MATERIALS RECOVERY FACILITIES

Effective Operation, Design and Management in Theory & in Practice

CLOSED LOOP CENTER for the Circular Economy

About the report

The development of this guide was sponsored by the American Beverage Association and led by the Closed Loop Center for the Circular Economy, an innovation firm that helps global brands, retailers and manufacturers solve their most pressing material challenges. To conduct the work, the Closed Loop Center commissioned Resource Recycling Systems (RRS), a mission-driven consultancy, staffed by experienced materials recovery facilities (MRF) experts, dedicated to providing circular economy and materials management solutions. The impetus for this guide was to disseminate knowledge that MRF management personnel could use to improve their operations for increased recovery of materials, thereby keeping more valuable resources in circulation and out of landfills or incinerators.

Acknowledgments

The report authors engaged several different MRF operators spanning most of the United States, four different equipment vendors, and subject matter experts to inform the key best practices which emerged as the industry's consensus. We would like to express our deepest gratitude to the representatives from the following organizations, who graciously took the time to participate in interviews and provide invaluable insights on standard best practices. Their expertise, knowledge, and willingness to share their experiences were instrumental in shaping our understanding and refining our approach:

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CP Group

Machinex

Van Dyk Recycling Solutions (VDRS)

As well as additional operators and subject matter experts who wish to remain anonymous.

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CAP Superior Fine Grind

Circular Services

Lexington-Fayette Urban County Government (LFUCG)

Napa Recycling and Waste Services

ReGen Monterey

Rumpke Waste & Recycling

CLOSED LOOP CENTER for the Circular Economy

Executive Summary & Guidance

The goal of this work is to equip materials recovery facilities in the US with actionable best practices to optimize recovery rates, increase material quality, maximize throughput, extend equipment life, and foster resilient, high-performing teams ready for industry evolution. This guide is intended to be used by MRF management personnel as a first step in identifying any areas of improvement at their facility. In addition to the guide itself, there is a set of complementary templates, available for download, which can be utilized as a basic structure for establishing some of the following best practices.

The guidance in this summary aggregates the recommendations that follow into a set of practices and procedures that together could provide a standard for MRFs to follow as a way of demonstrating to third parties (such as producer responsibility organizations (PROs) implementing EPR laws) the MRFs' adherence to best practices.

MRF adherence to these practices provides the verifiable evidence PROs need to meet state EPR compliance.

Key Guidance Areas

1

Metrics and Performance Optimization

Use data to drive smarter operations.

- Track
  - Downtime (reviewed daily, detail and track causes)
  - Hourly throughput (reviewed monthly)
  - Labor cost per ton in aggregate and per staffed station (reviewed quarterly)
  - Recyclables in residual (daily visual audits, quarterly physical audits)
  - Residual percentage (reviewed monthly)
  - Bale quality (daily visual audits, physical audits on an exception basis)
  - Incoming material composition (visual ongoing, physical audits on an exception basis)
  - Incoming vehicles (ongoing)
- Develop procedures for modifying throughput in response to changes in incoming material composition or quality, staffing changes, equipment outages, and other factors.
- Annually use compiled data to assess retrofit opportunities (e.g., screens, optical sorters, AI upgrades).
- Standardize sampling and auditing to facilitate improvements within supply chains.
- Utilize statewide materials acceptance lists in EPR states with data and audit protocols incorporated into systems management.

Includes: Metric tracking templates and audit strategy examples.

2

Equipment Maintenance and Spare Parts Management

Maximize uptime and system reliability.

- Develop and implement preventive maintenance (PM) programs with structured schedules and documentation; reevaluate and revise at least annually. Using online PM subscription programs may be a more practical alternative.
- Establish inventory tracking systems for critical spare parts and emergency response readiness including location/ source of parts and quarterly physical verification of parts' location.
- As part of daily supervisory walk-throughs (Section 4.11) verify PM task completion and status of repairs.

Includes: PM checklists and spare parts management templates.

3

Facility Management and Staff Organization

Build strong teams and maintain safe, efficient operations.

- Conduct mandatory training plus supplemental training addressing emergency stop functions, problem material handling, PPE use and evacuation procedures.
- Feature monthly safety topics at daily pre-shift meetings.
- Employ a full-time in-house or contracted safety specialist.
- Conduct job area-specific training (for sort staff, rolling stock operators, and baling staff) at time of hire, when staff assume a new position, or accompanying facility or stream changes.
- Develop and implement a program for cross-function training and position rotation.
- Track staff skills and interests to support reallocating positions and prioritizing high value material sorts during staffing shortages.
- Provide an incentive program for staff.
- Post metrics in break or meeting rooms to motivate staff; focus on output quality, uptime, etc.
- Maintain a clean, safe environment with daily housekeeping, lighting standards, and signage.
- Conduct daily management walk-throughs to monitor throughput, sorting, staffing, PM and repair status, and housekeeping.

Includes: Staff training guidelines, break room metrics boards, daily supervisor checklist templates.

4

Industry Relations

Strengthen collaboration to drive efficiency.

- Develop networks with local MRFs, equipment suppliers, contractors, haulers,and municipalities leading to:
  - Annual meetings with the facility's OEM(s)
  - Semi-annual meetings with communities, their recycling educators, and haulers
  - Annual open houses or similar public events
- Use relationship building to facilitate problem-solving, information sharing, and future contract negotiations.
- Embrace needs assessments that are key steps in EPR laws, work with PRO to ensure necessary information is included for program plan development.

Includes: Contract checklist template and partnership-building tips.

1

Metrics and Performance Optimization

Use data to drive smarter operations.

Routine tracking of key metrics can serve as a powerful tool for optimizing the operations of a MRF. Metrics can be used to understand facility performance, quality of commodities produced, and areas of weakness to target improvement or optimization. If it can be measured, it can be improved.

Performance

An important step in enhancing MRF operations is to emphasize and improve key performance metrics. Evaluating facility performance can be done by tracking downtime, throughput, and labor dollar per ton.

1.1 Downtime tracking

Monitoring all planned and unplanned downtime in MRFs is crucial for identifying recurring equipment issues. Downtime can be tracked by logging the total amount of time the facility is not operational and reviewing trends over time to highlight areas of concern. Additionally, the planned uptime percentage of a facility can be calculated with the following equation:

$$\frac{\text{Planned operating minutes} - \text{Unplanned downtime minutes}}{\text{Planned operating minutes}}$$

DOWNTIME TRACKING. Sample templates for tracking downtime and daily uptime can be found HERE

Using distinct and explicit categories for tracking downtime contributes to consistency. When tracking this data, consistency in tracking is very important and it is recommended to use distinct and explicit categories for tracking. For example, if you consider safety meetings to be a part of planned downtime, they should never be logged as unplanned downtime. Inconsistency in categorizing downtime could lead to misidentifying the root cause of an issue. It is essential to track downtime daily and review trends and identify opportunities for improvement monthly, at a minimum.

Identifying a specific piece of equipment that frequently causes downtime can significantly reduce future disruptions. Tracking downtime also helps to uncover operational inefficiencies and highlights areas within the MRF that may require upgrades or additional staffing, especially when downtime is caused by excessive wear on equipment or large material build-ups. For example, if a MRF tracks a 5% decrease in uptime due to material build-up on screens, that could indicate it is time to replace the discs or potentially upgrade the screen to a non-wrapping version. Using data in this way can help potential lenders understand the return on investment when purchasing new equipment or making upgrades.

1.2 Monitoring and adjusting throughput

MRFs should track the hourly rate of total material running through their system to compare it to the facility's designed throughput. Depending on MRF preference, throughput can be tracked in one of two ways:

- Use the weight of a truckload or measure bucket loads of material for a set weight and run the system with only that material and track the time it takes to process. Then, divide the tons processed by the hours to get tons per hour (TPH).
- Or, take the total material processed over a set time, as calculated by summing commodity and residue streams, and divide by the actual operating hours.

METRICS. A sample tracking log can be found HERE

Throughput should be verified monthly but could occur more frequently, such as on a

weekly basis, if overall system performance seems to be lagging.

Although each facility has a designed throughput rating, the actual throughput, for optimizing recovery, can vary day-to-day or load-to-load, depending on the condition and composition of the incoming material. Understanding the facility's maximum throughput for "perfect" material—typically the designed throughput—provides a starting point for making adjustments to the system and/or changing the throughput. Running material above the rated throughput increases risk of improper material sortation and increased contamination rates throughout all streams. As an operator gains familiarity with the system and the types of incoming streams, multiple throughputs and associated equipment settings or procedures should be established. Ultimately, MRF operators should strive to balance optimal material quality with throughput speed. The facility OEM should also be able to advise when trialing different throughputs and system settings, to maximize equipment performance.

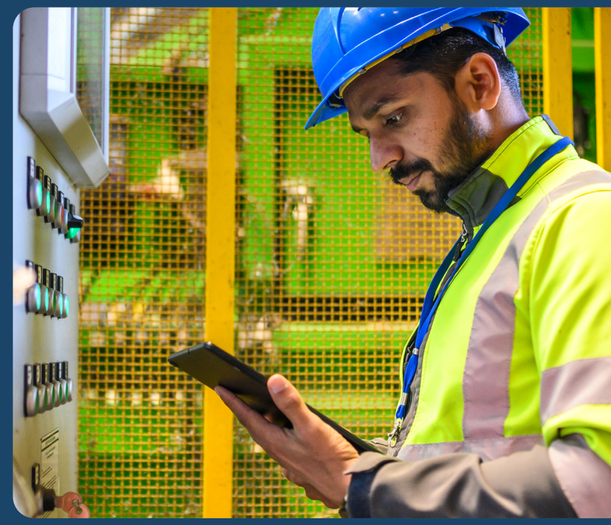
CASE STUDY

Lexington Fayette Urban County Government (LFUCG) Tracking Downtime for Operational Improvements

In 2022, the LFUCG MRF, which is owned and operated by LFUCG, was backed up on unprocessed material on their tip floor, forcing them to add extra operating hours during the week due to lack of sufficient daily uptime. Management would summarize and file away some of the causes of downtime in a document but would not take any further action on the noted issues. LFUCG eventually hired consultants to assess their MRF operations, and it was determined that actual facility uptime was less than 50% of the "Planned Run Time" (i.e. the portion of a shift dedicated to processing material).

The consultants worked with the operations manager, ensuring that they understood how downtime was calculated, the importance of accuracy in detailing causes of downtime, and then how to approach resolving the noted issues. A downtime tracking tool was developed to enter this data, providing an easy means of tracking trends and improvement. Another essential component was sharing the downtime issues with key personnel each day, to provide a full understanding on how staff should focus their attention.

Since the beginning of 2025, the LFUCG MRF has operated at over 65% average uptime and routinely hits 70% to 85% on some days. The improved uptime is due to downtime tracking and strengthening of the key personnel team's ability to identify and solve issues. In particular, using the downtime tracking tool illuminated issues resulting from quality of inbound material, which led to the addition of routine inbound contamination audits and a tip floor inspector who would assist the loader operator in identification of problem materials, preventing them from being fed into the system. The MRF also uses inbound material information to provide feedback to customers either with pictures, surcharges, or rejection of loads.



MRF rated capacity assumes ideal conditions: dry and homogeneously mixed material and proper material preparation at each sortation step (e.g. even and non-overlapping material spread on a belt prior to optical sortation).

Material stream factors, however, introduce less than ideal conditions that may require adjustments to facility throughput or procedures. For example:

Moisture content – Dry material will sort better than material that has experienced precipitation and potentially become frozen. Wet material can clump together, making individual items challenging to sort properly, and can cause greater clogging in trommels and glass crushers. Wetter material typically requires a decrease in throughput and potential adjustment to screen and ballistic separator angles. Some operators have found success in spreading out wet material to dry, if space is available, prior to processing, instead of landfilling the material. Alternatively, blending wet material with available dry material can reduce the impact of previously described processing issues.

Composition variations – Material composition can vary based on the source of the material (i.e. commercial or residential). If a facility does not have a separate line designed to process commercial loads, the facility throughput should be lowered when sorting this material, due to the greater concentration of corrugated cardboard in the stream vs. a residential stream. Depending on the amount of commercial material received and tip floor capacity, a separate shift may be warranted to process this material, allowing for reductions in staffing, thereby optimizing labor dollars per ton. Alternatively, residential and commercial streams could be blended in order to produce a homogenous stream.

Composition also changes over time based on trends in packaging and consumption. Examples of changes in packaging trends include more paper-based packaging, less glass packaging, and lightweighting. Lightweighting, which is a decrease in a package's weight for the same capacity, has resulted in more packaging units per ton than in years past. This may require lower throughput since processing more units per ton requires greater facility capacity than processing fewer units per ton of material. Examples of changes in composition from consumption patterns include greater use of corrugated cardboard, from increased online purchases. Staying cognizant of this trend in packaging, the proportion of lightweighted packaging in the facility's incoming stream, and how well facility equipment sorts the material will help inform when throughput adjustments are necessary to maintain recovery levels. One approach for better understanding the stream is to track changes in various recyclable, yet missed items which ended up on the last chance line to residue.

Finally, throughput adjustments should be considered in conjunction with staffing level and degree of system automation. When a MRF utilizing hand sorters does not have adequate staffing for the day, throughput may need to be lowered to reduce losses.

1.3 Labor Dollar Per Ton Calculations

Labor dollar per ton is the total cost of labor to process one ton of incoming material and is a crucial performance metric that helps ensure contract provisions adequately cover necessary expenses. Labor dollar per ton can be calculated facility-wide and by specific area with the following equation:

$$\frac{\text{Total hours worked by area} * \text{Respective hourly labor rate}}{\text{Total tons processed}}$$

METRICS. A sample tracking log can be found HERE

Changes in labor dollar per ton can reveal areas that may be overstaffed or, when considered alongside outgoing recyclables, indicate whether staff retraining might be necessary. It is important to track the number of staff stationed at various locations within the MRF daily. This includes pre-sorting, all quality control areas, fiber lines, container lines, and the last chance line.

Monthly evaluations of trends should be conducted to identify any necessary adjustments. While actual staffing levels at different stations may fluctuate due to changing material priorities, employee sickness, or leave, the labor dollar per ton should not significantly increase as a result of these factors. For example, if more PET is identified in the residue stream but the labor dollar per ton has remained consistent or decreased, the number of sort staff stationed on the container line should be evaluated to understand if the reason is due to poor equipment performance, inadequate number of sort staff, or the need to retrain staff.

Quality

1.4 Percent of outgoing commodity recyclables in residue stream

The percentage of valuable commodity recyclables present in the residue stream is a very important metric to track for monitoring the overall quality of the MRF sortation process. MRFs should aim to allow no more than 5% of accepted and marketable material in the residue stream. Commodity recyclables in residue should be monitored visually multiple times per day with monthly or quarterly physical audits based on visual observations.

Consistent shifts in the volume of recyclables in the residue stream over time indicate a need for more frequent physical audits.

Physical audits should be conducted by pulling a representative sample of material from the residue stream, manually sorting into MRF commodity streams, and recording the composition breakdown.

MATERIAL CHARACTERIZATION. A sample audit strategy and log can be found HERE

Some facilities may utilize integrated artificial intelligence (AI) for real-time audits of the residue/last chance line which could identify these issues much faster than a manual audit may allow. However, if AI is used on a line with significant burden depth, occasional hand sorts should be conducted to check the accuracy of results.

An increase in commodities in the residue stream should first trigger an evaluation of the responsible sort area to identify equipment or staffing requirements. If it is determined that the areas are running efficiently but the commodity is still ending up in residue, a MRF may need to look at overall stream composition changes and determine if a retrofit or upgrade is necessary.

1.5 Incoming stream evaluation

It is important to understand the overall stream composition coming into a MRF, to highlight if external discussions are necessary with community education leaders. Visually, an operator or designated staff should inspect incoming loads, looking for large amounts of contamination and hazards.

INCOMING LOAD TRACKING. A sample tracking tool can be found in HERE

There should be pre-determined thresholds for non-hazardous contamination and hazardous contamination. Identifying and setting aside loads with excess contamination can prevent potential operational issues, increase safety of sorters, and reduce labor demands on sorters to remove non-program items. If truck IDs for contaminated loads can be documented, potential patterns may arise, allowing for targeted feedback to haulers. This, coupled with contract terms and conditions that allow the MRF to surcharge contaminated loads, further incentivizes behavior change and defrays the cost for disposal for contamination and hazardous waste. A detailed physical audit may take place if there is a contractual requirement or a dispute on contamination concerns.

1.6 Bale quality inspection

Ongoing visual inspection of bales should serve as the first-level action for ensuring quality. If bales appear to have higher levels of contamination than is acceptable, it should be reported to the MRF Supervisor to evaluate equipment and sort staff efficiencies. Breaking open commodity bales for audits should be done only in extreme circumstances. If buyers issue warnings, downgrades, or rejections, then performing periodic bale breaks can identify whether changes have resulted in improvement. The material characterization below provides a guide to complete a formal bale break audit. Ideal bale specifications are published by the Recycled Materials Association (ReMA), for all commodity materials, as well as the Association of Plastic Recyclers (APR), for plastic commodities, which was developed collaboratively with ReMA specifications. If there are difficulties finding consistent end markets, MRFs should strive to meet ReMA bale specifications.

MATERIAL CHARACTERIZATION. View checklist for the audit process HERE

1.7 Setting commodity pricing

MRFs should strive to receive the highest value possible for their commodity streams, as a higher value indicates a cleaner bale, allowing the facility to sell commodities more competitively. Awareness of how well their commodity quality compares to others can be accomplished by utilizing commodity indices to understand regional and national pricing trends. Many MRFs utilize the commodity index, recyclingmarkets.net. Other available indices include srapindex.net and Secondary Commodity Composite Index. Additionally, MRFs can conduct auctions or sell off a spot market price for selling commodities to encourage competition.

1.8 Responsible End Markets

Be willing to comply with industry defined Responsible End Market definitions, which are a key parameter to all state EPR programs.

Optimization

Although facilities are initially designed to process a specified volume while sorting for the designated commodities based on characteristics of a given material stream, over time, facility capabilities may no longer meet the needs of a community or industry standards. This could be due to improved community access to recycling, leading to increased required annual throughput, inability to secure sort staff requiring a retrofit for automation, or higher mandated recovery standards, and thus a need to procure the latest technology. Alternatively, facility management may find opportunities to optimize the sortation process/operations or increase recovery, from implementing design changes or equipment upgrades, independently deciding to improve the facility.

CASE STUDY

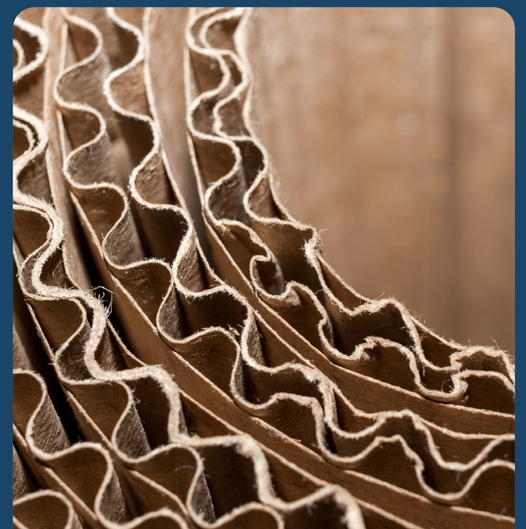
Small OCC recovery at Rumpke and LRS

Currently, total fiber makes up anywhere from 45-55% of the incoming material from residential single stream collection, with large pricing variability between the main two commodities typically produced, mixed paper and OCC (and brown fiber or “browns”). Considering that the proportion of OCC in the stream has increased drastically due to impacts from e-commerce, and at the same time OCC packaging sizes have gotten smaller, OCC screens, with standard disc spacing, are no longer capable of the same historical level of recovery. To combat this challenge, both Lakeshore Recycling Systems (LRS) or Rumpke Waste & Recycling (“Rumpke”) opted to install an optical sorter for increased fiber recovery and purity.

In 2018, LRS recognized the need to increase capacity and minimize labor on the fiber line. They invested in a dual eject optical sorter to clean up the mixed fiber stream, upwardly ejecting plastic and metal containers—later to be manually sorted—and downwardly ejecting brown fiber, sending it to the OCC bunker. The addition of the mixed fiber OS increased their outgoing OCC from 2 to 3 trailer loads per day.

Similarly, Rumpke set out with the goal of maximizing small OCC recovery—to be sold as OCC, not mixed fiber— utilizing optical sorters, in the design of their newest facility at Joyce Ave. The Rumpke facility that was eventually replaced by the one on Joyce Ave. recovered OCC via screens and manual sortation, documenting an OCC recovery of 20.38% (of the total outgoing commodities captured and sold), during the 12 months prior to the start-up at Joyce Ave. In comparison, at Joyce Ave., with the use of OS, OCC recovery was nearly double, coming in at 38.9%.

While commodity markets fluctuate, the optical sorter, system design, and operational parameters offer these facilities the opportunity to capitalize on the delta between the values of either Mixed Fiber or OCC.



1.9 Using metrics to assess the facility for upgrades to equipment and/or design

Depending on the age, condition, and space within a MRF, among other relevant factors, retrofitting may be more appropriate than designing a brand-new facility. Potential design changes and equipment upgrades may appear beneficial for obvious reasons, though the argument for change is best made with accompanying metrics, such as the ones previously discussed.

The following are some common areas of retrofit and items to review when considering their potential impact on overall facility performance:

Fiber & OCC screens

- Do fiber screens have anti-wrap shafts to reduce the required frequency of clearing wrapped material?
- Does the OCC screen need to be updated or resized to manage a greater amount of OCC than when the facility was first designed?

Film capture

- In what ways would the sortation process benefit from film removal (enhancing quality of other products, creating a new product for marketing, decreasing maintenance efforts from material wrapping on shafts)?
- What type of equipment might work best (pneumatic/film vacuum, optical sorter, robot)?

Glass cleanup

- What is the value of potentially capturable small format, non-glass material lost to the glass stream?
- How would removal of non-glass material (either for targeted recovery and marketing or for purely glass stream cleanup) improve the commodity value received for glass?

CASE STUDY

Film capture, Circular Services

Circular Services, a Closed Loop Partners company, operates a MRF in San Antonio, Texas that is equipped with a 50 ton-per-hour system to process both residential and commercial single-stream material—around 2% of which is comprised of films and flexible plastics. As a result of partial funding from The Recycling Partnership, Circular Services installed new equipment in August 2024, making it one of the first of its kind with the capability to sort hard-to-recycle materials such as film and flexibles. In just the first year of installation, 214.5 tons of the material were collected in one shift, with the potential to double. By 2030, as much as 1,530 tons of film is estimated to be captured at the facility every year.

CASE STUDY

Rigid small-format packaging recovery, Closed Loop Partners

The Center for the Circular Economy partnered with Circular Services to conduct fieldwork to identify recovery solutions for small-format packaging, which often slips through the cracks of recycling systems due to its size, contaminating the glass stream and ending up in landfills. They evaluated glass stream contamination at more than half a dozen materials recovery facilities (MRFs) across the U.S., collecting samples from two MRFs' glass streams and one glass recycling plant's residue streams. In September 2024, they installed a new glass screen at a materials recovery facility, resulting in a relative reduction of approximately 67% in mid-to-large size "small" plastic contamination in the glass stream. The recovery of these kinds of small plastic materials positively impacts the recovery of multiple material types:

- **Higher Recycled Glass Value:** Reducing plastic contamination in glass stream increases its market value
- **Lower Landfill Costs:** Diverting small plastics and metals from the waste stream at glass recycling plants reduces landfill expenses
- **Increased Revenue** from Sale of Small Materials

If interested in learning more on the topic, dive into our report on rigid small plastics recovery HERE.

A MRF may perform a characterization study on the incoming material and residue streams. If these studies show a significant amount of aluminum gets lost in the glass stream, like many MRFs have seen lately, a second eddy current separator (ECS) could be installed on the glass stream to increase capture of this highly valuable stream.

Optical or robotic sortation

- What step of the sortation process will the new equipment serve (primary sortation, cleanup step/QC, recovery from last chance line)? Optical sorters are better suited than robots, for high volume sortation. Robots may be acceptable for QC or recovery on a last chance line.
- What is the required picks per minute for the target material at the planned equipment location?
- Does the available space match the optimal required equipment? If the planned equipment will perform a primary sort and there is not enough space to retrofit an optical sorter, installing a robot instead may not prove beneficial, unless the target number of picks can be achieved with redundant robots.

Artificial intelligence (AI) system integration

- Are there system upgrades available, for either currently installed optical sorters or planned additional optical sorters, which could integrate AI within the system? If so, what benefits might this provide (ability to sort additional commodities, produce a cleaner commodity)?
- What composition data for which material lines in the facility would provide the most valuable information when assessing system performance? AI systems could be installed at multiple locations for a more comprehensive view, however, if only one AI system can be installed, it should be placed on the last chance line.

CASE STUDY

Equipment upgrades, Eureka Recycling

Eureka Recycling, a nonprofit, mission-based independent regional materials recovery facility (MRF) based in Minneapolis, Minnesota, received over $10 million financing from Closed Loop Partners' catalytic private credit arm, the Closed Loop Infrastructure Group, alongside American Beverage and The Recycling Partnership, to make key infrastructure upgrades amidst changes in the composition of materials processed by the facility. The capital financed additional optical sorters to decrease contamination and increase the quality of recovered materials that can be made into new materials, including mixed paper and old corrugated cardboard, polyethylene terephthalate (PET), aluminum, polyethylene and polypropylene. Upon completion of the upgrade, the new machines are estimated to increase the annual collection of PET and aluminum by 222 and 248 tons, respectively.

CASE STUDY

ReGen's use of AI to improve sortation and quality of commodities

ReGen Monterey historically utilized GoPro cameras to manually review footage to monitor plant efficiencies, resulting in significant man-hours from management and a delay between the first instance of mis-sortation, and when action was able to be taken to rectify the problem. They installed a Glacier AI system in 2022, which utilizes a dashboard capable of real-time monitoring of the residue stream. The AI system reduced the personnel time investment and allowed for the immediate response to mis-sorted items, which may be due to underperforming equipment in need of repair or contamination issues in the stream.

CASE STUDY

Rumpke's use of AI to reduce battery fires

The Rumpke Cincinnati MRF experienced 60 fires in 2022, so identification and removal of batteries—a common cause of facility fires— became a high priority for management. Rumpke learned of an x-ray technology capable of identifying batteries, even when located beneath layers of material. The unit would then use AI, pointing a green laser at the location of a battery, allowing sort staff to pull the stop cord on their line, to remove the battery from the stream. Since the installation of the unit, the following performance data was measured:

- Unit accuracy range: 92-95%
- Average detection: 71 batteries per day
- Removal rate: 70-80% (depending on team staffing levels and response time)

CASE STUDY

Closed Loop Center's AI-driven polypropylene study

Closed Loop Partners' Center for the Circular Economy and the Closed Loop Foundation led one of the most extensive and granular recyclable material characterization campaigns ever completed, harnessing the power of artificial intelligence. The study characterized more than 45 million individual PP and non-PP items at four MRFs in the U.S. for approximately three months. With the power of AI, we learned:

1. Clear and white food-grade PP is abundant in recycling streams. Clear and white material collectively comprised 75-85% of all PP characterized in this study, with most of these formats found to be likely food-grade material.

2. AI-enabled technologies can reliably quantify and classify recyclables with granularity, at scale. Automated AI technology provided accuracy that closely mirrored that of manual counts, suggesting these systems are capable of providing effective material characterization data at previously unavailable scales. This is dependent, however, on the systems (and the facilities at which the AI classification systems are deployed) operating according to best practices and incorporating sufficiently granular and validated material detection algorithms.

AI can help measure and track facility and equipment performance. Contemporary optical sortation technology provides dramatically better separation performance for recyclables. During this study, one MRF replaced an optical sorter that had reached the end of its service life. The AI classification system effectively quantified a 13 percentage-point performance improvement in PP purity after the new optical sorter's installation.

Baling material

- Are there any operational changes which would make baling more efficient, such that any associated downtime is significantly reduced or eliminated, with the current baler(s)? This could include ensuring the baler operator is adequately trained on operations or by extending baling operations to cover time before and/or after the operational shift.
- Is there space to install a second baler, such that commodities can be directed to either the first or second baler, in order to provide flexibility?
- Would the addition of a second baler, just for processing corrugated cardboard (OCC), allow for the acceptance of (more) commercial material streams?
- Is bale density maximized? Meeting particular bale densities will ensure that truckload weights are optimized, allowing for the best possible rate from material buyers. Additionally, producing denser bales means fewer are produced, thus decreasing wire usage.

EXAMPLE MRFs may face increased downtime due to limitations on baler throughput for high volume commodities such as OCC. Dependent upon the prevalence of downtime occurrences, MRFs may elect to install a second baler to process these materials. The financial benefit is seen through calculating the payback period, using the annual cost incurred during facility downtime (due to baling OCC) and the cost of purchasing a second baler.

A final consideration when assessing a potential retrofit is the OEM's ability to integrate the new equipment with the current system. Challenges or system capabilities may not transfer, if procuring new equipment from a company other than the original system provider. For example, if a MRF currently uses a SCADA system and is installing an optical sorter from an OEM other than the original system provider, additional effort may arise during installation or when repairs are required.

2

Equipment Maintenance and Spare Parts Management

Maximize uptime and system reliability.

Lack of proper preventive maintenance (PM) can hinder the sortation performance of equipment. Since a MRF itself is a system, comprised of several individual components, each of those pieces needs to be maintained to optimize recovery.

The following best practices areas are **bolded**, each with elaborated sections.

2.1 Development of a Preventative Maintenance schedule

A PM schedule is a plan of action for managing routine tasks known to be necessary for optimal equipment performance. Tasks are typically categorized by their required frequency (i.e. daily, weekly, monthly, quarterly, and annual tasks) and by equipment type (e.g. conveyors, optical sorters, etc.).
Developing a PM schedule involves understanding requirements of the system, such as which areas of equipment require lubrication, replacement of wear parts, tendencies of equipment and common areas for issues (e.g. needing to remove wrap on screen shafts, increasing frequency of maintenance on conveyor belts which receive more material, etc.), as well as reviewing the OEM-provided manual for the equipment. OEM manuals should include a list of PM action items, and their recommended frequency, for each piece of equipment in the system. These schedules may vary from MRF to MRF depending on equipment and layout.

PM CHECKLIST. A sample template for a standard PM schedulecan be found HERE

2.2 Documentation and tracking of Preventative Maintenance tasks

Documentation of PM tasks is necessary to ensure that management and other team members can view progress of maintenance technicians, identify spare parts which may need to be restocked, and to track whether tasks are being completed within the planned timeline. Documentation of PM tasks can be useful in flagging differing frequencies of need from what is published in OEM manuals, with major discrepancies being provided as feedback to the OEM, so they can comment on whether PM instructions reveal potential design flaws or are simply insufficient recommendations. At a minimum, documentation of PM tasks should include the task name, start/end dates, name of technician who performed the task, parts used, and name(s) of the manager/supervisor who reviewed the completed task or picture evidence of the completed task, within a spreadsheet.

Alternatively, there are programs which can be utilized via subscription, providing a basic structure and offering various features to streamline the process. Such programs may allow for:

- Technicians to document tasks via mobile device—instead of paper—and have the info (and pictures) upload directly into the tracking system
- Development of daily to-do lists
- Automatic tracking of parts usage and reminders for when reordering is necessary
- Analyzing compliance level of tasks (i.e. what percentage of tasks have been completed on time or are overdue).

Tracking the compliance level of PM tasks can aid in understanding the total time requirement for completion of various tasks, which may lead to adjustments in the scheduled maintenance shift or the number of technicians hired for the job. For example, if a MRF has screens which end up wrapped mid-shift, it may be necessary to stagger some staff schedules, such that sufficient staff are available during breaks to remove the wrap. Or, if the MRF runs two operational shifts, staffing enough technicians such that one is always on site, with some overlap in schedules, allowing for two-person tasks to be easily accomplished.

2.3 Hiring of qualified staff or appropriately training new staff

Hiring staff with the proper qualifications is another necessary component to ensure that equipment is maintained. Maintenance technicians typically need at least a mechanical background, though with the increasing automation in MRFs, electrical experience would also be preferred. Typically, MRFs will externally contract for electrical assistance, so that skillset is not absolutely necessary.

When seeking to hire another maintenance technician, the job posting should accurately detail the required skillsets, and the hiring manager should be knowledgeable in assessing whether the prospective candidate possesses those skills. If it is determined that a potential candidate or current technician is lacking in the necessary skillset for the job, they could be mentored by a knowledgeable staff member (if available) or receive training offered by a MRF OEM.

Several OEM's offer maintenance training in the form of in-person sessions or through virtual/online programs. Additionally, some OEM's offer maintenance services, whereby OEM technicians will visit a MRF to provide PM assistance, in lieu of in-house technicians managing the more specialized work, or if there is a short-term need for more manpower.

2.4 Performing routine walkthroughs to verify completion of PM tasks and to preemptively manage repairs

The maintenance manager should routinely walk through the MRF to ensure that staff have satisfactorily completed all PM tasks and repairs. This is especially useful if the facility has not implemented an online tracking system which allows for picture documentation to be uploaded or if the repair cannot be noticed easily in a photo.

Preventative maintenance measures are important to keep equipment operating at their best, but other equipment repairs will inevitably occur, due to the presence of undesirable items in the material stream and chance occurrences. Unexpected repairs should be tackled preemptively to minimize downtime or the need for more substantial repairs in the future. For example, a small tear in a conveyor belt may not initially pose a risk to operations, but if a non-program item, like balled up metal wire, makes its way to that conveyor, it could catch, resulting in a larger tear and an immediate need for belt repair or replacement. One or more staff members, such as the maintenance manager, maintenance technician, or MRF manager, should routinely walk through the MRF, visually reviewing equipment for minor damage which might require attention in the coming days or weeks. Staying alert to equipment condition can enable adequate time for procuring replacement parts and allow for minimizing disruptions to schedules.

Each operator should develop its own checklist; some examples of items to review include:

- Conveyor belt tracking
- Conveyor belt damage
- Missing discs on screens
- Oil leaks
- Non firing air-jets in optical sorter units
- Material buildup in conveyor belly pans and around return shafts
- Wrapped material on conveyor return roller shafts
- Check baler tolerances (e.g. knife or shear clearances, floor wear, etc.)

Spare Parts Management

Spare parts management is a task complementary to equipment maintenance, and it requires tracking inventory online as well as the physical organization of parts.

2.5 Understanding which parts are critical to have on hand in case of an emergency

The manual provided by The MRF's OEM manual should recommend a list of emergency spare parts to always have in stock; MRFs should use this list as a starting point for developing an onsite inventory of those parts along with the number of each part to stock. If a facility is missing the manual for some of the equipment in the facility, staff can always contact the OEM service department and inquire about a spare parts list. Parts deemed critical to the operation of a MRF should have spares on site at all times. OEM's typically provide a list of recommended parts that may be less critical but often need frequent replacements due to high levels of wear.

Common examples of emergency spare parts include conveyor belts of common width, optical lights and air nozzles, motors, baler wire tie components, chain belt links, and motor control center electrical components. Some spare parts may be suited for use among multiple pieces of equipment, allowing for fewer of that part to be stocked at the MRF.

2.6 Managing parts inventory

MRFs should document the procurement, inventory, and use of parts in a spreadsheet or as part of a subscription computer program, if one is being used to manage PM tasks, as previously described. Documentation could be streamlined by marking each part type with a code next to its storage location, which can be scanned and automatically uploaded to an online tracking system, providing real-time inventory of parts. To supplement online documentation of parts, it may prove useful to perform a quarterly review of stocked parts, checking that the type and number of each located physically on-site match what is listed online.

2.7 Knowing where to source parts and being aware of lead times

Although the OEM can provide a list of emergency spare parts, MRFs need not order all parts through the OEM. Local suppliers or other online companies can provide parts such as motors and some conveyor belts. Information on alternative sources for parts can minimize downtime when an unexpected equipment issue arises, as one supplier may be able to provide the replacement part quicker than another. Also, if there is a part that a local supplier always has in stock or could maintain in stock at the request of the facility, that could change the type and quantity of spare parts that are maintained at the MRF, assuming storage space is a constraint. Similarly, an OEM may guarantee particular parts in their inventory, further reducing the size of a MRF's onsite parts inventory.

Lead times for parts procurement are critical elements to track in the spare parts inventory, as lead times can vary by supplier and by type of part. Keeping strong relations with key equipment

manufacturers, integrators, and non-OEM parts suppliers helps ensure a MRF receives on-time critical parts. This relationship building will also help keep the lines of communication open on any delays to allow for the most efficient planning and downtime reduction. However, developing a parts sharing agreement ahead of time, in the instance of emergencies, should be considered to streamline the process and ensure both parties are protected.

2.8 Designating space for spare parts storage

If facility space allows, a designated area, within the MRF, should be allocated for spare parts storage. Creating an enclosed area, free of dust, and installing shelving, storage bins, and signage can lead to efficiency in locating, tracking use of, and maintenance of parts. Alternatively, if the facility is lacking space within the MRF for storage but there is room on the property, a shipping container (or multiple shipping containers) can be used instead. Additionally, where feasible, a climate-controlled room for spare electrical parts can be used to ensure these sensitive parts are safe from damage due to extreme temperatures and humidity.

3

Facility Management and Staff Organization

Build strong teams and maintain safe, efficient operations.

Management structure can help provide clear responsibilities for staff and set expectations and goals for the various roles required to operate a facility. MRF management should ensure key personnel, staff organization, and working environment are all functioning effectively.

The following best practices areas are **bolded**, each with elaborated sections.

Key Personnel Responsibilities

3.1 Ensure site safety

Safety should always remain any MRF's number one priority. To accomplish this, all site personnel should receive job specific safety training upon hire with standard refresher courses. In addition to any state or federal mandatory safety training, required, supplemental training should address, at a minimum:

- Emergency stop locations and functions
- Identification of problematic materials that pose a hazard such as needles and other sharps, lithium batteries, strings, ropes, wires, weapons, etc.
- Use of personal protective equipment (PPE) and their limitations
- Evacuation routes and emergency meeting point, in the instance of natural disaster, fire, etc.

To highlight potential risks in a MRF environment, a monthly safety topic should be selected and reviewed in daily pre-shift meetings. Safety topics may include Lock out tag out (a safety procedure for de-energizing and preventing unintended restart of equipment, until after mechanics have completed repairs), PPE, sortation techniques, etc. If there is an increase in safety incidents, additional spot training should be initiated.

A safety specialist position should be hired full-time or procured via outside contractor/ consultant. If a MRF is not in a position to hire a full-time safety specialist, workers comp insurance representatives or OSHA will do a safety walkthrough to highlight areas of non-compliance.

3.2 Job area training

Personnel should receive job-specific training regarding the facility, safety requirements, stream acceptance, and area specifics. Training should occur upon hire, job movement, and with facility or stream changes. Main position trainings may include:

Sorters

Proper sortation techniques:

- Any bagged material, unless readily identifiable as intentionally bagged program material (e.g. Hefty Renew Program™, shredded paper, film), should be tossed entirely into residue, due to potential unknown hazards.
- Material should be picked and not be 'swept' from the line as this can be a safety concern, leading to cuts/punctures.
- Large, heavy objects must be removed from the line only after activating the emergency pull cord or pause button for the associated conveyor. This will prevent injury as well as equipment damage.

- Using the proper PPE for work at a position, such as wearing sleeves for presort areas that require excessive reaching.
- Signage should be at each sort station to indicate what materials are sorted and where they are to be placed

Rolling stock operators

Fully understand proper use of equipment for safe operations, handling, and loading out of materials. Training should include:

- Proper bale stacking
- Tip floor management
- Proper feeding of the system
- Loadout quality control
- Driving safety, including communication protocols and adherence to traffic signage

Baler operators

- Proper use of the baler functions (auto or manual)
- Transitions from one commodity to another
- Making complete bales vs. partial bales

3.3 Assure full system understanding for personnel

To improve company morale and protect a facility from potential specialty job shortages, management should ensure proper cross training. Having personnel temporarily rotate to different positions within the MRF allows for more mental stimulation and engagement for workers. This allows them to understand more of the system and for management to find the right fit for workers' skills and ambitions. Having an overlap in key knowledge areas such as baling operations and some maintenance activities allows for operations to continue if staff take PTO, get sick, or leave the company.

Cross training and overlapping positions can also allow for easier job transitions. If a key staff member will be retiring, promoted, or leaving the company, the replacement should be hired prior to the current employee's departure, such that there is time for training from the experienced staff member.

3.4 Routinely review staffed sort positions and adjust based on available staff, material changes, and overall facility needs

Management should understand the system's key staffed positions and know which sort areas to prioritize in the case of staff shortages. This requires a baseline of targeted staffing levels at each area, which then provides a reference to make adjustments. Management should track workers' skillsets, training, and physical abilities (i.e., height, reach, picks per minute) to be able to make assignments in case of shortages or disruptions.

A MRF may operate adequately even if every potentially assignable position is not staffed. For example, a mixed paper QC line may still produce a sellable, quality product with the occasional shortage of manual sorters. Other positions such as pre-sort and loader and baler operations must be staffed for the facility to process material. Additionally, if a MRF has temporary staff shortages, the facility should prioritize high value commodity bales such as aluminum, HDPE, and PET, which are more likely to get downgraded if they do not meet specification. Also, if a facility is comprised of workers with various types of employment (e.g., internally staffed/non-union, permanent, temp/seasonal), positions of higher importance, such as machine operators, line leads,

or mechanics, should be staffed by permanent, in-house employees.

3.5 Incentivizing staff

Where possible, MRFs should implement staff incentives when quality and/or safety goals are met. Performance-related incentives may include bonuses or salary increases for meeting a set metric. Some performance-related incentives may only apply to specific job levels. For example, if a staff member worked a full month without an unexcused absence, it could result in an hourly pay increase or a gift card. Management level staff may receive annual bonuses for goals set in regards to:

Safety

- Low reportable incidence

Quality

- Residue rates
- Commodity compliance rates

Productivity

- Downtime
- Labor dollar per ton

Preventative Maintenance

- On-time completion of assigned PM tasks

Not all incentives need to be financial in nature. MRFs could offer an employee spotlight or employee of the month where workers are highlighted for their attendance, safety compliance and reporting, team support, or leadership achievements.

Career mobility opportunities also provide an incentive that allows workers to learn new skills and achieve greater pay. This can be achieved by offering the ability to learn new skills and move to a different position in the MRF or another area of company. For example, a key opportunity is for an existing employee to learn low-level maintenance functions, such as screen cleaning and oiling or greasing equipment. This training with an associated bump in pay for the service hours also helps build potential higher-level mechanics. Lastly, management targeting internal hires over external hires, where possible, can also improve morale and incentivize workers to go above and beyond in their current positions.

Staff Organization

3.6 Transparency

Posting key metrics that management is tracking helps engage workers and bring purpose to each individual staff member's part in the bigger picture, since some MRF positions can be tedious and taxing. It may be difficult for workers to see their impact on the facility as a whole, but by sharing metrics, such as on a board in a break room, workers may more clearly see their impact. Sample metrics (and their associated trends and goals) could include audit findings tracking missorted commodities, uptime reports by reason to show areas of the MRF causing significant unplanned downtime, and end market feedback on bale quality.

3.7 Team communication and collaboration

Each MRF should develop a diagram of their facility management structure with instructions on how to report safety issues, personnel problems, and other reporting responsibilities.
MRFs should conduct daily meetings for all sort staff prior to each shift start. A sample agenda may include:

- Welcome
- Safety spotlight discussion
- Stretch period
- Goals and objectives
- Questions and feedback from staff

Management should conduct a separate weekly meeting including sort area leads and supervisors from operations and maintenance. A sample agenda may include:

- Safety – incident reporting, highlighting any observed issues/ near misses
- Performance against goals and objectives
- Areas of improvement
- Open discussion (Staffing Concerns Etc.)

Working Environment

A clean and safe working environment is key to proper MRF operations and worker retention.

3.8 Installing clear and concise signage

Proper signage should be utilized at sort stations to aid staff in efficient identification of the different recovery streams. For example, adding signage to chutes, which names the stream and provides examples through pictures can serve as a learning tool for new staff and as a reminder for established staff. Also, developing a naming convention and labeling each equipment piece with a shorthand ID can help maintenance staff with recognition and provide a way to track preventative maintenance tasks and downtime related specifically to any one piece of equipment. If a facility operates with multilingual staff, all signage should include concise translations as well as images, where possible, to allow for better understanding. In areas where equipment poses greater risk, proper guarding is required in combination with chained off areas and proper signage denoting the hazards.

3.9 Regular housekeeping

Keeping a clean working environment is pivotal to both safety and quality of a MRF. With the equipment pushing the recyclable streams through a facility, it is common for items from the stream to fall to the floor and build up even after a single shift. There is also a level of dust inherent in the MRF environment, and if this is not regularly cleaned, there is a significant risk for slips or trips.

PM CHECKLIST. A sample template with daily and weekly housekeeping and PM checks can be found HERE

Proper cleaning also allows for ease of access to equipment to perform maintenance. Without regular cleaning, staff may need to divert resources to clear a safe pathway to reach equipment, increasing unplanned downtime.

MRF personnel should sweep and dust at every shift change and break. To reduce the amount of material falling to the floor from the line, personnel should also ensure that proper conveyor siding and tail pully flaps and guards are installed properly and are undamaged.

3.10 Proper lighting, heating and cooling throughout facility

Proper lighting is important for sort staff to be able to clearly see and identify hazards as well as the recyclable stream designations. A poorly lit facility can result in other safety issues, such as increased likelihood of missteps and falls.

Adequate lighting in working areas can also help improve staff morale. When the MRF is dark, it can make the working environment less hospitable and reduce overall productivity.

Providing heating and cooling equipment can also aid worker comfort. Radiant heaters can be placed where sorters work, or portable heaters can be used to accommodate staff who may work in less frequented areas. Likewise, fans can be placed were sorters work, to provide some relief from warmer conditions.

3.11 Perform routine visual walkthrough inspection

The MRF Manager/Supervisor or other designated qualified personnel should routinely walk through the MRF, reviewing overall operations and notifying the proper staff of any issues requiring troubleshooting. In particular, the designated personnel, should assess the following:

Throughput, belt speeds, burden depth, material spread at transitions

- Is the facility running at the appropriate throughput for the material?
- Is the system being fed at an even rate, such that burden depth is even?
- Is material flowing evenly at transitions?

Performance of optical sorters, robots, screens and ballistics, eddy current separators, etc.

- Do the output streams appear to be what is expected, based on the equipment?
- Are the optical sorters collaterally capturing non-target items?
- Do screen angles need to be adjusted based on the current incoming stream or weather impacts (i.e. moisture, temperature)?
- Is there a higher percentage of program items on the last chance line than expected, based on current equipment performance?

Staffing levels and placement

- Includes the number of employees needed for each area as well as the number of employees actually staffed
- See Section 3.4

Proper use of PPE by staff

- Are staff wearing the appropriate PPE?

Housekeeping

- Are work area floors free of debris?
- Is dust buildup being routinely managed?
- Are tools and equipment placed in designated areas when not in use?

Completion of shift change meetings

- See Section 3.7

Completion of daily PMs and inspection for upcoming equipment repairs

- See Section 2.4

Daily downtime log updated

- See Section 1.1

Verify incoming load tracker compliance

- See Section 1.5

DAILY CHECKLIST – SUPERVISOR. A template detailing these visual inspection best practices can be found HERE

4

Industry Relations

Strengthen collaboration to drive efficiency

MRF operators benefit from maintaining and investing in relationships with the various communities with which they interact. Developing a rapport with these stakeholders can result in information sharing, allow for easier problem solving, and give way to mutually beneficial outcomes, all bringing about more efficient, higher recovery recycling infrastructure.

The following best practices areas are **bolded**, each with elaborated sections below.

4.1 Developing a social network related to MRFs located in the same geographical area and/or among MRFs sharing similar equipment or design features

Becoming acquainted with neighboring MRF offers many potential benefits, such as:

- Diverting material during times of prolonged downtime or repairs
- Accessing backups for spare parts, if similar equipment is used
- Exchanging knowledge regarding operations or available staffing agencies in the area
- Receiving feedback on new equipment and site tours, when considering upgrades

A formal operating agreement between MRFs may be warranted under certain situations, to ensure that competing facilities mutually benefit and are safeguarded by well-thought-out terms and conditions.

4.2 Developing relations with equipment manufacturers and integrators

The MRF Manager, or other applicable staff such as the Maintenance Manager, should stay in communication with sales representatives and/or technicians from the facility's Original Equipment Manufacturer (OEM). Maintaining semi-annual or annual meetings provides the opportunity to learn about new technology offerings, which can help focus goals and planning for any future upgrades. Furthermore, the OEM representative can evaluate the extent of any potential retrofit—as new components may be available to upgrade current equipment—and make recommendations on the benefits of building a brand-new facility.

Managers can also develop a rapport with the OEM through contracting for quarterly preventative maintenance services, allowing for feedback on performance, verification to PM schedule, and highlight areas of opportunity for continuous improvement. Additionally, these quarterly evaluations can present an opportunity for MRF maintenance staff to shadow the OEM team and receive real-time training.

4.3 Developing relations with major repair contractors and non-OEM parts suppliers

Being familiar with local major repair contractors is beneficial, as an OEM is not always required or onsite maintenance technicians may be unable to handle major repairs. This can include tasks such as baler realignment or the installation of a new conveyor. Types of local or regional companies to become familiar with include: electricians, riggers, heavy machine repair companies, rolling stock dealerships or rental companies, and suppliers of non-OEM parts.

4.4 Developing relations with communities and haulers

Maintaining quarterly or annual meetings with key community stakeholders, recycling education staff, and, if applicable, the recycling hauler, provides an opportunity for the MRF to report on overall facility performance, inbound quality, commodity pricing, and adherence to contract terms etc., which can create greater engagement within the community. These meetings can also carve out time for MRF management to provide feedback for developing targeted education, based on common infeed contamination issues or material preparation, based on specific facility needs.

MRFs can also cultivate community relations by offering facility tours or an open house day, for the community to speak with management and learn about the recycling process. If the MRF lacks an education room or adequate means of offering tours, a video displaying the sortation process could be developed and made available online.

Many MRFs highlight the importance of remaining open to the residents they serve to allow for a greater understanding of how the MRFs operate and how detrimental hazardous or highly contaminated materials can be. APR recently worked with many MRFs and recyclers to open their doors and show efforts in recycling all material streams.

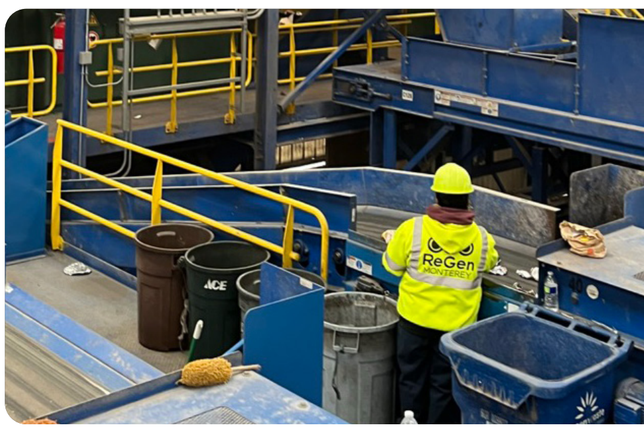
Neighboring MRFs may benefit from working together to engage local media to provide public service announcements regarding unaccepted materials and safety matters, such as fires. This provides a way to reach community members who may not be as actively involved in learning about their recycling program.

EXAMPLE **Circular Services**' MRF in Brooklyn is one of the largest and most sophisticated plants for commingled residential recyclables in North America. It processes most of New York City's curbside material, roughly 20,000 tons per month. The Brooklyn MRF is also home to a Recycling Education Center (REC), an interactive recycling space where visitors learn how the recycling process works and can view our operations from observation platforms. Students, community groups and corporate teams are welcome to visit the facility, where they can view the sorting process for hundreds of tons of recyclable materials, and learn how the facility processes approximately 1,000 tons of materials per day.

EXAMPLE In recent years, **ReGen Monterey (ReGen)**, a special district in western Monterey County, California, had seen a dramatic increase in fires at their MRF and landfill—averaging one fire per week. Franchise haulers were also experiencing fires in their collection trucks. Many of the fires were determined to be from batteries or battery-embedded products. ReGen leveraged relationships from their Technical Advisory Committee, comprised of the three franchise haulers in their service area, staff representatives from their nine member jurisdictions, and their counterpart, JPA, who services the eastern part of the County and brings recyclables to ReGen's MRF, to develop solutions for decreasing the frequency of battery fires.

ReGen worked with their haulers to ensure that they were collecting batteries in the same manner, which in turn allowed for unified messaging throughout the county, who shares one media market. ReGen then created a PSA video using footage of actual fires at their MRF and on collection trucks, and interviewed frontline MRF workers, urging the community to properly dispose of batteries, to protect workers and the public's recycling infrastructure. The award-winning video was shared widely on social media amongst all stakeholders, abbreviated to a 30-second PSA for TV, formulated for radio, and a campaign landing page was created.

This is a long-term initiative and ReGen monitors its effectiveness using frequency of facility fires and volume of batteries recovered though MRF magnets vs. proper HHW collection. The campaign has been



shared as a model at industry conferences across the State and internationally.

4.5 Developing relations with end markets

Although established bale specifications exist in the industry, understanding any unique requirements of end markets can enable MRFs to potentially sell commodities for a higher price. Additionally, this knowledge offers MRFs the opportunity to maximize recovery, since one end market may be able to process what another end market cannot process. Lastly, this MRF-end market relationship provides MRFs the information to confidently inform their communities on the destination of their recyclables, ensuring customers—or any regulatory entity—that material is being recovered.

4.6 Contract discussions

Depending on the facility operator-owner arrangement, the community meetings may serve as an additional opportunity to discuss future contract modifications, due to industry changes.

Every operation is unique, so the following list is not exhaustive and serves as a starting place. Topics to discuss while developing or renewing a processing contract between the operator and the community are:

Annual operating fee adjustment index

- Labor cost
  - EXAMPLE Adjustments to account for inflation
- Non-traditional labor adjustments
  - EXAMPLE An externally mandated, greater-than-inflation increase in pay rate, such as shifting to a living wage salary
- Indices, appropriate for various operational expenses, incurred at the MRF
  - EXAMPLE adjusting for increased cost for electricity

Inbound quality requirements

EXAMPLE Inbound material should not exceed more than 15% non-program material/contamination, or else be subject to a surcharge

EXAMPLE Inbound material containing hazardous materials will be subject to a surcharge and/or rejected. An explicit list of common non-program and hazardous materials should be developed for educational purposes and to enforce any required surcharge on incoming loads.

CONTRACTUAL CHECKLIST.
A sample checklist to review when updating or executing new contracts can be found HERE

Outbound quality requirements

EXAMPLE Adoption of specification standards for outbound commodities to meet end market needs. If a revenue sharing arrangement exists between the MRF and hauler or community, and commodities are downgraded (i.e. valued at a lower price per pound due to poor quality) due to extenuating circumstances, provisions to equitably manage absorption of revenue loss should be considered.

Acceptable material adjustments due to market conditions

EXAMPLE Commodity X may not be recovered if end markets do not exist within __ miles

EXAMPLE Commodity Y may not be recovered if market value drops such that sale of commodity becomes cost prohibitive

Inclement weather processing adjustments

EXAMPLE If inbound material contains X% moisture content, due to inclement weather, it will not be processed and instead disposed of

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Looking Ahead

Consideration of how these best practices might be implemented at material recovery facilities across the U.S. is the first step towards maximizing recovery of material streams. This could involve identifying which ones are realistically attainable, based on the structure of the organization and available financial resources, in combination with which ones hold the most potential for impact. Not all of the best practices discussed here will be applicable to any single facility, however, this document provides several overarching concepts, regarding the power of industry collaboration, the use of metrics to track and measure change, processes for maintaining the MRF equipment itself, and how to establish strong team dynamics for a safe and efficient workforce.

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