Pile Composting: A composting method where organic materials are piled and aerated without turning, often using perforated pipes or blowers.

Subscription service: A recurring, fee-based arrangement in which households, businesses, or organizations pay a provider for regular waste collection, recycling, or related services.

Throughput Capacity: The maximum amount of material that a facility or system can process over a specific period, usually measured per day or year.

Tons-Per-Year (TPY): A unit of measurement expressing the total weight of a material, substance, or waste stream generated, processed, or disposed of over the course of one year.

Trommel: A trommel is a type of screen that sorts materials based on size, using mesh which allows small materials to pass through and large materials to pass over. Trommel systems may employ screens of various sizes or screens with shredding technology.

Waste-to-Energy (WTE): A process or facility that converts non-recyclable waste materials into usable forms of energy, such as electricity, heat, or fuel, typically through combustion, gasification, or other thermal technologies.

Wet Separation: Wet separation techniques, as opposed to “dry” separation techniques, make use of water or the moisture-content of materials to aid separation. For example, pulping mashes high-moisture organic materials into a paste-like mixture to prepare for additional processing. Other wet separation processes place materials into tanks, where materials can be filtered by size through sieves that separate large items from smaller items. Tanks may also separate materials through flotation and settling, where buoyant materials may be skimmed from the top, and heavy materials sink to the bottom for recovery.

Windrow Composting: A long, narrow pile of organic materials arranged for composting, typically turned periodically to maintain aerobic conditions.

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