

Cost-Effective Contamination Reduction Methods

OREGON DEQ MULTI-SECTOR RECYCLING CONTAMINATION STUDY
PREPARED BY THE RECYCLING PARTNERSHIP AND CASCADIA CONSULTING
GROUP

Table of Contents

Executive Summary	3
Report Overview	3
Summary Recommendations	4
Research Approach and Summary Findings.....	9
Research Approach and Methodology	9
Summary of Research Findings	10
Summary of Tactics & Research Gaps	15
Summary of Recommendations	16
Detailed Research Findings	17
Research Approach and Methodology	17
Single-family Findings	18
Multifamily Findings.....	21
Commercial Findings	24
Self-Haul Findings	26
Diverse Audience Findings.....	28
Recommendations for Contamination Reduction Strategies.....	29
Background and Approach	29
Summary of Recommendations	30
Single-Family.....	30
Multifamily	34
Commercial.....	36
Self-Haul.....	39
Diverse Audiences	40
Recommendations for Future Research	42
References	67
Appendices	72
Appendix A: Research Notes.....	72
Appendix B: Recommended Material Audit Sort Categories.....	91

Executive Summary

Report Overview

This document assesses and summarizes the state of research on the cost and effectiveness of generator-facing contamination reduction methods with single-family, multifamily, commercial, and self-haul generators. This study was conducted by The Recycling Partnership with Cascadia Consulting Group (Cascadia) for the Oregon Department of Environmental Quality (DEQ). The study included review of study availability, research quality, and gaps in research. DEQ's goal for this memo was to identify:

- A list of the most promising contamination reduction strategies for DEQ to recommend to local governments. The list must be categorized by applicability to different generator types and include options for a range of community types.
- Recommendations for future field research that DEQ could consider funding or fostering in the next five years to fill the largest gaps in knowledge.

The document is divided into four sections:

1. Key Research Findings.

This section briefly summarizes the research approach, research findings, and effectiveness of (or lack of research on) contamination reduction tactics for each of the four generator types and diverse audiences. It also includes the recommendations for contamination reduction strategies for Oregon communities.

2. Detailed Research Findings

This section describes the research approach and provides more detail on the findings from existing contamination reduction research. This includes the findings from desktop research that identify existing research, best practices, and tactics with potential to reduce contamination with each of the four generator types.

3. Recommendations for Contamination Reduction Strategies

Building on the foundational research, this section includes recommendations for contamination reduction strategies for each sector, noting the applicability within the context of Oregon's recycling system and with a variety of community types. Each recommended strategy is supported by research findings and includes notes on any research gaps for that strategy.

4. Recommendations for Future Research

This section proposes study designs to fill the most critical research gaps, proposing at least one study for each generator type. This research could increase DEQ's confidence in the effectiveness or ineffectiveness of recommended strategies, add new tactics to the list of recommended strategies, or provide a better understanding of the applicability of strategies for Oregon communities.

Summary Recommendations

Table 1 through Table 4 summarizes the recommended contamination reduction strategies for each generator type and includes the research gaps, recommendations to fill these research gaps, estimated costs and likely cost-effectiveness of each strategy. The content of this table can help frame both what we know and what remains to be learned about each strategy.

Table 1. Key Results and Recommendations for Single-Family Residential Generators

Strategies	Contamination Reduction	Research Gaps	Recommended Research	Cost Estimate	Likely Cost-Effectiveness
Cart tagging (4 tags), cart rejection and mailing	19-62%	Effectiveness of strategy in areas with contamination of 10-15% Long term durability of impact	Testing of tactic in community with contamination rates of 10-15%	\$4-7 per household	Medium
Cart tagging (4 tags) and mailing	Unknown, in one study was half as effective as when combined with cart rejection	Effectiveness of strategy in areas with contamination of 10-15%	Testing of tactic in community with contamination rates of 10-15%	\$4-7 per household	Medium
Multipronged approach from British Columbia (cart inspections, cart rejection, paid media, mailings, outreach events, fines)	Unknown reduction, contamination levels of less than 10%	Specific impact of each tactic Equity in application of contamination charges to various demographic groups Cost to deploy	Implementation of each component as a unique strategy Survey or focus group with multicultural communities	Unknown	Unknown
Dual-stream collection	50% - 65% reduction	Durability of impact without supplemental education	Tracking of contamination for two years after implementation with limited education	\$8+ per household annually	Low

Strategies	Contamination Reduction	Research Gaps	Recommended Research	Cost Estimate	Likely Cost-Effectiveness
Cart tagging (2 tags), cart rejection and mailing [provisional recommendation]	Unknown, 19% reduction in one study	Effectiveness of strategy in areas with contamination of 10-15%	Testing of tactic in community with contamination rates of 10-15%	\$3-5 per household	Medium
Change cart decals and lid colors to increase recycling container clarity [provisional recommendation]	10-20%	Effectiveness of strategy in areas with less than 20% contamination Replication of findings to determine impact on routes with high contamination Cost to deploy	Testing of tactic in community with contamination rates less than 20% Testing of tactic on routes with high contamination	Unknown	Unknown
Cameras on collection trucks with generator feedback delivered by mail [provisional recommendation]	23-41%	Effectiveness of strategy Durability of impact	Testing strategy in two communities Tracking of contamination occurrence for up to 18 months after implementation	\$2-4 per household during the first year; \$1-\$2 annually in subsequent years	Unknown

Table 2. Key Results and Recommendations for Multifamily Residential Generators

Strategies	Contamination Reduction	Research Gaps	Recommended Research	Cost Estimate	Likely Cost-Effectiveness
Multipronged approach including inspections, education, and fines	Unknown reduction, contamination levels of 5-7%	Specific impact of each tactic Equity in application of contamination charges to various demographic groups Cost to deploy	Implementation of each component as a unique strategy Survey or focus group with multicultural communities	Unknown; costs will depend on property size	Unknown
Improvements to containers, service levels, and education [provisional recommendation]	Unknown, impact ranges from no impact to up to 55% reduction	Effectiveness of strategy Durability of impact	Testing of tactic in another community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
Containers with chute lids [provisional recommendation]	Unknown, 17% reduction in one study	Effectiveness of strategy Durability of impact Impact of chute lids on residents with disabilities	Testing of tactic in another community Tracking of contamination occurrence for up to 18 months after implementation Survey or focus group with residents with disabilities that live in multifamily housing	Unknown	Unknown
Inspections with service refusal [provisional recommendation]	Unknown, 29% reduction in one study	Effectiveness of strategy Durability of impact	Testing of tactic in another community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
Dual-stream collection [provisional recommendation]	Likely 50%	Durability of impact without supplemental education	Tracking of contamination for two years after implementation with limited education	Unknown	Unknown

Table 3. Key Results and Recommendations for Commercial Generators

Strategies	Contamination Reduction	Research Gaps	Recommended Research	Cost Estimate	Likely Cost-Effectiveness
Multipronged approach including inspections, education, and fines [provisional recommendation]	Unknown, contamination level of less than 7% in one community	Effectiveness of strategy Durability of impact	Testing of tactic in a community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
Containers with chute lids [provisional recommendation]	Unknown, 9% reduction in one community	Effectiveness of strategy Durability of impact	Testing of tactic in a community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
Inspections with service refusal [provisional recommendation]	Unknown	Effectiveness of strategy Durability of impact	Testing of tactic in a community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
On-board cameras, artificial intelligence, and generator feedback [provisional recommendation]	Unknown, 89% reduction in one article	Effectiveness of strategy Durability of impact	Testing of tactic in a community Tracking of contamination occurrence for up to 18 months after implementation	Unknown	Unknown
Dual-stream collection [provisional recommendation]	Unknown	Effectiveness of strategy Durability of impact without supplemental education	Testing of tactic in a community or on multiple commercial recycling routes Tracking of contamination for two years after implementation with limited education	Unknown	Unknown

Table 4. Key Results and Recommendations for Self-Haul Generators

Strategies	Contamination Reduction	Research Gaps	Recommended Research	Cost Estimate	Likely Cost-Effectiveness
Multipronged approach that combines onsite signage, resident mailings, social and traditional media promotions	Unknown, 58% reduction in one study	Specific impact of each tactic Durability of impact	Implementation of each component as a unique strategy Tracking of contamination occurrence for up to 18 months after implementation	\$2 per household plus \$1,000-\$2,000 per site	Medium
Full implementation of The Recycling Partnership Toolkit: combines educational survey, in person feedback, annual mailer, signage, website, social media promotions, and security features	20-28%	Specific impact of each tactic Durability of impact	Implementation of each component as a unique strategy Tracking of contamination occurrence for up to 18 months after implementation	\$2-\$3 per household plus \$8,000-\$12,000 per site	Medium
Mailings, signage, cameras, and electronic message board (no in person feedback, survey, or advertising)	Unknown, 74% reduction in one study	Specific impact of each tactic Durability of impact	Implementation of each component as a unique strategy Tracking of contamination occurrence for up to 18 months after implementation	\$2 per household plus \$5,000 per site	Medium
Full implementation of The Recycling Partnership Toolkit at a facility with no garbage service [recommended for research only]	Unknown	Impact on contamination	Comparison of recycling quality before and after implementation at least one facility with garbage service and one without garbage service	\$2-\$3 per household plus \$8,000-\$12,000 per site	Unknown

Research Approach and Summary Findings

This document assesses and summarizes the state of research on the cost and effectiveness of generator-facing contamination reduction methods with single-family, multifamily, commercial, and self-haul generators. This study was conducted by The Recycling Partnership with Cascadia Consulting Group (Cascadia) for the Oregon Department of Environmental Quality (DEQ). The study included review of study availability, research quality, and gaps in research. DEQ's goal for this memo was to identify:

- A list of the most promising contamination reduction strategies for DEQ to recommend to local governments. The list must be categorized by applicability to different generator types and include options for a range of community types.
- Recommendations for future field research that DEQ could consider funding or fostering in the next five years to fill the largest gaps in knowledge.

Research Approach and Methodology

The Recycling Partnership conducted desktop research to identify practices that have successfully reduced contamination or show potential to reduce contamination with single-family, multifamily, commercial, and self-haul to drop-off depots.

This research included the following approaches:

- Review of existing research meta-analysis and summaries conducted by and for DEQ, including literature reviews by Martin Brown (2022) and Cascadia (2020).
- Supplemental literature search of academic journals, government reports, and other relevant publications to identify research related to contamination reduction.
- Data call to The Recycling Partnership's community network and DEQ's Recycling Modernization Act email list to identify innovations and best practices that have been successful in other applicable contexts but may not be readily available online.
- Outreach to communities with high performing programs or that report low levels of contamination.

In this research, The Recycling Partnership attempted to identify strategies that would be responsive to needs of diverse populations, as defined by the [Oregon Department of Environmental Quality \(2023\) draft rule concept](#), and to examine four types of diverse populations including:

- People whose first language is not English
- People with low incomes
- People who live in rural areas
- People with disabilities

In conducting this research, The Recycling Partnership evaluated the rigor and applicability of the studies that were identified as most promising. Additionally, The Recycling Partnership considered the context in which studies may be applicable to different communities, budgets, and the current Oregon recycling system.

Summary of Research Findings

Oregon communities can learn from both successful and unsuccessful interventions deployed to reduce contamination with single-family, multifamily, commercial, and self-haul generators across the United States and Canada.

Single-family residential contamination is the most well studied, and research supports success with feedback, service rejection and education to reduce contamination. **Multifamily residential** contamination is moderately studied and more complex because many households share containers managed by a third party; however, programs that use a combination of education, service improvements, and enforcement have seen some success. With **self-haul at drop-off depots**, basic investments in education and signage can have a significant impact on contamination. **Commercial sector contamination** has major research gaps and much still needs to be studied for this sector, although we can apply the findings from other sectors.

In this research, many studies did not adequately measure effectiveness in reducing contamination, report total or per-household costs, or evaluate cost-effectiveness. Further research is needed to understand the effectiveness of various tactics, the durability of impacts and the cost effectiveness of contamination reduction strategies. This need is strongest in the commercial sector where very few studies have been conducted. Additionally, more information on cost is needed to determine cost effectiveness, especially for multifamily and commercial strategies.

Single-Family Residential

Table 5. Effective Tactics for Single-Family Residential Generators

Supported by 3+ solid studies	Combination of feedback cart tagging, service rejection, and mailings Dual-stream collection
Supported by 1-2 solid studies	Cart lids, different lid colors for recycling carts Switching to dual-stream collection Cameras on collection trucks with resident feedback Combination of inspections, cart rejection, community education and contamination charges

Contamination reduction with single-family generators is the most well studied, with the bulk of the research around feedback cart tags and mailings, which are shown to be effective. Four cart tags, service rejection and one mailer led to reductions in contamination between 19-62% in multiple communities (The Recycling Partnership, 2021c; The Recycling Partnership, 2022; Staub, 2021b; Waste Advantage Magazine, 2023). In four communities, the decrease in

contamination continued for ten months to three years after the intervention was completed (The Recycling Partnership, 2018; The Recycling Partnership, 2021c; The Recycling Partnership, 2022; M. Orr, personal communication, December 12, 2023).

Cart lids, different lid colors for recycling carts, switching to dual-stream collection, and cameras on collection trucks with resident feedback also reduced contamination (Loft, 2021; Prairie Robotics, 2022; Paben, 2019; Cascadia Consulting Group, 2020, The Recycling Partnership, 2024). Additionally, communities in British Columbia with single-stream collection have used a combination of inspections, cart rejection, community education and contamination charges have achieved low rates of contamination (City of Terrace, 2021; Link, 2023; M. Dick, personal communication, December 6, 2023; S. Subido, personal communication, December 21, 2023). Recycle BC noted many communities choose to operate multi-stream collection because of lower contamination. In 2022, the contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream collection (P. Cupcupin, personal communication, February 5, 2024).

The largest research gaps are the individual impact of various tactics at reducing contamination and the durability of impact for effective methods.

Multifamily Residential

Table 6. Effective Tactics for Multifamily Residential Generators

Supported by 3+ solid studies	<ul style="list-style-type: none"> • Multipronged approach including compliance and education: driver tagging, letters, inspection, and fines
Supported by 1-2 solid studies	<ul style="list-style-type: none"> • Improvements to containers, service levels, and education • Containers with chute lids • Inspections with service refusal

Many studies applied elements of successful single-family recycling and contamination reduction strategies to multifamily properties. While some of these studies have successfully reduced contamination, these reductions have not been as significant as they were for single-family properties (City of Toronto, 2019a; Lane County Public Works, 2021; Foreman, 2019; The Recycling Partnership, 2022; De Young et. al, 1995).

Strategies that combine education with changes to service levels, container location, and container types were more successful than education alone in three communities in Washington but had no impact on contamination in a Minnesota community (Cascadia Consulting Group, 2017; Green Solutions and Terra Linda Consulting, 2014; Waste Advantage Magazine, 2023; Wahlberg, 2020). Locking lids with a chute opening for recyclables have been part of successful contamination reduction initiatives in three communities (Continuous Improvement Fund, 2019, M. Giem, personal communication, December 8, 2023; J. Amador, personal communication, December 13, 2023).

Inspections and feedback on recycling quality are promising tactics for this sector. Regular container inspections with service rejections over a span of three years reduced contamination in

Toronto, Ontario from 16.02% to 11.32% (City of Toronto, 2019b). In two communities, contamination decreased at properties that used valet recycling collection with feedback on recycling quality or rejected materials. (Recycle Colorado, 2020; The Recycling Partnership, 2021d). However, both studies that looked at valet collection had significant limitations, described in this report, making it difficult to determine the impact of the interventions.

Efforts that combine inspections, education, and enforcement have been successful in three Pacific Northwest cities. Seattle, Washington attributes their contamination rate to coordinated efforts between operations, compliance, and education that combines driver training on contamination, driver tagging, letters sent for repeat contamination and, if contamination is not resolved, follow-up by an inspector with the potential of a \$50 fine (City of Seattle, 2022). Similarly, SeaTac, Washington has achieved a contamination rate of 5% with a strategy that combines inspections, technical assistance, chute lid openings, and contamination charges (Recology, n.d.; M. Giem, personal communication, December 8, 2023). A chute lid is a container lid with openings that allow only certain shapes or sizes of materials to enter (such as flattened cardboard or round cans and bottles) and keep out large items (such as bagged materials). The City of Kamloops, British Columbia has a multifamily contamination rate of 9% (Segundo & Schweers, 2023). With over 300 multifamily properties, the city provides education, inspections, service rejection, and contamination charges (M. Dick, personal communication, December 6, 2023).

Few multifamily studies have been replicated to validate their findings, making it difficult to determine which tactics are effective and even more challenging to determine the relative impact of tactics for the multifamily sector. Multifamily recycling and contamination are especially complex due to the wide variety of property sizes, types, layouts, and container configurations.

Commercial

Table 7. Effective Tactics for Commercial Generators

Supported by 3+ solid studies	<i>None</i>
Supported by 1-2 solid studies	Combined approach with audits, technical assistance, phone calls, warnings, and contamination charges Combined approach with audits, contamination charges and chute lids

While The Recycling Partnership found many articles listing best practices such as technical assistance, posters, and training, none of them had data to support their recommendations.

Inspections have contributed to contamination reduction in SeaTac, Washington and Denton, Texas (M. Giem, personal communication, December 8, 2023, J. Amador, personal communication, January 30, 2024). This strategy has also been effective with single-family and multifamily generators. Additionally, on-truck cameras and software that provide customer feedback is also a promising strategy for this sector.

Denton, Texas, the city distributed lock bars and chute lids at select commercial properties on the routes with high contamination, decreasing the commercial contamination rate by 9% compared to the previous year. Their commercial contamination rate is 34% (J. Amador, personal

communication, December 13, 2023; J. Amador, personal communication, January 30, 2024). This contamination rate is likely higher than in much of Oregon, suggesting that lock bars and chute lids may be the best fit on routes with highest contamination.

Given the lack of studies in this area, we looked to cities with low rates of contamination to identify program elements that may contribute to low contamination. SeaTac, Washington has reduced contamination to 6.5% with audits, technical assistance, warnings, and contamination charges (M. Giem, personal communication, December 8, 2023).

The Portland Metro area has a contamination rate of 14% and supports businesses in the region with technical assistance and resources such as stickers, signs, and flyers (Metro, 2020). Metro uses an education and technical assistance approach and does not include contamination monitoring or enforcement or focus on frequent contaminators.

The research gaps in the commercial sector are significant and additional investigation is needed to determine effective and cost-effective methods to reduce contamination.

Self-Haul

Table 8. Effective Tactics for Self-Haul Generators

Supported by 3+ solid studies	Combination of onsite signage, resident mailings, and media promotions Combination of onsite educational survey, in person feedback, annual mailer, signage, a website, social media promotions, and security features such as cameras or fencing
Supported by 1-2 solid studies	None

Studies conducted for drop-off recycling demonstrated a high level of contamination reduction with the addition of signage, resident mailings, direct onsite feedback to residents on recycling quality, and cameras to monitor contamination. Most of the studies that used updated signage and basic education reduced contamination by at least 20% (Township of McNab/Braeside, 2015; The Recycling Partnership, 2021b; The Recycling Partnership, 2023, Oulton, 2022). Site security features including fencing, cameras, and keycodes for residents resulted in a contamination rate of just 3% at one facility (L. Haubeil, personal communication, January 18, 2024).

Additional research is needed to determine how long the impacts and specific impacts of each strategy last, as most have been studied as bundled tactics. In addition, site conditions, such as staffing and access to garbage collection, are understudied and may impact recycling contamination rates.

Diverse Audiences

In searching for studies, an attempt was made to learn more about impact of tactics on residents first language other than English, with disabilities, with low incomes, and in rural areas. However, no studies included information about the impact on residents with disabilities. The findings within information on the impact on residents with a first language other than English, with low incomes, or on rural communities (other than drop-off) were limited to a few studies.

The self-haul to drop-off research included studies from rural areas as these are the areas that commonly have self-haul recycling programs. This research is detailed in the self-haul sections of this report. Research specific to rural areas from multifamily, commercial, and single-family audiences was not found.

Limited research was found on the impact of tactics with residents with a first language other than English or low-income residents. There was no information found for commercial or self-haul. Only one multifamily study explicitly focused on properties with multicultural communities. In this study, researchers deployed a combination of improvements to containers, service levels and education recycling that was translated and adjusted to provide adequate context (Cascadia Consulting Group, 2014). The project resulted in similar decreases in contamination as seen with other communities. The City of Kamloops issues tickets for contamination after repeat contamination. The tickets are issued to the homeowner, not the tenant, helping to address equity and issues with language as they suspect that the homeowners are more likely to be proficient in English and less likely to be low income (M. Dick, personal communication, December 6, 2023).

Summary of Tactics & Research Gaps

Tactic	Single-family	Multifamily	Commercial	Self-Haul
Feedback cart tagging and mailings	3+ studies	1-2 solid studies		
Cart decals and lid colors	Limited data	1-2 solid studies		
Cameras on collection trucks with generator feedback	1-2 Solid Studies			
Combination: BC multi-pronged approach (cart inspection & rejection, paid media, mailings, outreach events, fines)	3+ studies			
Larger garbage carts/containers on routes with high contamination	1-2 solid studies			
Dual-stream collection	3+ studies			
Containers labels, cart/container designs, signage		Limited data		1-2 solid studies
Combination: Improvements to containers, service levels and education		Limited data		3+ studies
Combination: Compliance, education, and enforcement		Limited data	1-2 solid studies	
Tactics for residents in rural or multicultural communities	Rural	Multicultural		

The color of the cell in the generator column denotes the quality and quantity of research.

White/Blank: Unknown impact due to no studies found, studies with inconclusive results or only found studies with significant limitations.

Orange: Limited data, one small study, sizable limitations

Yellow: One or two solid studies

Green: Three or more solid studies, replication in findings

Research did not identify studies demonstrating the impact of the following tactics:

- Service consequences such as cart removal, discontinuation of service after repeat contamination or contamination charges
- Standardized container colors
- Deposit-return systems to create alternative path for key contaminants

Additionally, the research did not provide clarity about potential of tactics to cause harm for residents with a first language other than English, with disabilities, or with low incomes. There was no information found for single-family, commercial, or self-haul. Only one multifamily study explicitly focused on properties with multicultural communities.

Summary of Recommendations

Based on the research findings, The Recycling Partnership evaluated whether enough published evidence exists to determine the effectiveness of contamination reduction strategies. This evaluation considered factors such as the quality and consistency of existing evidence, the types of evidence available, whether studies show a long-term effect, and the applicability of evidence to the specific characteristics of the Oregon recycling system and the variety of Oregon communities.

Where sufficient evidence exists, the list of recommended strategies for local governments identifies which generators they apply to and which community types they are most suitable for. Where sufficient research does not exist for all community types, we recommended strategies provisionally based on available data and propose to develop recommendations for future research.

Sector	Tactics
Single-family: Recommended	<ul style="list-style-type: none"> • Cart tagging (4 tags), cart rejection and mailing • Cart tagging (4 tags) and mailing • Multipronged approach from British Columbia • Dual-stream collection
Single-family: Provisional	<ul style="list-style-type: none"> • Cart tagging (2 tags), cart rejection and mailing • Change cart decals and lid colors to increase recycling container clarity • Cameras on collection trucks with generator feedback
Multifamily: Recommended	<ul style="list-style-type: none"> • Multipronged approach that combines inspections, education, and fines
Multifamily: Provisional	<ul style="list-style-type: none"> • Improvements to containers, service levels, and education • Containers with chute lids • Inspections with service refusal • Dual-stream collection
Commercial: Recommended	<ul style="list-style-type: none"> • None
Commercial: Provisional	<ul style="list-style-type: none"> • Multipronged approach that combines inspections, education, and fines • Containers with chute lids • Inspections with service refusal • On-board cameras, artificial intelligence, and generator feedback • Dual-stream collection
Self-Haul: Recommended	<ul style="list-style-type: none"> • Multipronged approach that combines signs, mailings, and advertising • Multipronged approach combines onsite survey, feedback, mailings, website, social media, and security features
Self-Haul: Provisional	<ul style="list-style-type: none"> • Improvements to site signage, direct mailings to residents, addition of cameras and electronic message board.

Detailed Research Findings

This section starts by describing the approach and methodology used in this research. It then describes findings on existing research, best practices, and tactics with potential to reduce contamination for each of the groups researched:

- Single-Family Residential
- Multifamily Residential
- Commercial
- Self-Haul
- Diverse Audiences

Research Approach and Methodology

Following the review of existing research, meta-analysis and summaries conducted by and for DEQ by Martin Brown (2022) and Cascadia (2020), The Recycling Partnership conducted a literature review on generator-facing contamination reduction strategies to identify and evaluate available studies.

The Recycling Partnership focused on identifying applicable research on strategies beyond education and feedback schemes that make up most of existing literature. These alternative strategies include socio-behavioral interventions, relationship-building and capacity-building work with community-based organizations, changes to operational systems, and technology-based feedback and monitoring. To identify relevant research, The Recycling Partnership reviewed Google Scholar, recycling industry publications, and findings from The Recycling Partnership's existing contamination programming.

The Recycling Partnership also met with recycling program managers to learn more about successful contamination reduction initiatives in SeaTac, Washington; Denton, Texas; Kamloops, British Columbia; and Abbotsford, British Columbia.

Finally, The Recycling Partnership and DEQ also reached out to their community networks to identify innovations and best practices that have been successful in other applicable contexts. The Recycling Partnership posted data requests to our robust network of over 3,000 community recycling program partners across the U.S. through our monthly community newsletters in November and December 2023, followed by posts to The Recycling Partnership's Facebook page with 420 community recycling coordinator members. The research request sought case studies or pilots for contamination reduction strategies for each recycling sector (single-family, multifamily, commercial, and self-haul). It also sought data on which tactics are effective for rural communities and with residents with a first language other than English, with disabilities, low income, or multicultural communities. The request highlighted contamination reduction programming or research in the following areas:

- Testing of materials, labels, and cart design
- Customer feedback, incentives, or service consequences

- Using AI, cameras, and other technologies
- Testing of cart and/or container design (such as modified lids), standardized colors and signage, and varying sizes and locations
- Programmatic or infrastructure changes such as switch to dual-stream collection

DEQ requested data and research from its Recycling Modernization Act email list for local governments, haulers, and others engaged in rulemaking in Oregon in January 2024, specifically asking for information on:

Testing of variables such as materials, labels, and signage or cart design, color, size, and location
Customer feedback, incentives, or service consequences

Using artificial intelligence, cameras, and other technologies

Programmatic or infrastructure changes such as switch to dual-stream collection

Research tailored to any type of customer or community, including single-family and multifamily residents, businesses, and self-haul, in both urban and rural settings.

The Recycling Partnership reviewed the few submissions received from both data requests and followed up by email with questions on relevant research. This data request minimally supplemented the literature review and interviews with program managers.

Single-family Findings

Research Summary

The bulk of the literature around contamination reduction tactics for single-family properties was focused on **cart tagging and mailings**. This tactic continues to be the most well-documented strategy for reducing contamination. In communities that distributed cart tags and mailings, contamination was reduced by 19-62% (The Recycling Partnership, 2021c; The Recycling Partnership, 2022; Staub, 2021b; Waste Advantage Magazine, 2023). Most studies measured the impact of these interventions over only a few months, making it difficult to determine the durability of impact. However, in four of the five studies (outlined below), the contamination reduction impact continued for ten months to three years (The Recycling Partnership, 2018; The Recycling Partnership, 2021c; The Recycling Partnership, 2022; M. Orr, personal communication, December 12, 2023).

The City of San Jose, California conducted pilots that examined the impact of **cart decals, lid colors, and garbage cart size**, which resulted in contamination reductions on routes with high contamination (Loft, 2021; R. Varghese, personal communication, March 30, 2023).

Cameras on collection trucks with feedback postcards are a promising strategy to gather more specific information about contaminants, identify individual households that are contaminating recycling, and offer feedback on recycling quality. In one pilot in the City of Regina, Saskatchewan, the community worked with Prairie Robotics on a three-month campaign where residents were mailed postcards that identified contamination in single-family carts. This pilot resulted in a 41.5% decrease in contamination (Prairie Robotics, 2022). In another study conducted by The Recycling Partnership (2024), generator feedback by mail reduced

contamination by 22.5%. As this technology is emerging, the studies and findings have not been widely replicated and limited data is available on its effectiveness.

Communities in British Columbia offer a glimpse of the possibilities to reduce contamination. Both the City of Kamloops (population 90,000) and the City of Abbotsford (population 150,000) have contamination rates under 7% with single-stream collection. These contamination rates were achieved with significant investment from the communities that combined **cart inspections, cart rejection, paid media, mailings, community outreach events and contamination fines** of up to \$100 per occurrence (M. Dick, personal communication, December 6, 2023; S. Subido, personal communication, December 21, 2023). Similar results have been seen in Terrance (population 12,000) with comparable education and enforcement (City of Terrance, 2021; Link, 2023).

Contamination has been reduced by 50-65% in several communities that had single-stream collection and **switched to dual-stream collection while providing education** (Paben, 2019; Cascadia Consulting Group, 2020). However, education is also deployed as communities are switching from single-stream to dual-stream collection, so the full reduction cannot be attributed to the change in collection alone. In British Columbia, many communities choose dual-stream collection because it results in lower contamination. In 2022 Recycling BC found the **contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream** collection. (P. Cupcupin, personal communication, February 5, 2024).

Single-family Research Gaps

The largest research gaps are the impacts of individual tactics on contamination, the cost-effectiveness of these tactics, and the durability of impacts for methods demonstrated to be effective.

Cart tagging, service rejection, and mailings have been well studied as effective contamination reduction strategies in the short term, but less is known about the durability of this impact. Four studies showed a durability of impact that is more than 10 months to three years. However, only one of these studies lasted more than one year after the program implementation, leaving a significant gap in the data to determine the durability of impact of these interventions.

Artificial intelligence, cameras and other technologies offer promising strategies to reduce contamination. However, limited data is available for this emerging technology, so the impact of these tactics is unknown even in the short term. Additionally, the information on the cost to implement these tactics is limited.

Abbotsford and Kamloops, BC have implemented numerous strategies resulting in low rates of contamination. However, because multiple strategies were implemented simultaneously, we cannot determine the impact of individual components.

The “pay as you throw” model may create a financial incentive for some households to place garbage in the recycling. More research is needed to better understand the prevalence of recycling contamination caused by lack of sufficient garbage service and tools to address this. The 2022 San Jose pilot where residents on high contamination routes were offered a larger cart

provides some insight how the rate model may be incentivizing contamination in some households. There is potential for AI, cameras, and other technologies to be useful tools in identifying households that are misusing recycling containers. Once households are identified, resident feedback, contamination charges and/or cart removal could help to address contamination. Although these strategies were common in the literature review, studies lack sufficient detail to determine their effectiveness. They also did not address the potential for pay-as-you-throw models with financial or service consequences to create disproportionate impacts on low-income households.

Other research gaps include the impact of:

- Tactics with residents with a first language other than English, with disabilities, with low incomes, or in rural or multicultural communities.
- Standardized colors and containers.
- Various cart labels and cart designs.
- Contamination charges and warnings.
- Discontinuation of service after repeat contamination.
- Enhancing drop-off or separate curbside recycling collection of contaminants, such as flexible plastics, to help move these materials out of the curbside recycling stream.

Single-family Tactics Summary & Research Gaps

Tactic	Impact on Contamination	Quantity & Quality of Research*	Specific Research Gaps
Cart tagging and mailings	19% - 46% reduction	3+ solid studies	<ul style="list-style-type: none"> • Durability of impact – Studies suggest 10 months to three years • Cost-effectiveness
Multipronged approach from BC (cart inspections, cart rejection, paid media, mailings, outreach events, fines)	Achieve contamination rates of less than 7%	3+ solid studies	<ul style="list-style-type: none"> • Specific impact of each intervention • Cost-effectiveness
Dual-stream collection	50% - 65% reduction	Results in 3+ communities	<ul style="list-style-type: none"> • Impact of collection change separate from education about dual-stream • Durability of impact • Cost-effectiveness

Tactic	Impact on Contamination	Quantity & Quality of Research*	Specific Research Gaps
Larger garbage carts on routes with high contamination	16 percentage points	1-2 solid studies	<ul style="list-style-type: none"> • Impact on individual households • Durability of impact • Cost-effectiveness
Cameras on collection trucks with resident feedback	22% - 41% reduction	1-2 solid studies	<ul style="list-style-type: none"> • Durability of impact • Cost-effectiveness
Cart decals and lid colors	20% reduction on routes with high contamination No impact on routes with average contamination	Limited data	<ul style="list-style-type: none"> • Results are from a single study (not replicated) • Durability of impact • Cost-effectiveness

*Quality and Quantity of Research:

- White/Blank: Unknown impact due to no studies found, studies with inconclusive results or only found studies with significant limitations.
- Orange: Limited data, one small study, sizable limitations
- Yellow: One or two solid studies
- Green: Three or more solid studies, replication in findings

Multifamily Findings

Research Summary

Many studies have applied elements of successful single-family contamination reduction strategies to multifamily properties. When applied to multifamily, the reductions have not been as significant as they were for single-family properties (City of Toronto, 2019a; Lane County Public Works, 2021; Foreman, 2019; The Recycling Partnership, 2022; De Young et. al, 1995). Common strategies include educational flyers or door hangers, in-home recycling bins, and workshops.

Strategies that combine changes to service levels, container locations, container types, and education, have been more successful at reducing contamination than education alone (Cascadia Consulting Group, 2017; Green Solutions and Terra Linda Consulting, 2014). In King County, Washington, contamination was reduced by an average of 50% at 18 properties, decreasing from an average of 16% to 8% by volume (Cascadia Consulting Group, 2017). In Lewis County, Washington, these efforts reduced contamination by up to 55% (Waste Advantage

Magazine, 2023). However, when similar interventions were deployed in Hennepin County, Minnesota, there was not a reduction in contamination (Wahlberg, 2020).

Inspections and feedback on recycling quality are promising tactics for this sector. Regular container inspections over three years reduced contamination in Toronto, Ontario from 16.02% to 11.32% (City of Toronto, 2019b). In Denver, Colorado, and San Marcos, Texas, contamination was reduced for properties that used valet recycling collection with feedback on recycling quality or rejected materials (Recycle Colorado, 2020; The Recycling Partnership, 2021d). However, both studies that looked at valet collection had significant limitations, making it difficult to determine the impact of the interventions.

In three communities, **locking lids with a chute opening for recyclables was part of successful contamination reduction initiatives.** In the Region of Peel, Ontario, lids resulted in a 17% reduction in contamination (Continuous Improvement Fund, 2019). The City of SeaTac, Washington, and Denton, Texas also reduced contamination with the addition of chute lids in combination with other tactics (M. Giem, personal communication, December 8, 2023; J. Amador, personal communication, December 13, 2023).

Seattle, Washington has a contamination rate of 11.4% for multifamily. The city attributes this to **coordinated efforts between operations, compliance, and education that combines driver training on contamination, driver tagging, letters sent for repeat contamination** and, if contamination is not resolved, follow-up by an inspector with the potential of a \$50 fine (City of Seattle, 2022). Similarly, SeaTac, Washington has reduced contamination to 5% with a strategy that **combines inspections, technical assistance, chute lids, and contamination changes** (Recology, n.d.; M. Giem, personal communication, December 8, 2023). The City of Kamloops, British Columbia has a multifamily contamination rate of 9% (Segundo & Schweers, 2023). With over 300 multifamily properties, the city provides education, inspections, service rejection, and contamination charges (M. Dick, personal communication, December 6, 2023).

Multifamily Research Gaps

Few studies have been replicated, making it difficult to determine which tactics are effective and even more challenging to determine the relative impact of tactics for the multifamily sector. Multifamily recycling and contamination are especially complex due to the wide variety of complex sizes and types, layouts, and varying types of container configurations.

Other research gaps include the impact of:

- Tactics with residents with a first language other than English, with disabilities, with low incomes, or in rural or multicultural communities.
- Standardized colors and containers.
- Various cart labels and cart designs.
- Contamination charges and warnings.
- Discontinuation of service after repeat contamination.
- Artificial intelligence, cameras, and other technologies; and

- Programmatic or infrastructure changes such as switching to dual-stream collection.

Multifamily Family Tactics Summary & Research Gaps

Tactic	Impact on Contamination	Quantity & Quality of Research*	Specific Research Gaps
Multipronged approach including compliance and education: driver tagging, letters, inspection, and fines	Seattle: Contamination rate of 11% SeaTac: Reduction from 40% to 5% over 3-years Kamloops: Contamination rate under 7%	Results in 3+ communities	Specific impact of each intervention Durability of impact
Unit-level feedback and rejection (valet waste)	Reduction, not statistically significant Improvement in quality, reducing contamination to 3%	1-2 solid studies	Impact of tactic Two studies show some reduction, with limitations
Improvements to carts, labels, and signage	Reduction (unspecified)	1-2 solid studies	Impact of tactic
Containers with chute lids	17% reduction in Peel, ON	Limited data	Results are from a single study (not replicated) Other pilots, combined lids with other tactics Durability of impact
Inspections with service refusal	29% reduction in Toronto over 3-years	Limited data	Results shown are from a single study (not replicated) Durability of impact
Improvements to containers, service levels + education	No impact in some studies Decreases in some studies	Studies with conflicting results, but 1-2 more showing decrease	Impact of tactics

In home bins, container decals, door hangers, mailings, on site education	No impact in some studies Decreases in some studies	Studies with conflicting results	Impact of tactics
---	--	----------------------------------	-------------------

***Quality and Quantity of Research**

- White/Blank: Unknown impact due to no studies found, studies with inconclusive results or only found studies with significant limitations
- Orange: Limited data, one small study, sizable limitations
- Yellow: One or two solid studies
- Green: Three or more solid studies, replication in findings

Commercial Findings

Research Summary

Very few studies and limited data were found on reducing contamination in the commercial sector. Many articles that list best practices such as technical assistance, posters, and training do not provide data to support these recommendations.

In a Resource Recycling article, WM reported that using **on-truck cameras and software to provide customer feedback resulted in an 89% reduction** in commercial recycling contamination (Staub, 2021). However, specifics of this measurement or parameters of this calculation were not included in the article.

The City of Denton, Texas routinely audits commercial containers and has tested additional measures to reduce contamination. In audits, when more than 50% contamination is observed, the container is not serviced: either the business must remove contamination or the container is serviced as garbage for \$75. Additionally, the city offers lock bars with chute lids for commercial properties that have high contamination **After distributing lock bar and chute lids at select commercial properties, the city hauled commercial contamination rate decreased by 9%** compared to the previous year (J. Amador, personal communication, December 13, 2023; Heffernan, M., 2023; J. Amador, personal communication, January 30, 2024)

Given the lack of studies in this area, it can be helpful to look at cities with low rates of contamination and consider the approaches that those communities use to achieve low contamination rates.

SeaTac, Washington has used a combination of routine **audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard to reduce recycling contamination, achieving a contamination rate of just 6.5%** (M. Giem, personal communication, December 8, 2023).

Metro (2020) found an average commercial contamination rate of 14%. This suggests that the combination of strategies implemented in the Metro region has been successful at reducing and maintaining a low level of contamination. Metro (n.d.) supports businesses in the region with technical assistance and resources such as stickers, signs, and flyers.

Commercial Research Gaps

Commercial is the most understudied generator sector. Within this sector, the research gaps are more prominent than the research findings. Few studies have been conducted in this sector, making it difficult to identify promising tactics for reducing contamination.

Research gaps include:

Effectiveness of various tactics including standardized colors and containers, various cart or container labels, cart or container designs, contamination charges and warnings, artificial intelligence, cameras, and other technologies, and programmatic or infrastructure changes such as switch to dual-stream collection.

Tactics with residents with a first language other than English, with disabilities, with low incomes, or in rural or multicultural communities.

Cost to implement various strategies.

Commercial Tactics Summary & Research Gaps

Tactic	Impact on Contamination	Quantity & Quality of Research*	Specific Research Gaps
SeaTac, WA: Routine audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard	Contamination rate of 6.5%	1-2 solid studies	Results are from a single community (not replicated) Impact of each tactic Durability of impact
Denton, TX: Routine audits - contamination must be removed or the container is serviced as garbage for \$75, lock bars with chute lids for properties with high contamination.	9% reduction in contamination; contamination rate of 34%	1-2 solid studies	Results are from a single community (not replicated) Impact of each tactic Durability of impact
On-board cameras, artificial intelligence and a contamination notification system resulted	89% reduction	Impact unknown	Results shown are from a single reference point Impact of tactic Durability of impact

Metro: Supports businesses in the region with technical assistance and resources such as stickers, signs, and flyers.	Contamination rate of 14%	Impact unknown	Impact of each tactic
---	---------------------------	----------------	-----------------------

*Quality and Quantity of Research

- White/Blank: Unknown impact due to no studies found, studies with inconclusive results or only found studies with significant limitations
- Orange: Limited data, one small study, sizable limitations
- Yellow: One or two solid studies
- Green: Three or more solid studies, replication in findings

Self-Haul Findings

Research Summary

Studies demonstrate contamination reduction at drop-off or self-haul facilities with the addition of signage, resident mailings, direct onsite feedback to residents on recycling quality, and cameras to monitor contamination. In most of the studies, with updated signage and basic education, **contamination decreased by at least 20%** (Township of McNab/Braeside, 2015; The Recycling Partnership, 2021b; The Recycling Partnership, 2023). In one community that implemented education with cameras and electronic message boards, contamination decreased by 50% (Oulton, 2022).

In another community, site security features including fencing, cameras and keycodes for residents have resulted in a contamination rate of just 3%. At this site, access was limited to residents that opted in to receive a code to access the facility (L. Haubeil, personal communication, January 18, 2024).

In one study at four drop-off sites in Ontario, the addition of large educational signs, without other interventions, resulted in an average decrease of 22% (Sullivan & Lafreniere, 2011).

Self-Haul Research Gaps

A combination of strategies that combines informational surveys, in person feedback at the drop-off facilities, annual mailers, signage at the facilities, a website, social media promotions, and site security features such as cameras or fencing is effective at reducing contamination. However, **there is limited data on the longevity of the reduction** on contamination. Additionally, except for signage, these tactics have not been studied individually, so the impact of each individual tactic is unknown.

All the studies included in the research were from rural areas with varying access to garbage services, including varying access to garbage service at the drop-off location. **It is unclear if the co-location of garbage collection at recycling drop-off sites reduces contamination**, though it

is logical that lack of easy garbage access could increase recycling contamination. Additionally, it is unknown whether co-location of collection containers for harder-to-recycle materials such as clothing, electronics, or plastic film could reduce recycling contamination.

The management of various drop-off sites was also not examined as part of this literature review. For example, research was not found on whether the availability of onsite staffing or personnel to discourage or remove illicit dumping or contamination at drop-off sites could reduce contamination.

Other research gaps include the impact of:

Tactics with residents with a first language other than English, with disabilities, with low incomes, or in rural or multicultural communities.

Various dumpster and site signage.

Cameras, fencing or other security features.

Container type (compactors, roll off, dumpster, etc.).

Self-Haul Tactics Summary & Research Gaps

Tactic	Impact on Contamination	Quantity & Quality of Research*	Specific Research Gaps
Multipronged approach that combines onsite signage, resident mailings, and media promotions	Typically, at least 20% reduction	3+ studies	Specific impact of each tactic Durability of impact
The Recycling Partnership has a toolkit that recommends onsite educational survey, in person feedback, annual mailer, signage, a website, social media promotions, and security features such as cameras or fencing	Greater reduction in contamination when recommendations were followed more diligently. 20% - 28% reduction	3+ studies	Specific impact of each tactic Durability of impact
Signs, cameras, and electronic message board	50% reduction	1-2 solid studies	Impact of tactic One study, with limitations
Large signage only	22% reduction	1-2 solid studies	Impact of tactic One study, with limitations
Enhanced security features	3% contamination rate	1-2 solid studies	Access to site is limited Results not replicated

*Quality and Quantity of Research

- White/Blank: Unknown impact due to no studies found, studies with inconclusive results or only found studies with significant limitations
- Orange: Limited data, one small study, sizable limitations
- Yellow: One or two solid studies
- Green: Three or more solid studies, replication in findings

Diverse Audience Findings

Research attempted to find studies on impact of tactics on residents with a first language other than English, with disabilities, with low incomes, and in rural areas. However, research on diverse audiences is minimal to missing. No studies included information about the impact on residents with disabilities or how to best serve this audience. The findings within information on the impact on residents with a first language other than English, with low incomes, or on rural communities (other than drop-off) were limited to a few studies.

Research on self-haul to drop-off sites included studies from rural areas, as these are the areas that commonly have self-haul recycling programs. The self-haul sections of this report describe this research. Research specific to rural areas from multifamily, commercial, and single-family audiences was not found.

Limited research was found on the impact of tactics on residents with a first language other than English or with low incomes. No information was found for commercial or self-haul generators. Only one multifamily study explicitly focused on properties with multicultural communities. In this study, researchers deployed a combination of improvements to containers, service levels and recycling education that was translated and culturally responsive to needs and preferences of the community (Cascadia Consulting Group, 2014). The project resulted in similar decreases in contamination as seen with other communities. The City of Kamloops issues tickets for contamination after repeat contamination. The tickets are issued to the homeowner, not the tenant, in attempt to avoid fining a renter, although costs may be passed to the tenant. Additionally, this makes it more likely that the person receiving the fine speaks English (M. Dick, personal communication, December 6, 2023).

The Recycling Partnership (2023b) published a resource for communities to introduce equitable outreach that includes tips for more inclusive outreach, a photo library, and transcreated recycling content. This resource could be useful in the implementation of contamination reduction campaigns and further research.

Recommendations for Contamination Reduction Strategies

Background and Approach

Based on the research findings, The Recycling Partnership evaluated whether enough published evidence exists to determine the cost-effectiveness of common contamination reduction strategies. This evaluation considered factors such as the quality and consistency of existing evidence, the types of evidence available, whether studies show a long-term effect, and the applicability of evidence to the specific characteristics of the Oregon recycling system and the variety of Oregon communities. When developing recommendations, the team considered that the anticipated funding from Oregon's producer responsibility organization through the Recycling Modernization Act is no more than \$3.00 per capita per year. For small local governments with 4,000 residents, the total budget could be limited to \$12,000 per year.

Where sufficient evidence exists, the list of recommended strategies for local governments identifies which generators they apply to, which community types they are most suitable for, and whether they are thought to support or pose challenges for diverse populations. The list includes strategies suitable for all the following community types:

- High- and low-density communities (urban, suburban, rural)
- Large, medium, and small cities
- Communities with and without opportunities to collaborate and share resources with neighboring communities.

Where enough evidence exists, The Recycling Partnership used insights from the literature review and the practical realities of the Oregon recycling system to recommend contamination reduction strategies for field testing and cost-effectiveness analysis in Phase 2 of this project. Recommendations considered the requirements outlined in ORS 459A.929(1)(c) and the suggestions provided to DEQ from local governments, haulers and others engaged in rulemaking who responded to DEQ's request for research and suggestions in January 2024.

Where sufficient research does not exist for all community types, we recommended strategies provisionally based on available data and propose to develop recommendations for future research. For example, if research does not exist to support contamination reduction strategies that would be applicable to a low-density, rural community with a small hauler, we made a recommendation for a program that draws on findings from similar applications and recommended prioritizing this type of community for future research.

Summary of Recommendations

Sector	Tactics
Single-family: Recommended	<ul style="list-style-type: none"> • Cart tagging (4 tags), cart rejection and mailing • Cart tagging (4 tags) and mailing • Multipronged approach from British Columbia • Dual-stream collection
Single-family: Provisional	<ul style="list-style-type: none"> • Cart tagging (2 tags), cart rejection and mailing • Change cart decals and lid colors to increase recycling container clarity • Cameras on collection trucks with generator feedback
Multifamily: Recommended	<ul style="list-style-type: none"> • Multipronged approach that combines inspections, education, and fines
Multifamily: Provisional	<ul style="list-style-type: none"> • Improvements to containers, service levels, and education • Containers with chute lids • Inspections with service refusal • Dual-stream collection
Commercial: Recommended	<ul style="list-style-type: none"> • None
Commercial: Provisional	<ul style="list-style-type: none"> • Multipronged approach that combines inspections, education, and fines • Containers with chute lids • Inspections with service refusal • On-board cameras, artificial intelligence, and generator feedback • Dual-stream collection
Self-Haul: Recommended	<ul style="list-style-type: none"> • Multipronged approach that combines signs, mailings, and advertising • Multipronged approach combines onsite survey, feedback, mailings, website, social media, and security features
Self-Haul: Provisional	<ul style="list-style-type: none"> • Improvements to site signage, direct mailings to residents, addition of cameras and electronic message board.

Single-Family

The following strategies are well documented as effective for single-family households and can be deployed in many communities across Oregon. **Recommended strategies for single-family households are:**

- Cart tagging (4 tags), cart rejection and mailing
- Cart tagging (4 tags) and mailing
- Multipronged approach from British Columbia (cart inspections, cart rejection, paid media, mailings, outreach events, fines)

- Dual-stream collection

The effectiveness of the following tactics is less well documented. However, these tactics are included in recommendations to ensure there is a strategy on the list for every community type, even those with limited budgets, and because of the potential impact, even if the research is less compelling. **Provisional strategies for single-family households are:**

- Cart tagging (2 tags), cart rejection and mailing
- Change cart decals and lid colors to increase recycling container clarity
- Cameras on collection trucks with generator feedback

Table 9. Recommendations for Single-Family Residential Generators

Recommended or Provisional Tactic	Community Density			City Size			Feasible to Collaborate with Neighboring Communities
	High	Medium	Low	Large	Medium	Small	
Cart tagging (4 tags), cart rejection, and mailing	R	R	NA	R	R	R	R
Cart tagging (4 tags) and mailing	R	R	NA	R	R	R	R
Multipronged approach from British Columbia	R	R	NA	R	R	R	R
Dual-stream collection	R	R	R	R	R	R	R
Cart tagging (2 tags), cart rejection and mailing	P	P	NA	P	P	P	P
Change cart decals and lid colors to increase recycling container clarity	P	P	P	P	P	P	P
Cameras on collection trucks with generator feedback	P	P	P	P	P	P	P

- Green (R): Effective, relevant tactic with well documented results effectiveness in reducing contamination.
- Yellow (P): Likely effective, relevant tactic with some documented results effectiveness in reducing contamination.
- White (NA): Tactic is likely not applicable to this community type due to cost constraints

The following subsections summarize why these strategies are recommended or provisionally recommended.

Cart Tagging (4 tags), Cart Rejection and Mailing

A systematic approach with four rounds of cart tagging, cart rejection, and mailers are well-documented strategies for reducing recycling contamination. In communities that distributed cart tags and mailings, contamination was reduced by 19-62% (The Recycling Partnership, 2021c; The Recycling Partnership, 2022; Staub, 2021b). In four of the five studies outlined in the literature review, the contamination reduction impact continued for ten months to three years when additional measurement was conducted that found a lasting impact (The Recycling Partnership, 2018; The Recycling Partnership, 2021c; The Recycling Partnership, 2022; M. Orr, personal communication, December 12, 2023).

Cart Tagging (4 tags) and Mailing

When cart inspections are coupled with service rejection, this increases the contamination reduction. New Bedford and Dartmouth, Massachusetts are neighboring communities and share a recycling coordinator. New Bedford chose to tag carts only, while Dartmouth also rejected carts and reduced contamination by nearly twice the rate (The Recycling Partnership, 2018b). While less effective than cart tagging coupled with rejection, cart tagging, and mailings are still an effective strategy to reduce contamination.

Multipronged Approach from British Columbia

Three communities in British Columbia have successfully reduced contamination in single-stream collection to below 7% with cart inspections, cart rejection, paid media, mailings, outreach events, and fines (City of Terrace, 2021; Link, 2023; M. Dick, personal communication, December 6, 2023; S. Subido, personal communication, December 21, 2023).

While data is not available to show the impact of each component of this program, communities that deploy these tactics concurrently will likely see reductions in contamination.

Dual-Stream Collection

Many communities in British Columbia choose to operate multi-stream collection because of lower contamination. In 2022, the contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream collection (P. Cupcupin, personal communication, February 5, 2024). Communities that have switched from single-stream to dual-stream collection and implemented education campaigns also have lower rates of contamination (Paben, 2019).

Despite the low contamination rate, Cascadia Consulting Group (2020) found that dual-stream collection was not cost effective for Oregon as the cost was estimated to be at least \$0.65 per month per household (\$7.80 annually, in 2020 dollars) for a two-cart system, without accounting for potential impacts to sortation costs or commodity values. Dual-stream collection is likely cost prohibitive for many Oregon communities and space prohibitive for others, but it appears likely to decrease contamination.

Cart Tagging (2 tags), Cart Rejection, and Mailing

The Recycling Partnership recommends four rounds of cart inspections, feedback tags, and mailers as the optimal contamination reduction package, balancing cost, and contamination reduction. The reduction seen with two or three rounds of cart tagging was not as significant of reduction as is typically seen with four rounds of cart tagging. However, two rounds are still an effective tactic for reducing contamination if staff or budget is a barrier.

In Lewis County, Washington, two rounds of cart tagging, cart rejection, and mailers reduced contamination by 19% (Waste Advantage Magazine, 2023; M. Case, personal communication, December 4, 2023). In Snohomish County, Washington two rounds of cart tagging resulted in a statistically significant reduction in the occurrence of plastic bags and bagged recycling (Cascadia Consulting Group, 2018). Cincinnati, Ohio conducted two cart tagging and inspection projects, one with five rounds of tagging and one with three rounds of tagging. The project with five rounds reduced contamination by 29% while the project with three inspections reduced contamination by 19% (The Recycling Partnership, 2022).

Change Cart Decals and Lid Colors

Cart decals and lid colors can make it easier for residents to recognize the difference between a garbage and a recycling cart. Based on the available data, these tactics are most applicable in communities with similar colored recycling and garbage carts and on routes with higher-than-average contamination.

In Peoria, Arizona recycling carts are dark brown and garbage carts are light brown. When recycling cart lids were changed to blue, recycling contamination decreased. This decrease was greater when combined with additional education (Archibald, 2021). In San Jose, California new lids with recycling graphics were replaced on carts on routes with high contamination, resulting in a 20% reduction in contamination (Loft, 2021). However, in this same community, contamination did not decrease on routes with average contamination that received new lids with recycling graphics (R. Varghese, personal communication, March 30, 2023)

Cameras on Collection Trucks with Generator Feedback

Onboard cameras could be used to collect information about household-level contamination and then mailings could be used to deliver feedback to residents. Based on the effectiveness of four rounds of cart tagging over four collection cycles, up to four mailings over four collection cycles are recommended per household to provide multiple rounds of feedback. It is likely that contamination identified by cameras and feedback provided directly to generators is an effective tactic to reduce contamination in a more cost-effective manner than cart tagging in some communities.

In one pilot in the City of Regina, Saskatchewan, contamination was reduced by 41.5% after a three-month campaign where residents were mailed postcards that identified contamination in single-family carts (Prairie Robotics, 2022). Data from a recent study conducted by The Recycling Partnership (2024) also found a 22.5% reduction with this tactic.

Based on the limited available data and the promising cost effectiveness of this strategy, The Recycling Partnership recommends prioritizing this as a tactic for further study.

Multifamily

The following strategy is recommended for multifamily properties. This combination of strategies effectively reduced contamination in four communities and would likely be effective in many communities across Oregon. **Recommended strategies for multifamily generators are:**

- Multipronged approach including inspections, technical assistance, and fines

Based on the available research, some strategies are provisionally recommended for multifamily properties. Despite limited research on the effectiveness of these tactics, they are listed to ensure there is a strategy on the list for every community type, even those with limited budgets.

Provisional strategies for multifamily generators are:

- Improvements to containers, service levels, and education
- Containers with chute lids
- Inspections with service refusal
- Dual-stream collection

Based on the limited available data available for this generator type, The Recycling Partnership recommends prioritizing further study with multifamily generators.

Table 10. Recommendations for Multifamily Residential Generators

Recommended Tactic	Community Density			City Size			Feasible to Collaborate with Neighboring Communities
	High	Medium	Low	Large	Medium	Small	
Multipronged approach including inspections, education, and fines	R	R	R	R	R	NA	R
Improvements to containers, service levels, and education	P	P	P	P	P	P	P
Containers with chute lids	P	P	P	P	P	P	P
Inspections with service refusal	P	P	NA	P	P	P	P
Dual-stream collection	P	P	P	P	P	P	P

- Green (R): Effective, relevant tactic with well documented results effectiveness in reducing contamination.

- Yellow (P): Likely effective, relevant tactic with some documented results effectiveness in reducing contamination.
- White (NA): Tactic is likely not applicable to this community type due to cost constraints.

The following subsections summarize why these strategies are recommended or provisionally recommended.

Multipronged Approach with Inspections, Technical Assistance and Fines

Seattle, Washington; SeaTac, Washington; Denton, Texas; and Kamloops, British Columbia have all successfully reduced contamination with a combination of inspections, technical assistance, and fines (City of Seattle, 2022; Recology, n.d.; M. Giem, personal communication, December 8, 2023; Heffernan, 2023; M. Dick, personal communication, December 6, 2023). While the impact of each individual element is unknown, this package has been successful in four communities. The largest cost of these programs is administrative, likely making this approach infeasible for small communities with limited staff.

Improvements to Containers, Service Levels and Education

Educational tactics deployed without other strategies did not reliably decrease contamination at multifamily properties. These findings are consistent with other behavior change research that education alone is typically insufficient to change behavior.

Strategies that combine changes to service levels, container location, and container types, coupled with education, have been more successful at reducing contamination than education alone (Cascadia Consulting Group, 2017; Green Solutions and Terra Linda Consulting, 2014). In King County, Washington, these combined strategies reduced contamination by an average of 50% at 18 properties (Cascadia Consulting Group, 2017). In Lewis County, Washington, these efforts reduced contamination by up to 55% (Waste Advantage Magazine, 2023).

By working with multifamily property managers to ensure convenient access to recycling at the property, sufficient recycling capacity and educating residents, contamination reduction is more likely to have an impact than education alone.

Containers with Chute Lids

In three communities, locking lids with a chute opening for recyclables were part of successful contamination reduction initiatives. In the Region of Peel, Ontario, lids resulted in a 17% reduction in contamination (Continuous Improvement Fund, 2019). The City of SeaTac, Washington, and Denton, Texas also reduced contamination when using chute lids in combination with other tactics (M. Giem, personal communication, December 8, 2023; J. Amador, personal communication, December 13, 2023).

Two of the three studies included chute lids as part of a larger initiative; however, even when deployed alone, lids will likely reduce contamination. Additionally, lids are likely to have a more durable impact than educational strategies as the lids permanently make it more difficult to place large contaminants or bagged recyclables in the recycling container.

Inspections with Service Refusal

Only one study was found that tested inspections with service refusal. In Toronto, Ontario regular container inspections over three years reduced contamination from 16.02% to 11.32% (City of Toronto, 2019b). The findings from this study align with the findings from single-family generators, that inspections and service refusals are effective in reducing contamination. In this study, inspections were conducted by a crew dedicated to this task, though in some cases it may make sense for the hauler to perform inspections.

Dual-Stream Collection

Many communities in British Columbia choose to operate multi-stream collection because of lower contamination. In 2022, the contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream collection (P. Cupcupin, personal communication, February 5, 2024). This statistic includes multifamily properties, but the data is not separated into single-family and multifamily contamination rates, so it is not possible to discern the contamination rate of dual-stream collection in British Columbia. However, it is likely that dual-stream collection would have lower rates of contamination at multifamily properties given the contamination rates of single-family with dual-stream collection.

Despite the low contamination rate, Cascadia Consulting Group (2020) found that single-family dual-stream collection was not cost effective for Oregon as the cost was estimated to be at least \$0.65 per month per household (\$7.80 annually, in 2020 dollars), but the cost impacts for multifamily services were not estimated. Dual-stream collection is likely cost prohibitive for many Oregon communities and may be space prohibitive for multifamily properties, but if feasible it would likely decrease contamination at multifamily properties.

Commercial

Based on the available research, the following strategies are recommended for commercial properties. The research on the effectiveness of these tactics is limited, however, these are included to ensure there is a strategy on the list for every community type, even those with limited budgets, and because of the potential impact. **Provisional strategies for commercial generators are:**

- Multipronged approach including inspections, education, and fines
- Containers with chute lids
- Inspections with service refusal
- On-board cameras, artificial intelligence, and generator feedback
- Dual-stream collection

Based on the limited available data available for this generator type, The Recycling Partnership recommends prioritizing further study with commercial generators.

Table 11. Recommendations for Commercial Generators

Recommended Tactic	Community Density			City Size			Feasible to Collaborate with Neighboring Communities
	High	Medium	Low	Large	Medium	Small	
Multipronged approach including inspections, education, and fines	P	P	P	P	P	NA	P
Containers with chute lids	P	P	P	P	P	P	P
Inspections with service refusal	P	P	NA	P	P	P	P
On-board cameras, artificial intelligence, and generator feedback	P	P	P	P	P	P	P
Dual-stream collection	P	P	P	P	P	P	P

- Green (R): Effective, relevant tactic with well documented results effectiveness in reducing contamination.
- Yellow (P): Likely effective, relevant tactic with some documented results effectiveness in reducing contamination.
- White (NA): Tactic is likely not applicable to this community type due to cost constraints.

The following subsections summarize why these strategies are recommended or provisionally recommended.

Inspections, Education and Fines

The City of SeaTac, Washington has used a combination of routine audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard to reduce recycling contamination, achieving a contamination rate of just 6.5% (M. Giem, personal communication, December 8, 2023). A similar approach reduced contamination in three other cities with multifamily generators (City of Seattle, 2022; Heffernan, 2023; M. Dick, personal communication, December 6, 2023). Although only one of these data points is from commercial, the finding from multifamily application was successful, and it is reasonable to assume that this tactic would reduce contamination with commercial generators as well.

The largest cost of these programs is administrative, likely making this approach infeasible for small communities with limited staff. In some cases, the hauler may be willing to complete this work on behalf of the community, which could make it a feasible approach in a smaller community.

Containers with Chute Lids

In Denton, Texas, after distributing lock bar and chute lids at select commercial properties, the commercial contamination rate decreased by 9% compared to the previous year (J. Amador, personal communication, January 30, 2024). Additionally, in a multifamily study in the Region of Peel, Ontario, chute lids resulted in a 17% reduction in contamination (Continuous Improvement Fund, 2019). Although only one of these data points is from commercial, the finding from the Region of Peel is likely transferable, and it is reasonable to assume that this tactic would reduce contamination with commercial generators as well.

Inspections with Service Refusal

Only one study was found that tested inspections with service refusal and this study looked at multifamily generators, not commercial generators. In Toronto, Ontario regular container inspections over three years reduced contamination from 16.02% to 11.32% (City of Toronto, 2019b). The findings from this study align with the findings from single-family generators, that inspections and service refusals are effective in reducing contamination. This finding is likely transferable, and it is reasonable to assume that this tactic would reduce contamination with commercial generators as well.

In the Toronto study, inspections were conducted by a crew dedicated to this task, though in some cases it may make sense for the hauler to perform inspections.

On-board Cameras, Artificial Intelligence and Generator Feedback

Only one article was found that referenced the effectiveness of this strategy noting that within three months contamination had been reduced by 89% (Staub, 2021). This one data point does not provide sufficient evidence that this is an effective tactic, and the research methodology was largely unspecified. However, given the success of generator feedback in other sectors, it is reasonable to assume that this may also apply to commercial contamination reduction if the feedback can reach someone at the business with both a reason and the ability to make changes.

Dual-Stream Collection

Many communities in British Columbia choose to operate multi-stream collection because of lower contamination. In 2022, the contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream collection (P. Cupcupin, personal communication, February 5, 2024). This statistic is not specific to commercial recycling; however, it is likely that dual-stream collection would have lower rates of contamination at commercial properties given the low contamination rates of single-family with dual-stream collection.

Self-Haul

The following strategies are recommended for communities with self-haul recycling. These strategies are well documented as effective strategies and can be deployed in many communities across Oregon. **Recommended strategies for self-haul generators are:**

- Multipronged approach that combines onsite signage, resident mailings, and various social and traditional media promotions.
- Implementation of The Recycling Partnership's Drop-off Quality Improvement Toolkit that includes an onsite survey of residents to inform and educate them, in-person feedback, onsite signage, direct mailings to residents, a website and social media promotions, as well as site security features such as cameras or fencing.

The following strategies are also recommended for communities with self-haul recycling, but the effectiveness of these tactics is less well documented. These tactics are included to ensure the list includes potentially effective strategies for every community type, even those with limited budgets even if the research is less compelling. **Provisional strategies for self-haul generators are:**

- Improvements to site signage, direct mailings to residents, addition of cameras and electronic message board. Note that this strategy differs from those listed above as it does not include an onsite survey to residents to inform and educate them and the campaign, in-person feedback, a website, or advertising.

Signs, Mailings, and Advertising

This approach combines onsite signage, resident mailings, and various social and traditional media promotions. This tactic applies to self-haul sites in any type of community and allows for a community to collaborate with neighboring communities.

The Township of McNab/Braeside, Ontario mailed recycling information to all residents, added new signage to recycling sites, and placed ads in local papers promoting acceptable and unacceptable materials. This resulted in a 58% decrease in contamination fines from the hauler and a 54% decrease in staff time at the self-haul sites to remove contamination (Township of McNab/Braeside, 2015).

While this study showed a dramatic decrease in contamination fines and staff time, it is not possible to determine the impact of each of the components. While studies demonstrate the effectiveness of direct mailers and onsite signage, The Recycling Partnership did not find data on the effectiveness of social or traditional media alone.

Full Implementation of The Recycling Partnership Toolkit

The Recycling Partnership has a toolkit that recommends sites to conduct an onsite survey of residents to inform and educate, provide in-person feedback at the drop-off site, send at least one annual mailer, install or upgrade signage at the site, use a website and social media promotions,

and use site security features such as cameras or fencing. This approach encourages the full implementation of the toolkit for optimum success. These tactics apply to most self-haul sites and allow a community to collaborate with neighboring communities.

Deployment of the toolkit reduced contamination by 26-28% at drop-off sites in communities in Michigan and Ohio (The Recycling Partnership, 2021b; The Recycling Partnership, 2023). While the individual elements of the toolkit have not all been studied separately for effectiveness, drawing on findings from the work of several communities in Michigan, direct mailings, onsite signage, staffing for direct resident feedback and surveys, and added security features seem most critical for reducing contamination. No studies were found that demonstrate the impact of social, web, or traditional print media alone on contamination at self-haul locations.

Education, Signage, Cameras, and Electronic Message Board

This approach combines new or updated signage, the addition of site security cameras, and the use of an electronic message board to relay a rotation of educational messaging to site users. Two solid waste districts in Ohio added signs to drop-off facilities and used education that combined mailers, onsite signs, billboards, websites, and social media. These signage and education methods reduced contamination by 50%. Another community also added cameras and electronic message boards onsite, resulting in a 73.4% reduction in contamination (Oulton, 2022).

It is difficult to determine the effectiveness of the electronic messaging boards compared to the cameras and mailed education. Potentially the rotating nature of the messages on the electronic board might have indicated to patrons that their recycling was important and impactful and that the community was paying attention; however, the same could also be said for the cameras. Further research could help to determine if rotating messages are any more impactful than static signage.

The purchase of an electronic message board may be cost prohibitive for some Oregon communities; however, there may be instances where signs can be rented or borrowed from other departments or shared across communities that could keep this option within budget. A community could also consider a smaller option with a fixed message that could generate similar contamination reductions. This approach is applicable to all self-haul sites and allows a community to collaborate with neighboring communities.

Diverse Audiences

In this research, The Recycling Partnership attempted to identify strategies that would be responsive to needs of diverse populations including:

- People whose first language is not English
- People with low incomes
- People who live in rural areas
- People with disabilities

Based on the limited available data available for the impacts of tactics with diverse populations, The Recycling Partnership recommends prioritizing further study to ensure there are no adverse impacts and to understand how to deploy effective and inclusive contamination reduction programming.

The following subsections summarize the limited findings and provisional recommendations for working with diverse populations.

People whose First Language is Not English

Limited research was found on the impact of tactics with residents with a first language other than English. Only one study in the literature review included translated or transcreated materials, and this campaign reduced contamination at multicultural multifamily complexes (Cascadia Consulting Group, 2014). Translation and transcreation could reasonably be applied to educational elements of contamination reduction materials for all generator types to increase the opportunity for impact.

People with Low Incomes

Contamination charges or service consequences as part of a contamination reduction strategy could disproportionately impact residents with low incomes. To minimize the potential impact, these strategies could be combined with clear communication, warnings, and support for signing up for low-income collection rates (where offered by the hauler or community). In the case of tickets or charges, the City of Kamloops issues tickets to the homeowner, not the tenant, although costs may be passed to the tenant (M. Dick, personal communication, December 6, 2023).

People who Live in Rural Areas

Research on self-haul to drop-off sites included studies from rural areas as these are the areas that commonly have self-haul recycling programs. Research specific to rural areas for single-family, multifamily, and commercial audiences was not found. However, the strategies recommended and provisionally recommended for audiences with on-route collection would apply to rural areas. At the same time, the lack of customer density may make the strategies recommended for on-route single-family, multifamily, and commercial collection cost prohibitive in rural areas.

People with Disabilities

No studies were found that included information about contamination reduction with residents with disabilities. Containers with chute lids may create challenges for some residents with disabilities, though it may not be different from the challenges created by any large collection container. Further research is needed on this topic.

Recommendations for Future Research

Where sufficient evidence does not exist, The Recycling Partnership drew upon conclusions obtained during the literature review process to identify the significant data gaps in the literature and recommend research to fill those gaps. This work was an effort to recommend cost effective strategies to reduce contamination where reliable justification is not present in existing research.

The study design concepts are a proposed framework for carrying out additional research. Additional specificity around the exact research protocol will need to be established before the research is executed.

The study designs concepts included here draw on the research from this task and focus on more traditional methods. DEQ also has a strong interest in partnering testing novel approaches for reaching diverse communities and strategies that fill additional gaps in research for rural communities, vulnerable communities, and testing trusted messengers.

Study Design 1: Single-family Cameras on Trucks

Strategy: Cameras on collection trucks with Artificial Intelligence (AI) and generator feedback delivered by mail

Generator Type: Single-family

Contamination Type(s) & Rates: Any material type, community with state-wide average for contamination

Research Gap(s): Effectiveness of strategy, durability of impact

Cameras on collection trucks with artificial intelligence and generator feedback is a promising strategy to reduce contamination. The following study would help determine if feedback generated from artificial intelligence (AI) on curbside recycling trucks is as effective as a cart tagging project, and if so, determine the number of inspections needed to be effective.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits
Intervention 1	Four rounds of cart tagging, one mailer, service rejection	Four or eight weeks, depending on collection recycling frequency	Pre and post recycling audits Frequency of contaminants over tagging period
Intervention 2	Feedback mailers for four collection cycles	Four or eight weeks, depending on collection recycling frequency	Pre and post recycling audits Frequency of contaminants
Intervention 3	Feedback mailers for eight collection cycles	Eight or 16 weeks, depending on collection recycling frequency	Pre and post recycling audits Frequency of contaminants

Recommended Sample Size and Demographics:

- At a minimum, all intervention groups and the control should include four routes with at least 700 households per route. If back-up trucks do not have camera technology, five to six routes are preferred to increase the likelihood that at least four routes will have consistent monitoring.
- A demographic analysis of each route should also be completed to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Weekly or every other week

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize into contamination to learn more about specific contaminants. See appendix B for material audit category recommendations.

Audit Schedule:

- Baseline – No more than one month before the intervention start date.
- One to Two Months Post Intervention – Within two months of the intervention conclusion.
- Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.
- 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Measurement for Intervention Groups 2 and 3 will also include:

- Cameras on the trucks - Collect data one month prior to the interventions, for the duration of the intervention and for a minimum of one month after the intervention, up to one year would be preferred to track the durability of these impacts.
- Similar to cart tagging with quality inspectors, cameras on the trucks will track:
 - Frequency of contaminant occurrences
 - Contamination by type

Study Design 2: Single-family Right Sizing Garbage Service

Strategy: Increasing the size of garbage carts for residents with full or overflowing garbage cans and multiple instances of recycling contamination

Generator Type: Single-family

Contamination Type(s) & Rates: Any material type with a focus on household garbage, higher than statewide average contamination rate

Research Gap(s): Effectiveness of strategy, durability of impact

This strategy builds on the pilots conducted by the City of San Jose where insufficient garbage capacity was correlated with higher rates of recycling contamination. The following strategy uses either AI cameras on garbage and recycling trucks to identify fill rates and contamination rates or manual inspections. Cameras would also be installed on routes in the control group. The interventions would test if right sizing garbage containers reduced contamination.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	None	N/A	Pre and post recycling audits Frequency of contaminated recycling carts Number of occurrences of contaminants in recycling carts by material Recycling and Garbage Tonnage
Intervention 1	Right sizing curbside carts with AI cameras. AI will identify individual household fill rates of garbage carts and level of contaminated recycling carts. If 50% of inspections show full garbage carts and contamination in recycling over an eight-week period, it	12 months	Pre and post recycling audits Frequency of contaminated recycling carts Number of occurrences of contaminants in recycling carts by material Recycling and Garbage Tonnage

	will trigger deployment of a larger garbage cart.		
Intervention 2	Right sizing curbside carts with in-person inspections. Staff will identify individual household fill rates of garbage carts and level of contaminated recycling carts. If 50% of inspections show full garbage carts and contamination in recycling, it will trigger deployment of a larger garbage cart.	4 collection cycles (4 or 8 weeks depending on recycling collection frequency)	Pre and post recycling audits Frequency of contaminated recycling carts Number of occurrences of contaminants in recycling carts by material Recycling and Garbage Tonnage

Recommended Sample Size and Demographics:

- At a minimum, intervention group and the control should include four routes with at least 700 households per route. All trucks servicing these routes will be required to be equipped with AI cameras.
- A demographic analysis of each route should also be completed to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Weekly or every other week

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into at least two categories: contaminants and quality recyclables. Communities can further categorize into contamination to learn more about specific contaminants. See Appendix A for material audit categories list for recommendations. In addition, cart-based audits could be conducted to determine the impact on the households that received larger carts.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.

- 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Additional Measurement:

Cameras on the trucks - Collect data for at least one month or four collections whichever is greater, prior to the interventions to establish baseline, for the duration of the intervention and same time frame as baseline after the intervention. Up to one year would be preferred to track the durability of these impacts. Cameras on the trucks will track:

- Frequency of contaminant occurrences
- Contamination by type

Study Design 3: Single-family Dual-stream

Strategy: Dual-stream collection in a community that is beginning single-family recycling service.

Generator Type: Single-family

Contamination Type(s) & Rates: N/A (new program only)

Research Gap(s): Effectiveness of strategy, durability of impact

On average, dual-stream collection has lower rates of contamination. This study will explore the contamination of recycling upon the start of a new dual-stream collection service.

The primary challenge with assessing the effectiveness of this strategy is establishing reliable control. An ideal control would be a community that is similar to the intervention community that is starting commingled recycling collection. It would also be possible to have the control and intervention in the same community, if the community was able to deploy commingle collection in one part of the community and dual-stream in another part of the community.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	None (or new single-stream collection)	N/A	Pre and post recycling audits
Intervention 1	New dual-stream collection	N/A	Pre and post recycling audits

We do not recommend an intervention that establishes dual-stream collection with a single cart, serviced one week for fiber and one week for containers. Although we have not studied this specifically, based on our research, it seems unlikely that residents would be able to remember which week was for each material stream. Additionally, it would likely create challenges for storage of recyclables once interior containers were full.

Recommended Sample Size and Demographics:

- If possible, the intervention groups and the control should include four routes with at least 700 households per route.
- A demographic analysis of each route should also be completed to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Weekly or every other week

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into at least two categories: contaminants and quality recyclables. Communities can further categorize contamination to learn more about specific contaminants. See appendix B for material audit category recommendations.

Audit Schedule:

- Six to Twelve Month Post Intervention
- 24 Month Post Intervention (Optional) – If a six to 12-month audit shows positive results, an audit 24-months post intervention would be recommended.

Study Design 4: Multifamily Improvements to Containers, Service Levels and Education

Generator Type: Multifamily

Contamination Type(s) & Rates: Any material type, community with statewide average for contamination

Research Gap(s): Improved container placement and labeling, changes to service levels, and resident communication have shown mixed results in reducing contamination. There is also some research on the impact of these tactics on multicultural populations, though further research is needed to understand the impact and effectiveness. In this study, service improvements and education will be tested with the general population and with properties with majority multicultural populations.

Trash for Peace, a community-based organization, suggested an apartment champion model. In this model, the champions are paid an hourly stipend, for 5 to 10 hours per month, to serve as on-site promoter and liaison between other tenants as a third party that is not the landlord, property manager, service provider, contractor, or other organization. Champions take on the role of distributing recycling collection bags, brochures, presentations, and serving as a resource for tenants.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Weekly visual inspections
Intervention 1	Improvements to containers, service levels and education	Six months	Pre and post recycling audits Weekly visual inspections
Intervention 2	Improvement to containers, service levels and education at properties with majority multicultural populations	Six months	Pre and post recycling audits Weekly visual inspections
Intervention 3	Improvement to containers, service levels and education	Six months	Pre and post recycling audits Weekly visual inspections

	conducted by Apartment Champions		
Intervention 4	Improvements to containers, service levels, education, and cameras at enclosures	Six months	Pre and post recycling audits Weekly visual inspections

Recommended Sample Size and Demographics:

- At a minimum, intervention group and the control should include four properties per group. Five or more sites in each group would provide more reliable data. Ideally, a mix of property sizes would be included in each group so that the impact of property size can be minimized.
- A demographic analysis of each set of properties should also be completed, if data is available, to ensure that properties with multicultural residents are included in both the intervention and control groups. The demographic makeup of the control and group 1 can be representative of the local population. By testing the same tactics with different audiences in groups 1 and 2, this will deepen the understanding of these tactics with various populations.

Recycling Collection Frequency: Minimum weekly collection

Measurement Method(s):

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. The samples should be collected from the properties in each group separately. This will likely require a dedicated route or sorting materials onsite at each property.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.
 - 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Recommendations for Future Research | Study Design 4: Multifamily Improvements to Containers, Service Levels and Education

Due to the variability of multifamily recycling, weekly visual inspections are also recommended one month prior to the interventions, during the interventions, and one month following the interventions. In the visual audit, auditors would note an estimated percent of contamination, count or estimate the number of contaminants, and take a photo of the container contents.

Study Design 5: Multifamily Doorstep Collection

Strategy: Doorstep collection service of recycling at multifamily properties with resident feedback and rejection

Generator Type: Multifamily

Contamination Type(s) & Rates: Any material type, community with state-wide average for contamination

Research Gap(s): Effectiveness of strategy, durability of impact

Feedback and service rejection at the point of recycling has been effective at reducing contamination with single-family residents. In this study, similar tactics would be deployed at multifamily properties to test if resident feedback and service rejections reduce contamination.

In this study, the doorstep service providers would be trained on accepted recyclables and provide feedback in the form of an oops door hanger, and in some cases, they would not collect recyclables that are contaminated. There would be no changes to the contamination monitoring or service rejection from the recycling service provider.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Weekly visual inspections
Intervention 1	Establish doorstep collection service	6 months	Pre and post recycling audits Weekly visual inspections
Intervention 2	Establish doorstep collection service, feedback to residents with oops door hanger	6 months	Pre and post recycling audits Weekly visual inspections
Intervention 3	Establish doorstep collection service, feedback to residents with oops door hanger, and service rejection	6 months	Pre and post recycling audits Weekly visual inspections

Recommended Sample Size and Demographics:

- At a minimum, the intervention and the control should include four properties per group. If possible, five or more sites in each group would provide more reliable data.
- A demographic analysis of each set of properties should also be completed, if data is available, to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Minimum weekly collection

Measurement Method(s):

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. The samples should be collected from the properties in each group separately. This will likely require a dedicated route or sorting materials onsite.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.
 - 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Due to the variability of multifamily recycling, weekly visual inspections are also recommended one month prior to the interventions, during the interventions, and one month following the interventions.

Study Design 6: Commercial Cameras on Trucks with Feedback

Strategy: Cameras on collection trucks with Artificial Intelligence (AI) and generator feedback to business owners/managers delivered by e-mail and/or phone calls for varied amount of collection cycles

Generator Type: Commercial

Contamination Type(s) & Rates: AI trained material types, commercial routes with average or above average contamination

Research Gap(s): Effectiveness of strategy, durability of impact

Cameras on commercial collection trucks with artificial intelligence and generator feedback is a promising strategy with commercial generators to reduce contamination. The following study would help determine if feedback generated from artificial intelligence (AI) on commercial recycling trucks is a promising strategy with this sector and if so, determining the number of inspections needed to be effective.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Frequency and number of contaminant occurrences
Intervention 1	Feedback with automated emails and/or letters	24 weeks	Pre and post recycling audits Frequency and number of contaminant occurrences
Intervention 2	Feedback with automated emails and/or letters, with fines after three instances of contamination	24 weeks	Pre and post recycling audits Frequency and number of contaminant occurrences

Recommended Sample Size:

- At a minimum, intervention group and the control should include four routes. All trucks servicing these routes will be required to be equipped with AI cameras.
- As feasible, all intervention groups and the control should attempt to select routes that are similar to one another (e.g., number of commercial establishments on route, types of businesses). If multiple trucks are used for selected routes, cameras will be installed on all trucks to ensure consistent monitoring.

Recycling Collection Frequency: Collections at least once/week

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize into contamination to learn more about specific contaminants. See Appendix A for a recommended material list of audit categories.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.
 - 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Cameras on the trucks - Collect data for at least one month or four collections, whichever is greater, prior to the interventions to establish baseline, for the intervention's duration and same period as baseline after the intervention. Up to one year would be preferred to track the durability of these impacts. Cameras on the trucks will track:

- Frequency of contaminant occurrences
- Contamination by type

Study Design 7: Commercial Multipronged Approach

Strategy: Multipronged approach (inspections, rejections, fines) compared to technical assistance or fines only

Generator Type: Commercial

Contamination Type(s) & Rates: Any material types, commercial routes with average or above average contamination

Research Gap(s): Effectiveness of strategy, durability of impact

There is a lack of research on contamination reduction strategies in the commercial sector. This study will build on the limited findings from existing research with this sector and help identify promising strategies for contamination reduction.

Exclude multi-tenant buildings from this study, as feasible. If the tactics tested in this study are effective future studies could explore the effectiveness of the strategies with multi-tenant buildings.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Contamination occurrences
Intervention 1	Container inspections, rejections (conducted by a dedicated inspection crew)	24 weeks	Pre and post recycling audits Contamination occurrences
Intervention 2	Container inspections, rejections (conducted by a dedicated inspection crew), and fines after one warning in person or by phone call	24 weeks	Pre and post recycling audits Contamination occurrences
Intervention 3	Technical assistance including container labels, education materials, recommendations for container configuration, staff presentations	24 weeks	Pre and post recycling audits Contamination occurrences

Intervention 4	Fines, after one warning by mail or phone call (no service rejections)	24 weeks	Pre and post recycling audits Contamination occurrences
----------------	--	----------	--

Recommended Sample Size:

- At a minimum, intervention group and the control should include four routes. All trucks servicing these routes will be required to be equipped with AI cameras.
- As feasible, all intervention groups and the control should attempt to select routes that are similar to one another (e.g., number of commercial establishments on route, types of businesses). If multiple trucks are used for selected routes, cameras will be installed on all trucks to ensure consistent monitoring.

Recycling Collection Frequency: Collections at least once/week

Measurement Method(s):

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize into contamination to learn more about specific contaminants. See Appendix A for a recommended material list of audit categories.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended
 - 24 Month Post Intervention (Optional) - If 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended

Cameras on the trucks - Collect data for at least one month or four collections, whichever is greater, prior to the interventions to establish baseline, for the intervention's duration and same period as baseline after the intervention. Up to one year would be preferred to track the durability of these impacts. Cameras on the trucks will track:

- Frequency of contaminant occurrences
- Contamination by type

Study Design 8: Commercial Dual-stream

Strategy: Switch commercial collection from commingled to dual-stream collection

Generator Type: Commercial

Contamination Type(s) & Rates: Any material types, commercial routes with average or above average contamination

Research Gap(s): Effectiveness of strategy, durability of impact

On average, dual-stream collection has lower rates of contamination. This study will test the impact of dual-stream collection and education on recycling quality in the commercial sector. To tease out the impact of education, one intervention group will receive education only.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits
Intervention 1	Switch to dual-stream collection, education on dual-stream including collection guidelines and phone calls to businesses	Six months	Pre and post recycling audits
Intervention 2	Education on commingled collection including collection guidelines and phone calls to businesses	Six months	Pre and post recycling audits

Recommended Sample Size:

- At a minimum, intervention groups and the control should include four routes.
- As feasible, all intervention groups and the control should attempt to select routes that are similar to one another (e.g., number of commercial establishments on route, types of businesses).

Recycling Collection Frequency: Collections at least once/week

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize into contamination to learn more about specific contaminants. See appendix B for material audit category recommendations.

Audit Schedule:

- Baseline not more than one month before the intervention start date
- Six to nine months post intervention
- 24 months post intervention (optional) – If six to 12-month audit show positive results, an audit 24-months post intervention would be recommended.

Study Design 9: Security Features at Self-haul

Strategy: Self-haul Security Features (cameras, fencing, coded entry)

Generator Type: Self-haul

Contamination Type(s) & Rates: Any material type, community with state-wide average for contamination or higher

Research Gap(s): Effectiveness of strategy, durability of impact

Various camera systems at self-haul sites and in containers to address illicit dumping and contamination. The following study would help determine if on-site cameras with and without monitoring and feedback, certain security features, and/or coded entry will reduce contamination and illicit dumping and if so, to what extent. All strategies will include clear and consistent container signage about acceptable and unacceptable materials as well as signage on-site about cameras.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 1	Cameras and signage with no monitoring (no pictures or video taken)	12 months	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 2	Cameras and signage with monitoring and two feedback mailers to residents. The feedback mailers would list specific issues with contamination (e.g.: plastic bags, bagged garbage).	12 months	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 3	Coded entry and cameras with monitoring	12 months	Pre and post recycling audits

			Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 4	Cameras in containers with site manager feedback provided to residents in person with a printed handout.	12 months	Pre and post recycling audits Frequency and number of occurrences of contaminants

Recommended Sample Size and Demographics:

- At a minimum, all intervention groups and the control should include three self-haul sites. If possible, five or more sites in each group would provide more reliable data.
- A demographic analysis of each site should also be completed to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Minimum of weekly, aim for consistency amongst intervention groups

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize contamination to learn more about specific contaminants. See Appendix A for material audit categories list for recommendations.

- Audit Schedule:
 - Baseline – No more than one month before the intervention start date
 - One to Two Months Post Intervention – Within two months of the intervention conclusion
 - Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended
 - 24 Month Post Intervention (Optional) - If 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended

Measurement for Intervention Groups 2-4 will also include:

- Number of illicit dumping occurrences at each site

Measurement for Intervention Group 4 will also include:

- Number and frequency of contaminants identified

Study Design 10: Self-haul Site Improvements, Education, Security, and Staffing

Strategy: Self-Haul Multipronged Approach

Generator Type: Self-haul

Contamination Type(s) & Rates: Any material type, community with state-wide average for contamination or higher

Research Gap(s): Effectiveness of individual strategies, durability of impact

Implementation of The Recycling Partnership’s Drop Off Toolkit has helped reduce contamination across multiple self-haul sites. The impact of each component of the strategy is unknown. The following study would help determine the effectiveness of each strategy and the cumulative effectiveness.

Intervention(s) & Measurement:

Group	Intervention Tactic	Duration of Intervention	Measurement Methods
Control	none	N/A	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 1	Site Signage Improvements, with images, accepted and unaccepted materials in at least two languages	24 weeks	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 2	Site signage improvements, four direct mailings to residents	24 weeks	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 3	Site signage improvements,	24 weeks	Pre and post recycling audits

	four direct mailings to residents, fake cameras for perceived security		Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler)
Intervention 4	Site signage improvements, four direct mailings to residents, fake cameras for perceived security, 20 hours per week of onsite staffing	24 weeks	Pre and post recycling audits Frequency of illicit dumping-material outside of containers (monitored and tracked by hauler) Frequency of contaminants

Direct mailings would be based on best management practices developed through behavior change work on single-family households: at least four direct mailings with tested messaging on contamination and proper recycling topics. Onsite staffing will include a minimum of 20 hours per week, conducted during peak usage periods. Onsite staff will pull out visible contamination (from the top layer of material only), clean up illicit dumping, or any material left outside of the containers, provide direct feedback to patrons, and conduct surveys to gather usage data.

Recommended Sample Size and Demographics:

- At a minimum, all intervention groups and the control should include three self-haul sites. If possible, five or more sites in each group would provide more reliable data.
- A demographic analysis of each site should also be completed to ensure that demographics are similar between intervention groups and the control. Recommended demographics to control for: race, average household income, and level of education.

Recycling Collection Frequency: Minimum of weekly collection of the drop off container

Measurement Method(s):

All intervention groups and control:

Recycling Audits – For each audit, recycling will be categorized and weighed into a minimum of two categories: contaminants and quality recyclables. Communities can further categorize contamination to learn more about specific contaminants. See attached material audit categories list for recommendations.

Audit Schedule:

- Baseline – No more than one month before the intervention start date
- One to Two Months Post Intervention – Within two months of the intervention conclusion
- Twelve Month Post Intervention (Optional) If one to two-month audit shows positive results, an audit 12-months post intervention would be recommended.
- 24 Month Post Intervention (Optional) - If a 12-month audit shows continued positive results, an audit 24-months post intervention would be recommended.

Measurement for Intervention Groups 1-4 and Control will also include:

- Number of illicit dumping occurrences at each site

References

Archibald, Alicia (2021). *Technical Memorandum: Peoria Load-Based Generation and Capture Study Pre/Post Intervention Comparison Summary*. Kessler Consulting Company. Unpublished internal company document.

Cal Recycle. (2024) Mandatory Commercial Recycling. California.
<https://calrecycle.ca.gov/Recycle/Commercial/>

Cascadia Consulting Group. (2014, March). *Final Report: King County UTC Area Multifamily Recycling Pilots Culturally Competent Strategies for Increasing Recycling at Properties with Hispanic-Latino Residents*. Cascadia Consulting Group. <https://kingcounty.gov/~media/depts/dnrp/solid-waste/about/planning/documents/kc-utc-multifamily-recycling-project-2013-final-report.ashx?la=en>

Cascadia Consulting Group. (2017). *2017 Project Summary: Multifamily Recycling Services in the WUTC-Regulated King County*. Cascadia Consulting Group.
<https://www.wmnorthwest.com/20XXsummary/mf/materials/WM%20Multifamily%20Outreach%20Report%20-%20King%20County.pdf>

Cascadia Consulting Group prepared for Waste Management / Snohomish County Solid Waste / King County Solid Waste. (2018, November). *Contamination Reduction Tag Study*.

Cascadia Consulting Group. (2020, April 10). *Improving Oregon Recycling Systems Infrastructure Research: Collection Alternatives Research (Phase 2 Task 1)*.
<https://www.oregon.gov/deq/recycling/Documents/RSCcollectAlternatives.pdf>

Casey, Anthony. (2020, August 11). *How We Can Prevent Recycling Contamination*. Recycle B.C.
<https://recyclebc.ca/prevent-recycling-contamination/>

City of Abbotsford. (2023). *Contamination Remediation Plan*. <https://www.abbotsford.ca/CRP>

City of Hayward. (2023, March 28). Waste Management Soon to Charge Fees for Contaminated Recyclables and Overfilled Bins. Sustainability. <https://www.hayward-ca.gov/discover/news/mar23/waste-management-soon-charge-fees-contaminated-recyclables-and-overfilled-bins>

City of San Antonio. (n.d.) Solid Waste Management: Rates & Fees.
<https://www.sa.gov/Directory/Departments/SWMD/CurbSide-Service/Rates-Fees#Other-Fees>

City of San Jose. (n.d.) *Recycling*. City of San Jose.
<https://www.sanjoseca.gov/home/showpublishedimage/15019/637715300422500000>. Retrieved January 10, 2024.

City of Seattle. (2022, April). *Appendix B: Recycling Contamination and Outreach Plan*.
<https://www.seattle.gov/documents/departments/spu/documents/plans/2022solidwastedraftappb.pdf>

City of Tacoma. (2020) *Measuring Recycling Contamination and Behavior Change Using Survey 123 (ArcGIS Survey 123) [data file]*.
<https://geoduck.maps.arcgis.com/apps/dashboards/01625f120d804622a96951e312554753>. Accessed January 18, 2024.

City of Terrace. (2021, August 23). Upcoming Remediation Plan. https://engage.terrace.ca/one-change-per-week/news_feed/upcoming-remediation-plan

City of Toronto. (2019, February 2). *CIF 979: Promotion & Education Engagement to Establish Multi-Residential Best Practices*. City of Toronto. https://thecif.ca/wp-content/uploads/2019/02/979-Toronto_Final_Report.pdf

City of Toronto. (2019, September) *Toronto, Multi- Residential Front-End Loading Bin Contamination Abatement Project City of Toronto Report 1101*. City of Toronto. https://thecif.ca/wp-content/uploads/2019/12/1011-Toronto_Final_Report_r.pdf

Continuous Improvement Fund. (2019, November 1). *Doing Battle with Contamination? Peel Region just Completed a Study on Gravity Locks you Need to Read!* Continuous Improvement Fund. <https://thecif.ca/doing-battle-with-contamination-peel-region-just-completed-a-study-on-gravity-locks-you-need-to-read/>

De Young, R., Boerschig, S., Carney, S., Dillenbeck, A., Elster, M., Horst, S., Kleiner, B., & Thomson, B. (1995). Recycling in Multi-Family Dwellings: Increasing Participation and Decreasing Contamination. *Population and Environment*, 16(3), 253–267. <http://www.jstor.org/stable/27503397>

Foreman, Rebecca. (2019, November). *Multi-Residential Contamination Abatement Promotion & Education Campaign Project 1055*. Quinte Waste Solutions. <https://thecif.ca/wp-content/uploads/2019/12/PN-1055-MR-Contamination-Abatement-PE-Campaign-QWS-Dec-2019.pdf>

Goldstein, N. (2020, September 14). Reducing Contamination in Residential Curbside Carts. Biocycle. <https://www.biocycle.net/reducing-contamination-in-residential-curbside-carts/>
Green Solutions and Terra Linda Consultants. (2014, December). *Clark County Multi-Family Recycling Contamination Project: Final Report*. Green Solutions and Terra Linda Consultants. https://www.ezview.wa.gov/Portals/_1962/Documents/rcrr/Clark%20County%20MultiFamily%20Contamination%20Report.pdf

Guttchen, P., Church, H., Gimpel, S., Jones, S., Smith, A., Wadley, D., & Wesch, P. (2020, September). *Recycling Contamination Reduction Best Management Practices & Resources Companion Guide*. Washington State Department of Ecology. <https://apps.ecology.wa.gov/publications/documents/2007031.pdf>

Heffernan, Marissa. (2023, October 18). *On the Ground Excellence*. Resource Recycling. <https://resource-recycling.com/recycling/2023/10/18/on-the-ground-excellence/>

Link, Rod. (2023, May 12). Terrace in pursuit of People who don't Recycle Properly. Terrace Standard. <https://www.terracestandard.com/news/terrace-in-pursuit-of-people-who-dont-recycle-properly-6075412>

Lane County Public Works. (2021, June 30). Lane County Multifamily Recycling Improvement Project Report.

Loft, Jennie. (2021, November 22). *News Release: City Pilot Project Improves Recycling Behavior: Environmental Services Department Deploys Recycling Cart Lids with Helpful Recycling Tips, Reducing Contamination by 20 Percent*. City of San Jose. <https://www.sanjoseca.gov/Home/Components/News/News/3536/4699>

- Metro. (2020, May) Commercial Mixed Recyclables Composition Study. Metro. <https://www.oregonmetro.gov/sites/default/files/2020/05/21/commercial-mixed-recyclables-composition-study-20200521.pdf>
- Metro. (n.d.) *Guide to Recycling and Waste Reduction at Work*. Metro. <https://www.oregonmetro.gov/tools-working/guide-recycling-work>
- Oulton, Erin. (2022, February 16). Drop-off Contamination Studies Waste Characterizations [PowerPoint slides]. GT Environmental. <https://epa.ohio.gov/static/Portals/34/document/general/Drop-off%20Contamination%20Studies%20Waste%20Characterizations.pdf>. Retrieved December 4, 2023.
- Paben, Jared. (2019, May 14). *Experts duel over dual-stream's merits*. Resource Recycling. <https://resource-recycling.com/recycling/2019/05/14/experts-duel-over-dual-streams-merits/>
- Paben, Jared. (2020, June 23). *How Do Urban and Rural Recycling Streams Compare*. Resource Recycling. <https://resource-recycling.com/recycling/2020/06/23/how-do-urban-and-rural-recycling-streams-compare/>
- Prairie Robotics. March 9, 2022. City of Regina. <https://www.prairierobotics.com/studies/city-of-regina>.
- Recology. (n.d.) *Recology Contamination Reduction Plan for the City of SeaTac*. Recology. <https://www.seatacwa.gov/home/showpublisheddocument/32693/637858881269630000>
- Recology. (n.d.) Recycling Legislation: SF Zero Waste Initiatives. Recology. <https://www.recology.com/recology-san-francisco/recycling-legislation/>
- Recycle Colorado. (2020, June). *Multifamily Complex Recycling Pilot*. Recycle Colorado. <https://www.recyclecolorado.org/assets/docs/RECO%20MFC%20Pilot%20Report.pdf>
- Regina Leader-Post. (2021, August 12). City's CartSmart Program Adds Cameras to Catch Improper Recycling. Regina Leader Post. <https://leaderpost.com/news/local-news/citys-cartsmart-program-adds-cameras-to-catch-improper-recycling#:~:text=The%20success%20of%20the%20city's,go%20into%20a%20blue%20cart.>
- Republic Services. (n.d.) Welcome to Republic Services of Corvallis, OR. <https://www.republicservices.com/municipality/corvallis-or>
- Rivera, Dinga. (2023). Residential Recycling Contamination Study [PowerPoint slides]. Unpublished internal company document.
- Romanow, K., Osmond, V., Anderson J. (2023, April 23). Residential Garbage Cart Pilot Status Report [PowerPoint slides]. City of San Jose. <https://sanjose.legistar.com/View.ashx?M=F&ID=11807822&GUID=CC758F31-8438-4E31-B924-DCFBC890E4D6>. Retrieved January 3, 2024.
- San Francisco Department of the Environment. (2019, January 15). Official Notice: New Law Takes Effect – July 1, 2019. San Francisco Department of the Environment. <https://www.recology.com/wp-content/uploads/2019/01/SFE-letter-FINAL-1.pdf>
- Segundo, M., & Schweers, M. (2023, July 25). From Data to Decision-making. Resource Recycling. <https://resource-recycling.com/recycling/2023/07/20/from-data-to-decision-making/>

- Staffki, Brian. (2018, January). *Multi-Tenant Recycling Literature Review*. Oregon Department of Environmental Quality. <https://www.oregon.gov/deq/FilterDocs/recMultiTenLitRev.pdf>
- Staub, Colin. (2021, October 19). *WM details shift in recycling stream and end markets*. Resource Recycling. <https://resource-recycling.com/recycling/2021/10/19/wm-details-shifts-in-recycling-stream-and-end-markets/>
- Staub, Colin. (2021, November 9). *The Tag Trend*. Resource Recycling. <https://resource-recycling.com/recycling/2021/11/09/the-tag-trend/>
- Sullivan, J., & Lafreniere, D. (2011). *Improved Rural Recycling Depots through Signage*. Municipality of West Nipissing. https://thecif.ca/pdf/reports/PN-101-Final_Report.pdf
- The Recycling Partnership. (2018). *Backslide in MA*. Unpublished internal company document.
- The Recycling Partnership. (2018). *Contamination Reduction Kit: Feet on the Street Overview*. The Recycling Partnership. https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2021/10/Feet-on-the-Street-Overview-Recycling-Partnership.pdf
- The Recycling Partnership. (2021). *Drop-off Recycling Contamination Reduction Kit: 6 Steps to Replicate The Recycling Partnership's Drop-off Anti-Contamination Program*. The Recycling Partnership. https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2022/01/2021-Anti-Contamination-Toolkit-Dropoff.pdf
- The Recycling Partnership (2021). *Drop-off Results*. Unpublished internal company document.
- The Recycling Partnership. (2021, December 1) *Case Study: A Look at Contamination Reduction in the State of Washington*. The Recycling Partnership. <https://recyclingpartnership.org/case-study-a-look-at-contamination-reduction-in-the-state-of-washington/>
- The Recycling Partnership. (2021, May). *Final Report: San Marcos Multifamily Recycling Audit*. Unpublished internal company document.
- The Recycling Partnership. (2021, December 1). *Spokane MF Project*. Unpublished internal company document.
- The Recycling Partnership. (2022). *Recycling Contamination Reduction Kit: Ohio Case Studies*. The Recycling Partnership. https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2021/09/OH-Case-Studies-Recycling-Partnership-1.pdf
- The Recycling Partnership. (2022, May 24). *Investing in Multifamily Communities Pays Dividends*. The Recycling Partnership. <https://recyclingpartnership.org/investing-in-multifamily-communities-pays-dividends/>
- The Recycling Partnership. (2023). *Ohio EPA Drop-Off Quality Improvement: All Project Results*. Unpublished internal company document.
- The Recycling Partnership. (2023). *Introduction to Creating More Equitable Recycling Outreach*. The Recycling Partnership. https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2023/09/Equitable-Outreach-Guide.pdf

The Recycling Partnership. (2024). *Case Study: Personalized Recycling Education to Reduce Contamination*. The Recycling Partnership. <https://recyclingpartnership.org/case-study-personalized-recycling-education/>

Township of McNab/Braeside. (2015, April 13). *Final Report: Township of McNab/Braeside Small Program P&E Plan Implementation*. Township of McNab/Braeside. https://thecif.ca/wp-content/uploads/2018/04/819.6-McNab_Braeside_Final_Report.pdf

Wahlberg, Kirsten. (2020). *How can a local government implement environmental education for immigrant communities that live in apartment buildings?* School of Education Student Capstone Theses and Dissertations. 4491. https://digitalcommons.hamline.edu/hse_all/4491.

Waste Advantage Magazine (2023, November 6). Report Cards Educate Lewis County, WA Curbside Recycling Customers. Waste Advantage Magazine. <https://wasteadvantagemag.com/report-cards-educate-lewis-county-wa-curbside-recycling-customers/>

Wong, K., & Lawrence, L. (n.d.) WM Smart Truck Terminology: Always Working Towards a Sustainable Tomorrow [PowerPoint slides]. WM. <https://epa.ohio.gov/static/Portals/34/document/general/WM%20-%20Smart%20TruckSM%20Program%20Overview.pdf>. Retrieved December 7, 2023.

Appendices

Appendix A: Research Notes

This section includes notes from the desktop research and is included to provide additional context and insight into the studies referenced in the main report. Please note that these are rough notes and are not polished for publication.

Single-family Research Notes

Cart Tagging, Mailings, and General Education

Much of the available single-family research supported the use of cart tagging, cart rejection, and mailers as effective strategies to reduce contamination. In communities that distributed cart tags, contamination was reduced by 10-46% (Waste Advantage Magazine, 2023; The Recycling Partnership, 2022.; The Recycling Partnership, 2021c; Staub, 2021b). Five studies contained longer-term contamination data. In four of these five studies, the contamination rate was lower than the baseline rate ten months to three years after the interventions. For projects completed by The Recycling Partnership in 2023, the cost was generally \$4-7 per household.

The City of Spokane and Spokane County, Washington reduced contamination by 46% by tagging over 13,000 carts. After 10 months, contamination had increased slightly but was still below the pre-tagging rate (The Recycling Partnership, 2021c).

In Akron, Ohio the baseline contamination rate was 39%. After four rounds of cart tagging and two mailings, contamination was reduced by 28% to an overall contamination rate of 28%. Two years later, the contamination rate was 22% (The Recycling Partnership, 2022).

The City of Cambridge, Massachusetts implemented a campaign that combined cart inspections and oops tags with cart rejection, postcards, bill inserts, new cart decals, and advertising in public spaces. The combination of these interventions reduced the city-wide residential contamination rate of 11% in 2018 to 4.2% in 2020. Since 2020, the city has not conducted any cart tagging or specific outreach on contamination. In the summer of 2023, their residential contamination rate was 5% (M. Orr, personal communication, December 12, 2023).

In 2017 Dartmouth, Massachusetts conducted four rounds of feedback cart tagging with 711 households. In the first week of the visual inspection audits, 33% of households had contamination and by the fourth round of tagging, only 19% of carts had contamination. One year later, 90 households were randomly audited and only 6% of households had contamination, suggesting contamination continued to decrease after the interventions concluded and the impact of tagging was sustained for over one year (The Recycling Partnership, 2018).

In 2017 New Bedford, Massachusetts conducted four rounds of feedback cart tagging with 1,116 households. In the first week of the visual inspection audits, 40% of households had contamination and by the fourth round of tagging, only 31% of carts had contamination. One year later, 90 households were randomly audited and 48% of households had contamination, suggesting the impact of tagging did not last past one year (The Recycling Partnership, 2018). However, in this study, tagging was feedback only and there were no service consequences for contamination.

In most communities, four rounds of cart tagging are deployed. The Recycling Partnership recommends four rounds of tags for the optimal reduction in contamination. **Combining cart inspections with service rejection** increases contamination reduction. New Bedford and Dartmouth are neighboring communities in Massachusetts that share a recycling coordinator. New Bedford chose to tag carts only, while Dartmouth also rejected carts and reduced contamination by nearly twice New Bedford's rate (The Recycling Partnership, 2018b).

The City of Tacoma, Washington (2020) conducted a pilot with 244 households. The city started by conducting visual audits to establish baseline contamination. The city then conducted three interventions and measured contamination change after each intervention. First, the city used **cart tags with feedback** on recycling quality, resulting in a 2% reduction in contamination. The city then added a **social media campaign**, that reduced contamination by another 2%, for a total of 4% for the first and second interventions. Third the city sent a **postcard with personalized feedback** notifying residents of the levels and types of contamination found during the first three observations. This reduced contamination by another 6% relative to after the second intervention, for a total reduction of 12%. Additionally, Tacoma observed fewer cases of “extreme” or “high” contamination as the project progressed (City of Tacoma, 2020). While the personalized postcard resulted in the greatest reduction in contamination relative to the other interventions, it is not possible to isolate the impact of the postcard alone or to determine if this intervention had a greater impact because it benefited from awareness raised by the first two interventions.

The City of Napa, California tested multiple contamination reduction strategies with single-family households including various combinations of **one round of cart tagging, one or two mailings, and bin stickers**. While some of the interventions impacted the occurrence of specific contaminants in the recycling, none of the strategies reduced overall contamination at a statistically significant level. In this study, intervention groups each included a few hundred homes for mailings and bin stickers, and the cart tagging group included over 1,000 households (Goldstein, 2020).

Cameras, Artificial Intelligence, and Automated Feedback

Cameras on collection trucks are a promising but unproven strategy to gather more information about specific contaminants, identify individual households that are contaminating recycling and offer feedback on recycling quality.

During a pilot, the City of Regina, Saskatchewan worked with Prairie Robotics to measure contamination over a one-month baseline followed by a three-month campaign where residents were mailed postcards that identified contamination in single-family carts. The postcards were yellow with an emphasis on “Oops” messaging, like what is seen on many cart tags. This was coupled with an earned media campaign that highlighted contamination. The pilot included 11,875 households and resulted in a 41.5% decrease in contamination after sending 10,254 postcards to residents. The total project cost was \$21,900, including the cameras and mailings (Prairie Robotics, 2022). Before the pilot, the city had an annual single-family contamination rate of 9.5% in 2020 (Regina Leader-Post, 2021). The contamination rate was not measured after the pilot, other than the data provided by Prairie Robotics (D. Adams, personal communication, December 27, 2023)

WM (formerly Waste Management) uses an on-truck camera and technology system. In one presentation found online by WM, it noted that in pilot WM Smart Truck programs, cart contamination was reduced from an average of 20% to 1-2% with no other information about the pilot referenced (Wong & Lawrence, n.d.).

The City of Abbotsford, British Columbia used on truck camera technology to identify contamination and send mailers to residents as part of a multi-pronged approach. They did not measure the impact of this tactic and cost data was not available.

Service Consequences

The impact of service consequences is unknown because measurement data was not available. Several cities have implemented programs where recycling carts are removed, or service is suspended, after repeated contamination (Staub, 2021b). Due to the small number of households that have had service suspended, it is difficult to evaluate these efforts' effectiveness.

Many cities have adopted contamination charges to fine residents with contamination in their carts. Charges were commonly \$10-\$30 and generally are provided only after a warning. The charges were generally issued by the hauler or the municipality (City of Hayward, 2023; City of San Antonio, n.d.; Republic Services, n.d.). Despite the prevalence of contamination charges, little information is available on the effectiveness of charges in reducing contamination with single-family households or the costs to implement these programs.

Testing of Lids, Labels, and Garbage Cart Sizes

New lids and cart labels contributed to contamination reduction in two communities. In San Jose, increasing the size of garbage carts on routes with high recycling contamination reduced recycling contamination.

The Recycling Partnership worked with Peoria, Arizona on a contamination study that examined the **impact of inspections, cart tagging, education, and lid replacement.** The city collects garbage in light brown carts and recyclables in dark brown carts. The study included three routes that received different tactics: 1) educational recycling information only, 2) educational recycling information and a new blue recycling cart lid, 3) educational recycling information, a new blue recycling cart lid, feedback cart tag, and if the cart was contaminated, service was refused, 4) control group where no changes occurred. The measurement included both pre- and post-recycling composition audits. The post-audit occurred 13 weeks after the implementation strategy. **All three intervention groups had a decrease in contamination relative to the control.** (Archibald, 2021).

Change in Contamination from Pre- to Post Audits

Route	Change in Contamination Rate
Route 1	4.4% increase
Route 2	10.3% decrease
Route 3	7.7% decrease
Route 4 (control)	10% increase

Adapted from “Technical Memorandum: Peoria Load-Based Generation and Capture Study Pre/Post Intervention Comparison Summary.” By A. Archibald, 2021, unpublished internal company document, p4.

The City of San Jose, California conducted a pilot with 5,000 households over five collection routes where **new lids with recycling graphics were placed on recycling carts**. The city conducts robust recycling education, but no additional efforts were targeted at these routes. Before the pilot, the average contamination rate for these routes was 73% and after the pilot, **average contamination was reduced by 20%**. The graphics included images of accepted and unaccepted items with text in three languages. The impact was greatest on routes with high contamination (Loft, 2021). However, the new lids with recycling graphics did not reduce contamination on routes with average contamination. The cityside average contamination is 51%. (R. Varghese, personal communication, March 30, 2023)



Image Source: (City of San Jose, n.d.)

The City of San Jose, California also conducted a pilot to **test the correlation between larger garbage carts and recycling contamination**. The city-wide single-family contamination rate was 51% in 2020 and 57% in 2022. In the pilot, the city offered 4,200 homes larger garbage carts at no charge on routes with higher-than-average contamination. Contamination decreased on all pilot routes between 2020 and 2022. When comparing the 2020 contamination rates with the 2022 (post intervention), the **average reduction in contamination was 16 percentage points**. Additionally, garbage tons increased on these routes, suggesting that garbage moved from the recycling to the garbage cart (Romanow, et. al, 2023). This study did not include a control, so it is possible that other factors, including city programming, contributed to the reduction in contamination.

Multilayer Approaches by British Columbia Communities

A combination of education, audits, and contamination fines has helped communities in British Columbia maintain low contamination rates.

Both the City of Kamloops (population 90,000) and the City of Abbotsford (population 150,000) have contamination rates under 7% with single-stream collection. These communities deployed

significant programming in a **combination of education, audits, and contamination fines** that combined cart inspections, cart rejection, paid media, mailings, community outreach events, and contamination fines of up to \$100 per occurrence (M. Dick, personal communication, December 6, 2023; S. Subido, personal communication, December 21, 2023).

City of Terrace, BC reduced contamination from 13.8% in 2018 to 5% in 2019 with a combination of hopper cameras for visual screening, contamination reports to track repeat contamination, fines, and social media advertising (Casey, 2020). While this was initially successful, by 2021 contamination increased back up to 13%. In response, the city implemented additional cart screening, cart rejection, and added contamination charges in 2023 (City of Terrace, 2021; Link, 2023). Current contamination rate data was not available.

Switch to Dual-stream Collection

Communities with dual-stream collection have lower rates of contamination in British Columbia. Communities that have switched from single-stream to dual-stream collection and implemented education campaigns also have lower rates of contamination.

In a review of community recycling programs that switched from single-stream to dual-stream collection, Cascadia Consulting Group (2020) found that **dual-stream collection reduces contamination**. However, the communities conducted outreach efforts at the same time they switched to dual-stream collection, making it difficult to isolate the impact of the collection method from education. This study also noted that the switch to **dual-stream collection was not cost effective for Oregon** as the cost was estimated to be at least \$0.65 per month per household (\$7.80 annually, in 2020 dollars) (Cascadia Consulting Group, 2020).

In the California Bay Area, a hauler switched from single-stream to dual-stream collection using split carts with one side for fiber and one side for containers. With this system, Milpitas, a community of 14,000 single-family households, **reduced contamination from 25% to 10%** with a net savings of \$0.47 per household per month (\$5.64 annually), as the commodity value increase of \$0.68 more than offset the \$0.21 increase in the cost of new trucks and carts (Paben, 2019). Lake Worth, Florida saw a **reduction in city-wide contamination from 20% to 7% when it switched to dual-stream collection**, coupled with education including bill inserts, news releases, public signs, billboards, new stickers, door hangers, and paid advertising. With the capital investment for containers, the city estimates a 10.5-year payback (Paben, 2019).

Recycle BC noted many communities choose to operate multi-stream collection because of lower contamination. In 2022, the **contamination rate for single-stream collection was 8.64%, while the rate was 4.48% for multi-stream collection** (P. Cupcupin, personal communication, February 5, 2024).

Other Findings

The Washington State Department of Ecology published a guide with best practices for reducing contamination. The guide encourages programs to use a combination of communications and outreach, operational elements, policies and mandates, incentives, and pricing to reduce contamination. Approaches include recycling best practices such as clear messaging that

accounts for resident landfill aversion and the complexity of recycling, consistency with the hauler and local programs, program websites, and informing residents through a variety of channels. Single-family specific programs include cart tagging and rejection, targeted route mailers and consistency with blue recycling bins (Guttchen, et. al., 2020). All recommendations were supported by the state’s research, though the specific studies were not reviewed as part of this literature review due to limited available research hours.

Recycle BC attributed low contamination rates across the province to the multifaced approach that includes collection, curbside monitoring and enforcement, training, audits, and education. Furthermore, depots collect common contaminants like flexible plastics to maintain high-quality paper bales from commingled collection (P. Cupcupin, personal communication, December 14, 2023).

Research did not find information on tactics specific to rural residents. However, in a study conducted by the Continuous Improvement Fund in Ontario, recycling audits were compared from single-family and multifamily recycling programs in medium-sized urban cities and in rural areas. In comparing three years of audits, rural areas had similar levels of contamination (6.76% in rural areas compared to 6.61% in urban areas) (Paben, 2020).

Multifamily Research Notes

Educational Tactics

Educational strategies have mixed results in reducing contamination with many campaigns having no measurable impact on recycling contamination.

The City of Toronto offers multifamily-specific **recycling calendars, posters, stickers, and sorting guides in 18 languages, workshops, onsite technical assistance, advertising and direct mail campaigns, and a look-up item app**. In addition to these strategies, they conducted a pilot comparing various communication strategies including lobby displays, chute room posters, direct mail and/or onsite education. Before implementing the pilot, the city conducted focus group research, surveys, waste composition studies and created new recycling communications materials. The impact was measured with pre and post waste composition studies for the twenty participating buildings plus a control group. They found that **none of the strategies deployed reduced contamination**. They found that chute room posters were more effective at driving clicks to the website over direct mail to residents (City of Toronto, 2019a).

Quinte Waste Solutions, a municipal waste service board in Ontario, Canada conducted a multifamily pilot to reduce black plastic and polycoated cups in the recycling by delivering **seven door hangers** with the message “black plastic and coffee cups are garbage” with matching posters in each building. When comparing waste audit data for intervention and control properties, **only one of the three intervention properties had a decrease** in these materials in the recycling relative to the control (Foreman, 2019).

The Recycling Partnership worked with Orlando, Florida at three large, multifamily properties with 250 – 460 units each with recycling collection in dumpsters. The interventions included the distribution of **in-unit recycling bins and recycling instructions**. In visual inspections, **two of**

the three properties had a reduction in the number of contaminants present post intervention with a reduction of 31% at one property and 59% at the other. The third property showed an increase in contamination. (The Recycling Partnership, 2022; Rivera, 2023)

Lane County, Oregon worked with The Recycling Partnership to conduct a study to determine if basic education would reduce contamination with 25 properties of 2,062 units. Education was provided at properties with **a letter to property managers, earned local media, an informational handout and in-unit recycling totes for residents**. As determined through visual inspections, **of the 25 properties in the study, 14 properties reduced contamination by an average of 56%** (Lane County Public Works, 2021).

The City of Tacoma, Washington implemented a Community Ambassador Program with multifamily properties to build trust, increase language access, and develop partnerships with organizations that support Tacoma's immigrant community. In this pilot, **the city conducted 39 educational trainings** with 455 participants with partner organizations and in languages other than English. At these trainings, the team used a train-the-trainer model to have the community trainers translate information, frame the content appropriately, and share information with friends, family, and neighbors. The city is expanding this program and hopes that it will reduce contamination, although **the pilot program did not conduct measurements around contamination** (P. Peck, personal communication, January 16, 2024).

De Young et. al (1995) conducted an experimental study with 98 recycling complexes in Ann Arbor, Michigan. Researchers found that **feedback on the complex's recycling delivered by postcard, a written resident commitment, and general feedback on recycling delivered by newsletter, were effective in reducing contamination and the effect was largest in medium-sized (11-30) complexes**. These techniques had a limited impact in small properties (less than 10 units) as these properties had fewer issues with contamination. None of the treatments impacted contamination at the large complexes. This study also found that volunteer recycling coordinators did not impact recycling quality. Researchers attribute the challenges at larger complexes to the feelings of anonymity and non-involvement from residents, along with social conditions that erode the impact of social norms (De Young et. al, 1995).

The Recycling Partnership (2021e) conducted a project with Spokane County, Washington to provide **educational flyers and door hangers and in-unit tote bags to multifamily residents** at 35 properties with 1,807 units. Eight of these properties started recycling service as part of this project. There was one control property with 416 units. Visual inspections of recycling were completed before, during, and after the interventions for seven inspections at each property, recording the garbage and recycling fullness and contamination. Before the interventions, the **average recycling contamination rate was 18% and was reduced to 6% three months after the tote bag distribution**, while the control was 20% during the baseline period and 35% three months after the tote bag distribution. The average cost per unit was \$20 (The Recycling Partnership, 2021e).

Improvements to Containers, Service Levels, and Education

Strategies that combine changes to service levels, container location, container types, and education, have been more successful at reducing contamination than education alone.

Cascadia Consulting Group (2014) worked with King County, Washington to pilot strategies for increasing recycling at properties with Hispanic-Latino residents. In this study, eight test properties and three control properties were selected in Unincorporated King County with higher numbers of Hispanic-Latino residents, low recycling, and high levels of garbage in recycling. Properties ranged from an unknown number of Hispanic-Latino residents to 100%, with most properties having over 50% Hispanic-Latino residents. Base interventions included **letters to property managers, recycling infrastructure recommendations, service level changes, and resident engagement**. Resident education tactics included **in-unit recycling totes, educational magnets, container decals, illegal dumping signs, and bilingual door-to-door outreach** (group 1). Additionally, three properties also received recycling **information cards with culturally relevant images** (group 2) and another three properties hosted a community event (group 3). As measured in waste audits over a six-to-nine-month period, **all groups had a reduction in contamination of 20% relative to the control. Group 2 had the greatest decrease in contamination**. The cost for door-to-door education was \$54/unit (\$3,592 per property) and technical assistance was \$2,182 per property.

In King County, Cascadia Consulting Group (2017) conducted a study of 52 properties with 2,407 units to implement service level changes. In this study, **properties that had infrastructure improvements** (conveniently placed recycling, clarity of which containers are for recycling, blue recycling containers, and at least 20 gallons of recycling service per unit) **and resident education saw an increase in recycling volume and a decrease in contamination**. In comparing pre and post audits at 18 properties, the average contamination, by volume, decreased by 50%, from a baseline of 16% down to 8%.

Lewis County, Washington conducted a pilot project with 250 multifamily units that reduced contamination by 55% (Waste Advantage Magazine, 2023). Lewis County worked with seven properties to make recommendations for **service adjustments, and distributed educational materials including recycling signs, flyers, and tote bags for residents**. When comparing the pre-contamination levels with the post-contamination levels, a **55% reduction** was observed a few weeks after the intervention (M. Case, personal communication, December 4, 2023). Because the interventions were conducted simultaneously it was not possible to determine the impact of each element.

In a study conducted in Clark County, Washington (Green Solutions and Terra Linda Consulting, 2014) with 33 properties, researchers found improvements in recycling quality as noted by auditors through visual inspection at multifamily properties after improvements were made to carts, labels, and recycling signage.

A study was conducted in Hennepin County, Minnesota to specifically examine recycling education for immigrant populations to increase recycling and decrease contamination with six properties with 35-300 units. Most residents at participating properties were non-native English speakers. The interventions combined **co-location of trash and recycling, color coding bins, ensuring adequate capacity, icon-based signage, posting signage, in-unit recycling tote bags, access to a culturally relevant recycling event, and a recycling quiz**. Pre and post waste audits for intervention and control properties found no **decrease in contamination** (Wahlberg, 2020).

Unit Level Feedback and Rejection

Feedback on recycling quality at the resident doorstep are promising tactics for this sector.

Recycle Colorado (2020) worked with the City of Denver on a six-month pilot with eight multifamily properties where four properties were supplied with 2-yard recycling containers and four properties were provided door-side valet service twice per week. **All properties were provided with in-unit recycling baskets, and education to property managers and residents.** At the properties with valet service, when collecting recyclables, **staff pulled out contaminants and left them in the resident's basket with an oops tag.** For properties with 2-yard bins, visual audits were used to determine recycling quality. At properties with valet service, both recycling weights and visual audits were conducted. The measurement data had numerous limitations, but **the contamination rate with valet service was estimated to be less than 3% compared to 10-15% with the traditional recycling service.**

The Recycling Partnership worked with San Marcos, Texas to test three different interventions at multifamily properties to increase the quantity and quality of recyclable materials collected. Interventions included education only (13 properties with 2519 units), education and in home bins (11 properties with 1639 units), and education and in home bins with weekly valet collection service (5 properties with 1342 units). Recycling volume was measured for three-weeks prior and post intervention and showed that both groups that received the in-home bins increased recycling quantity and decreased contamination, though this finding was not statistically significant (The Recycling Partnership, 2021d).

Service Consequences & Refusal

Inspections with service refusal is a promising tactic for this sector.

In a contamination reduction initiative, the city of Toronto hired a crew of six inspectors to audit containers four days per week. On average, each crew inspected 65 buildings per day, for 780 inspections per week. **If inspectors found recycling was more than 25% contaminated, the property manager was given the option to remove contamination or have the container serviced as garbage,** and inspectors left a notice of non-compliance at the site. Inspectors focused on routes with the highest contamination level. **Over three years, contamination was reduced from 16.02% to 11.32%** (City of Toronto, 2019b).

Some communities have multifamily contamination charges. Despite the prevalence of contamination charges, little information is available on the effectiveness of charges in reducing contamination in multifamily households. Seattle, Washington; SeaTac, Washington; and Denton, Texas have contamination charges in combination with other program elements.

Containers with Chute lids

The Region of Peel, Ontario **piloted gravity locks with a chute opening for recyclables** on front load containers at multifamily properties. In the pilot, residents were provided with **informational door hangers, in person education, and tote bags to collect recycling.** Pilot included 11 properties with 17 front load containers. In the pilot, **contamination was reduced**

from 35% to 31% over the first six months and then decreased to 29% after another six months (Continuous Improvement Fund, 2019).

The City of SeaTac, Washington, and Denton, Texas have also seen success in reducing contamination with the addition of chute lids. However, in these two communities, chute lids were deployed simultaneously with other tactics, making it difficult to determine the impact of the lids alone.

Multilayer Approaches with Inspections and Enforcement

Communities with a combination of inspections, compliance, and education have reduced contamination at multifamily properties.

The City of Seattle, Washington reports 11.4% contamination for multifamily in their Recycling Contamination and Outreach Plan (City of Seattle, 2022). In this report, the city attributes low contamination levels to coordinated efforts between operations, compliance and education that combined driver training on contamination, driver tagging, letters sent for repeat contamination and if contamination is not resolved, follow up by an inspector with the potential of a \$50 fine. Additionally, property managers can request visits from bilingual staff, flyers, posters, and stickers for outreach materials, including multilingual materials. Recycling container labels included the four most common languages spoken in Seattle. The city is also moving towards harmonized colors of the single-family and multifamily recycling containers (City of Seattle, 2022).

Over the past five years, the City of SeaTac, Washington has tested and implemented strategies to reduce contamination in multifamily and commercial properties. Their current contamination reduction plan includes routine audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard. Annually in January, each commercial and multifamily property in the city is audited. If contamination is found, followed up is made with a phone call, letter, copy of the inspection report, and monthly audits until no contamination is present. Properties that have contamination are audited monthly, or more frequently, until issues are resolved. If more than 10 instances of contamination occur, recycling service can be removed (Recology, n.d.)

In 2019 when this program was first launched in SeaTac, the January inspections found **183 contaminated containers during 217 visual audits**. Due to repeat contamination, 2,087 visual inspections were completed with an average contamination of 42%. The city issued 465 contamination fines. **By January 2022, only 22 properties had contamination in visual audits and MRF audits measured commercial contamination at 6.5%**. No contamination fines were issued that year. A small number of properties discontinued recycling during this time (M. Giem, personal communication, December 8, 2023).

The City of Denton, Texas implemented a pilot program with lock bars and chute lids on containers at multifamily properties on a route with high contamination. Additionally, the city provided recycling information to property managers, updated decals on containers and offered in-unit recycling bags. Before and after the pilot, contamination was measured by collecting materials from participating multifamily properties on a dedicated route and sorting materials at

the MRF (J. Amador, personal communication, December 13, 2023). **The contamination rate was 64% before the pilot and 39% after the interventions** (Heffernan, 2023). The city has maintained a multifamily and commercial contamination rate that is below 40%, suggesting a sustained impact from the pilot interventions. Additionally, the city audits multifamily as part of their city-wide recycling audits. When an auditor inspects a container and finds more than 15% contamination, the container is not serviced, and the property has the option to have the container serviced as garbage a fee or remove contaminants. While on site, the auditor updates recycling decals as needed (J. Amador, personal communication, December 13, 2023).

The City of Kamloops, British Columbia has a multifamily contamination rate of 9% (Segundo & Schweers, 2023). The city has over 300 multifamily properties with 12,000 units and most are managed by the same five property management companies. The city has worked to develop relationships with the property managers and provides **free door to door education, pop up events, in home bins, and custom signage**. The contamination program is mostly managed by **recycling drivers as they leave feedback on bins and remove small amounts of contamination**. The drivers do not service contaminated bins and property managers seem to be motivated to reduce contamination so that they do not need to deal with the hassle of un-serviced containers. **If contamination is not removed, the city charges a \$100 fine plus** the cost to service the container as garbage (M. Dick, personal communication, December 6, 2023).

Other Findings

The Washington State Department of Ecology published a guide with best practices for reducing contamination. The guide encourages programs to use a combination of communications and outreach, operational elements, policies and mandates, and incentives and pricing to reduce contamination. Approaches include recycling best practices such as clear messaging that accounts for resident landfill aversion and the complexity of recycling, consistency with hauler and local programs, program websites and informing residents through a variety of channels. Multifamily specific elements include building relationships with property managers, onsite technical assistance, ongoing resident communications, move in guides, attending community gatherings and supporting recycling champions at properties. Additionally, setting up properties with convenient recycling, clear containers with standard cart and container colors, adequate capacity, chute lids, contamination charges, audits, hauler cameras and technology, and minimum service level ordinances were recommended (Guttchen, et. al., 2020). All recommendations were supported by the state's research, though the specific studies were not reviewed as part of this literature review due to limited available research hours.

Brian Stafki (2018) from Oregon DEQ conducted a multi-tenant literature review. Stafki included the following related to contamination:

“Contamination may also become an issue if signage is only in English (Fish, 2015; Metro, 2017; Campbell Delong Resources, Inc., 2014) Enlisting the assistance of groups that already work within specific focus communities can lead to a better understanding of their specific barriers to recycling (Washington Multifamily Recycling Study Group, 2014)” (Stafki, 2018, p. 11)

“Similarly, a long-term, values-based, community engagement campaign was launched in West London, United Kingdom. This approach aimed to change behavior by addressing issues

important to the community, rather than focusing only on recycling. Fifty-one initiatives, reaching 3,200 residents in 13 public housing complexes, were designed, and delivered by 67 resident volunteers, in collaboration with program staff. The total volume of recycling collected increased by an average of 21 percent in pilot complexes and observable contamination decreased by an average of 14 percent (Cascadia Consulting, 2012)” (Stafki, 2018, p. 17)

Commercial Research Notes

Cameras, Artificial Intelligence, and Automated Feedback

Numerous articles reviewed expressed enthusiasm for camera systems, either in dumpsters or on trucks, without data on effectiveness or study results.

Only one article referenced the effectiveness of this strategy with WM. WM uses Smart Truck technology that includes on-board cameras, artificial intelligence, and a contamination notification system. WM reported when a fleet of trucks that services commercial customers was rolled out in Northern California, within three months contamination had been reduced by 89% (Staub, 2021). However, the specifics of this measurement or community were not shared in the article.

Service Consequences

As was found in the residential sector, some communities have commercial contamination charges to fine properties for contamination. In the literature review, no information was found on the effectiveness of charges in reducing contamination in this sector.

SeaTac, Washington and Denton, Texas have contamination charges in combination with other program elements. As these charges are part of a larger contamination reduction strategy, it is difficult to determine the impact of contamination charges alone.

Multilayer Approaches with Inspections and Enforcement

SeaTac, Washington and Denton, Texas have used a combination of inspections, technical assistance, and charges to reduce contamination.

Over the past five years, the City of SeaTac, Washington has tested and implemented strategies to reduce contamination in multifamily and commercial properties. Their current contamination reduction plan **combines routine audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard.** Annually in January, each commercial and multifamily property in the city is audited. If contamination is found, they follow up with a phone call, letter, copy of the inspection report, and monthly audits until no contamination is present. Properties that have contamination are audited monthly, or more frequently, until issues are resolved. If more than 10 instances of contamination occur, recycling service can be removed (Recology, n.d.)

In 2019 when this program was first launched in SeaTac, inspections in January noted 183 contaminated containers during 217 visual audits. Due to repeat contamination, 2,087 visual

inspections were completed with an average contamination rate of 42%. The city issued 465 contamination fines. By January 2022, only 22 properties had contamination in visual audits and **MRF audits measured commercial contamination at 6.5%**. No contamination fines were issued that year (M. Giem, personal communication, December 8, 2023). One limitation of this data for the commercial sector is that service is open market. The snapshot provided by SeaTac only includes commercial service that is provided by the franchised waste hauler.

The City of Denton, Texas audits commercial containers as part of their city-wide recycling audits. When an auditor inspects a container and finds more than 50% contamination, the container is not serviced, and the property has the option to have the container serviced as garbage for \$75 or remove contaminants. While on site, the auditor updates recycling decals as needed (J. Amador, personal communication, December 13, 2023).

Denton also **offers lock bars with chute lids for commercial properties that have high contamination** (Heffernan, M., 2023). After distributing lock bar and chute lids at select commercial properties, the commercial **contamination rate decreased by 9%** compared to the previous year. While some businesses prefer the lids as they help reduce contamination, some businesses have expressed concern with buildup contamination outside the container. Some businesses have noted that it is more manageable to deal with contamination outside the dumpster than once it has been placed in the dumpster. The city also offers educational posters and employee training (J. Amador, personal communication, January 30, 2024).

Other Findings

A commercial mixed recyclables composition study from Metro (2020) found an average contamination rate of 14%. This suggests that the combination of strategies implemented in the Metro region has been successful at reducing and maintaining a low level of contamination. Metro (n.d.) supports businesses in the region with technical assistance and resources such as stickers, signs, and flyers.

The City of Seattle (2022) notes in their Recycling Contamination and Outreach Plan that most commercial recycling is source separated with limited contamination. Due to this, Seattle prioritizes contamination reduction efforts on residential recycling. The city supports business recycling with posters, flyers, stickers, interior collection bins, training, and technical assistance. Additionally, they work closely with large institutions such as school districts and universities.

The City of San Francisco, California has a requirement that all large refuse generators (40 cubic yards or more of uncompacted waste per week) have their waste audited at least once every three years and must have less than 10% recycling contamination to pass the audit. If the business fails the audit, they must engage with the city's technical assistance team (Recology, n.d.b). In a letter to businesses from the San Francisco Department of the Environment (2019) notes that they may assess fines for up to \$1,000 per day for non-compliance and that properties have avoided contamination by working with city staff. The contamination rate for San Francisco was not identified during the literature review.

The Washington State Department of Ecology published a guide with best practices for reducing contamination. The guide encourages programs to use a combination of communications and

outreach, operational elements, policies and mandates, and incentives and pricing to reduce contamination. Approaches include recycling best practices such as clear messaging that accounts for resident landfill aversion and the complexity of recycling, consistency with hauler and local programs, program websites and informing residents through a variety of channels. Commercial specific elements include technical assistance, indoor and outdoor signage, working with business organizations, seeking consistent color with the residential recycling colors, contamination audits, hauler cameras and technology (Guttchen, et. al., 2020). All recommendations were supported by the state's research, though the specific studies were not reviewed as part of this literature review.

California requires that all businesses that generate over four cubic yards of solid waste must recycle. Local governments are required to provide recycling education, outreach, and monitoring of businesses and, in some cases, enforcement (Cal Recycle, 2024). With these requirements in place, it is likely that Oregon could learn about the effectiveness of this approach. However, documentation was not found about the effectiveness of these programs at reducing contamination. As part of the literature review, numerous commercial recycling case studies were reviewed from the Institute for Local Government, an organization that supports local governments in California, but none of the case studies addressed recycling contamination.

Self-Haul Research Notes

Educational Tactics

The Recycling Partnership has conducted drop-off quality improvement projects with municipalities to reduce contamination and increase participation at rural drop-off locations. **The Recycling Partnership has an Anti-Contamination Toolkit specific to drop-off facilities that has been informed through data backed pilots.** The Toolkit recommends the following strategies: onsite survey of residents to inform/target education, in person feedback at the drop-off facility, annual mailer, signage at the facility, a website and social media promotions, as well as site security features such as cameras or fencing (The Recycling Partnership, 2021). The Recycling Partnership pilot studies showed a higher level of contamination reduction when the Toolkit recommendations were followed more diligently and more of the recommendations were implemented.

Additional studies to reduce contamination at drop-off include:

In collaboration with six counties and a solid waste authority in Michigan (Alpena County, Antrim County, Manistee County, Emmet County, Cheboygan County, Presque Isle County, Portland Township, RRRASOC), The Recycling Partnership used educational mailers and site signage, onsite staff to conduct surveys and provide direct feedback to residents on their recycling. On average, **contamination was reduced by 26%** based on MRF audits. (The Recycling Partnership, 2021b)

The Recycling Partnership worked with three solid waste districts in Ohio (Athens-Hocking, Mahoning County and Ottawa Sandusky Seneca) on anti-contamination projects at their drop-off sites using strategies like the previous Michigan work, including onsite surveys and direct feedback, collection container cameras and updated site signage. Combined, the three projects

saw **contamination reduced by an average of 28%** based on a MRF audit, visual inspections, and cameras within drop-off containers (The Recycling Partnership, 2023).

The Township of McNab/Braeside, Ontario is a community of 3,114 single-family households with curbside and depot recycling collection. For less than \$1,500, the township **mailed recycling information to all residents, added new graphic signs to recycling depots, and placed six ads in local papers** promoting accepted and unacceptable recyclables. When comparing year-over-year contamination fines from the recycling contractor, there was a **58% decrease in contamination fines**. Over this same period, there was a 54% decrease in staff time at the depots to remove contamination (Township of McNab/Braeside, 2015).

Two solid waste districts in Ohio, Adams-Clermont, and Lucas County, conducted a drop-off recycling, site-based illegal-dumping, and anti-contamination project in 2018 to test the efficacy of using **education and signage** to reduce onsite contamination. Adams-Clermont used cameras and electronic message boards onsite, resulting in a **73.4% reduction in contamination**, from 41% to 10.9%. Lucas County conducted an educational campaign using mailers, onsite signs, billboards, websites, and social media, resulting in a **50% contamination reduction**, from 24% to 12% (Oulton, 2022).

Enhanced Security Features

The Ross, Pickaway, Highland, Fayette Recycling and Solid Waste District (RPHF) in Ohio operates 32 drop-off recycling sites with front load containers for recycling. Most communities in this area do not have curbside recycling collection. The average contamination rate between all sites was 15% with a few sites with contamination over 50%. In 2021, RPHF opened a new recycling drop-off with **security features including an eight-foot commercial grade chain link fence (\$9,859), fire and security fence with gate and access control system (\$30,300), and new signage (\$610)**. The site is open 5am-10pm with video surveillance that can be accessed with a key code. Residents can register to access the site at no cost to receive their four-digit code with educational materials about accepted recyclables. One thousand three hundred households have active membership. As determined in waste sorts conducted by RPHF staff, **the site has 3% contamination** (L. Haubeil, personal communication, January 18, 2024).

Addition of Signs Only

At four rural recycling depots in West Nipissing, Ontario **eight-foot by eight-foot signs** were added next to recycling bins showing accepted and unacceptable items. Contamination was visually monitored for 13 weeks visually on a rotating schedule of days (Mondays, Wednesdays, and Fridays) to establish a baseline. Contamination was ranked 1-10, with 10 having no contamination, by MRF employees and management staff. The average contamination was 6.35. They followed the same process after signs were installed, one year later, during the same months. The average contamination was 7.77 on the 10-point scale, a **decrease of 22%** (Sullivan & Lafreniere, 2011).

Other Findings

The Washington State Department of Ecology published a guide with best practices for reducing contamination. The guide encourages programs to use a combination of communications and outreach, operational elements, policies and mandates, and incentives and pricing to reduce contamination. Approaches include recycling best practices such as clear messaging that accounts for resident landfill aversion and the complexity of recycling, consistency with hauler and local programs, program websites and informing residents through a variety of channels. Drop-off specific recommendations include staff or volunteers to educate residents at drop-off, collecting drop boxes with other community services, and signs to show accepted materials (Guttchen, et. al., 2020). All recommendations were supported by the state's research, though the specific studies were not reviewed as part of this literature review due to limited available research hours.

Notes from on Multi-Tactic Efforts from Select Communities

Following the literature review and call for research, The Recycling Partnership reached out to communities that have implemented successful contamination reduction programs or high performing programs that lack written reports or documentation. Through conversations with these communities, The Recycling Partnership identified existing research that was not well documented or published online.

When speaking with communities, The Recycling Partnership incorporated questions that help to address the quality of the research and programming, including questions about methodology, sample size, measurement, program costs and durability of any reductions in contamination.

SeaTac, Washington

Over the past five years, the City of SeaTac has tested and implemented strategies to reduce contamination in multifamily and commercial properties. Their current contamination reduction plan includes routine audits, technical assistance, phone calls and written warnings, followed by contamination charges starting at \$10 per yard. Annually in January, each commercial and multifamily property in the city is audited. If contamination is found, follow up is made with phone call, letter, copy of the inspection report, and monthly audits until no contamination is present. Properties that have contamination are audited monthly, or more frequently, until issues are resolved. If more than 10 instances of contamination occur, recycling service can be removed (Recology, n.d.).

In 2019 when this program was first launched, the January inspections found 183 contaminated containers during 217 visual audits. Due to repeat contamination, 2,087 visual inspections were completed with an average contamination of 42%. The city issued 465 contamination fines. By January 2022, only 22 properties had contamination in visual audits and MRF audits measured commercial contamination at 6.5%. No contamination fines were issued that year (M. Giem, personal communication, December 8, 2023).

The city implemented a pilot program with seven multifamily properties that included chute dumpster lids for commingled recycling with a separate collection container for plastic bags. The

plastic bag collection was intended to serve as a place to recycle plastic bags, which had been identified as a top contaminant, but were filled with garbage and were discontinued. The chute lids were effective at reducing contamination in the recycling as noted in visual inspections. After the pilot, lids were made available to any property with contamination. As a result of these efforts, the city's multifamily contamination rate went from 40% to 5% as measured through visual inspections by the hauler and MRF audits (M. Giem, personal communication, October 5, 2023).



Chute lid installed on container in SeaTac, WA (M. Giem, personal communication, October 6, 2023).

Kamloops, British Columbia

City of Kamloops was featured in a case study in Resource Recycling for implementing programing that reduced the residential contamination rate to 7% and multifamily to 9%, with daily audits for single-family and multifamily recycling and education through an app. Kamloops has 27,000 single-family households and 12,000 multifamily units (Segundo & Schweers, 2023).

In a follow-up conversation with Marcia Dick, Solid Waste Reduction Coordinator for the City of Kamloops, Dick cited their container auditing as the main source of education and feedback. In addition to the audits, the city also provided education through print, radio, social media, TV, earned media, bus ads, city communications, annual mailers, booths at events and school presentations. The city has single-stream collection.

The city employs two full time inspectors and seasonal staff to review recycling contents, pull out contaminants and leave contaminants for residents to dispose of. Each year they inspect about 7,000 households. Marcia Dick estimates that about 2% of residents do not respond to tags. If they do not respond, a process is followed to attempt to resolve the issue, this includes a mailed letter, a red sticker on the cart requiring a call to the city for service, suspension of service, a follow up inspection and, if the issue is still not resolved, a \$100 ticket is issued.

Tickets are very rarely issued. The tickets are issued to the homeowner, not the tenant, helping to address equity and issues with language.

The city has over 300 multifamily properties and most are managed by the same five property management companies. The city has worked to develop relationships with the property managers and provide free door to door education, pop up events, in home bins, and custom signage. The contamination program is mostly managed by recycling drivers as they leave feedback on bins and remove small amounts of contamination. The drivers do not service contaminated bins and property managers seem to be motivated to reduce contamination so that they do not need to deal with the hassle of un-serviced containers. If contamination is not removed, the city charges a \$100 fine plus the cost to service the container as garbage (M. Dick, personal communication, December 6, 2023).

Denton, Texas

The City of Denton has implemented strategies to reduce contamination with multifamily and commercial properties. The city hauls single-stream material from commercial and multifamily properties that opt to use the city service and offers technical assistance to all properties within the city. In a pilot program, lock bars and chute lids were added to containers at multifamily properties on a route with high contamination. Additionally, the city provided recycling information to property managers, updated decals on containers and offered in-unit recycling bags. Before and after the pilot, contamination was measured by collecting materials from participating multifamily properties on a dedicated route and sorting materials at the MRF (J. Amador, personal communication, December 13, 2023). The contamination rate was 64% prior to the pilot and 39% after the interventions (Heffernan, 2023).

Since the success of the pilot, the city is phasing in lock bars and chute lids at multifamily and commercial containers city wide. The city has a year-end multifamily and commercial contamination rate of 34% suggesting a sustained impact from the pilot interventions (J. Amador, personal communication, December 13, 2023).

Additionally, the city audits multifamily and commercial containers as part of their city-wide recycling audits. When an auditor inspects a container and finds more than 15% contamination, the container is not serviced, and the property has the option to have the container serviced as garbage for a fee or remove contaminants. While on site, the auditor updates recycling decals as needed (J. Amador, personal communication, December 13, 2023).

Abbotsford, British Columbia

The City of Abbotsford collects single-family recycling in a fully automated single-stream program (City of Abbotsford, 2023). Part of the city is serviced by a municipal fleet and part by a private hauler. Recycle BC identified a city-wide curbside recycling contamination rate of 14% based on audits completed May 2021 – August 2022 (City of Abbotsford, 2023). At this time, the city had a seasonal cart inspection for contamination with rejection for carts that had significant contamination. The city also spoke with residents at community outreach events and provided utility bill inserts with recycling information (S. Subido, personal communication, December 21, 2023).

With the goal of reducing contamination by 25%, the city implemented numerous additional contamination reduction measures including:

Increased cart inspections to year-round, rather than seasonal. In addition to notifying residents about contamination, the city places stickers on properly sorted carts and residents can enter a drawing to win prizes and discounts on Solid Waste User fees.

Followed up with residents that receive cart tags with a warning letter and second recycling audit. If recycling is still contaminated, a ticket is issued.

Added camera technology to trucks to supplement auditor inspections. The private hauler uses onboard truck technology to identify contamination and send mailers to residents.

Hosted a recycling information session for community members to provide transparency into the recycling program and educate residents.

Started social media and paid advertising campaigns (City of Abbotsford, 2023; S. Subido, personal communication, December 21, 2023).

The city also offers translations services and print material in languages commonly spoken in the community. The combination of these efforts has reduced the city's contamination based on the most recent round of audits conducted by Recycle BC (S. Subido, personal communication, December 21, 2023).

Appendix B: Recommended Material Audit Sort Categories

Aluminum Cans
Aluminum Foil and Trays
Aseptic and gable top containers
Bagged recyclables
Bagged waste
Batteries
Bulky contaminants
Bulky Rigid Plastics
C&D waste
Colored HDPE Bottles
Corrugated cardboard
E-waste and small appliances
Food waste
Glass Bottles and Jars
Hazardous/Special waste
Mixed paper
Natural HDPE Bottles
Non-bottle HDPE Containers
Non-bottle PET containers - Clamshells
Non-bottle PET containers – Cups
Other contaminants
Other non-bottle PET rigids - Clear
Other non-bottle PET rigids - Opaque/Pigmented
Other Plastic (#3, #4, #6, and #7) Cups
Other plastic film & flexibles
Other Polypropylene Non-bottle Rigids
Other Small Rigid Packaging Containers (#3, #4, #6, and #7)
PET Bottles, Jugs, and Jars - Clear
PET Bottles, Jugs, and Jars - Opaque/ Pigmented
Plastic bags and clean film
Plastic garbage bags
Polypropylene Bottles, Jugs, and Jars
Polypropylene Clamshells
Polypropylene Cups
Polypropylene Tubs
Sharps
Steel Cans
Tanglers
Textiles and shoes
Unacceptable glass, ceramics, and porcelain
Unacceptable metals
Unacceptable paper
Unacceptable rigid plastics
Yard waste