CIF # 1089 – Next Gen Technologies

Final Report

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ECOCOMPASS

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Acknowledgement

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Acknowledgement - Steering Committee

The Project Team would like to thank the following Regional Public Works Commissioners of Ontario (RPWCO) members who served on the Steering Committee and provided valuable feedback and insight during the course of this study.

RPWCO Members

- Erwin Pascual, Peel Region, RPWCO lead
- Cameron Walsh, Guelph
- Cathy Copot-Nepszy, EWSWA
- Dennis Siu, York Region
- Jay Stanford, London
- Sumantra Datta Ray, Toronto

- Carrie Nash, CIF, Senior Program Manager

Acknowledgement - Vendors

- The Project Team would also like to extend a special thanks to the following vendors who responded to multiple calls, and provided demos, specification sheets and other materials over the course of the project.
- **DISCLAIMER:** Vendors identified do not represent a comprehensive list, nor does the Project Team endorse any specific vendor.

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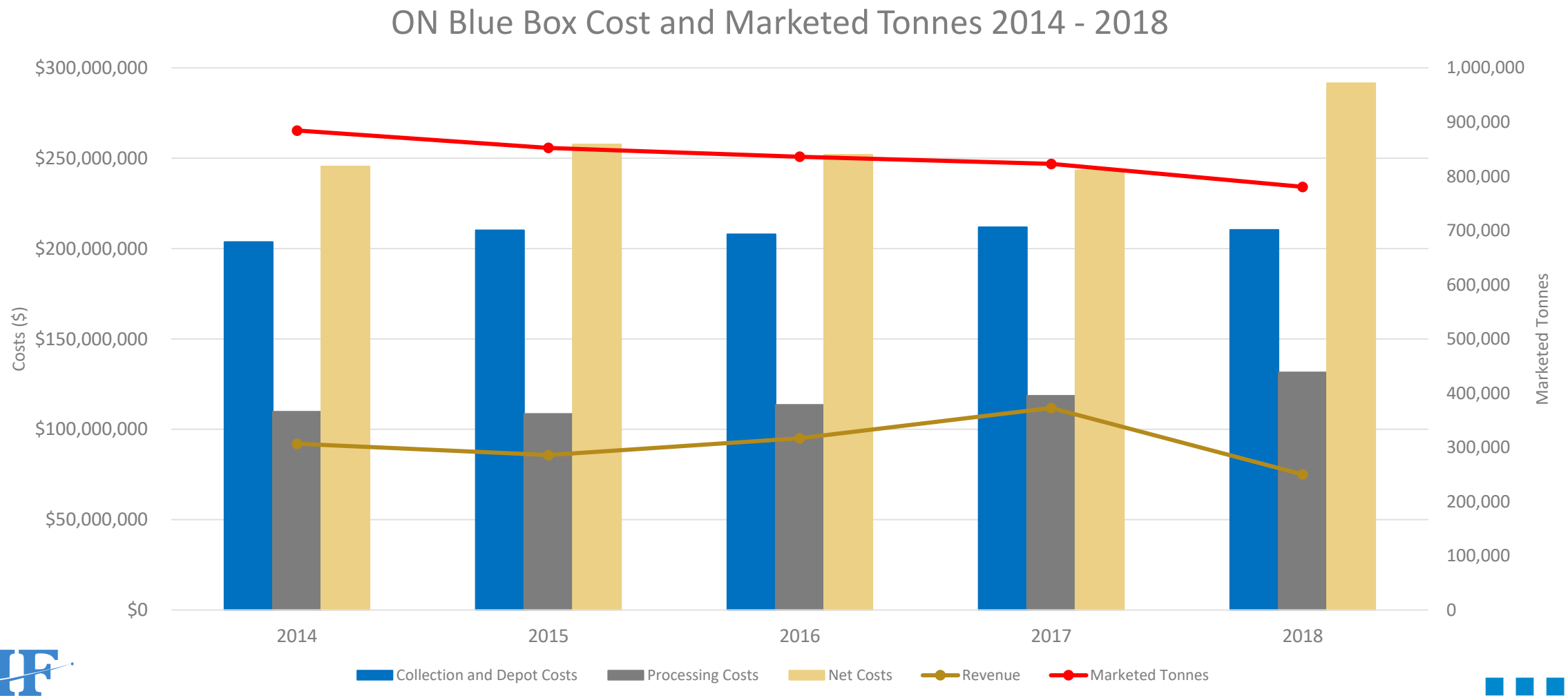
Background

- Municipal recycling costs have continued to increase annually, due to the increasing complexity and lightweighting of the packaging supplied into the market. As packaging becomes more complex and multi-layered, it results in greater sorting challenges, and greater confusion amongst residents which contributes to higher contamination rates.
- Additionally, China's implementation of its National Sword (2017) and Blue Sky (2018) policies resulted in greater restrictions and the outright bans on the importation of several post-consumer recyclable commodities. These policies have forced MRF operators to not only evaluate how materials are sorted at MRFs, but also how to prevent contamination from entering the MRF.
- Ontario (ON) is also in the midst of transitioning its current shared Extended Producer Responsibility (EPR) Blue Box program to Individual Producer Responsibility (IPR). This transition will see producers take over the operational and financial responsibility of the Blue Box program from 2023 – 2025.

Background (continued)



Methodology

- The Project Team conducted a broad scan of technologies and initiatives used or in development for the collection and sorting of recyclable materials. Initial findings ranged from defining the right material mix to complete automated systems (software and hardware).
- To better assess the findings, these technologies and initiatives were grouped into four categories:
  - Collection Bins & Systems
  - Collection Vehicles
  - MRF Equipment
  - Miscellaneous
- A total of **41** technologies were identified.
- **DISCLAIMER:** Vendors identified do not represent a comprehensive list, nor does the Project Team endorse any specific vendor.

Long List (Details provided in Appendix A)

Collection Bins & Systems	Collection Vehicles	MRF Equipment	Miscellaneous
• In-Bin Remote Sensors and Cameras • RFID Equipped Trucks and Bins • Bin Spring Closures • In-Ground Collection Bins • Underground Collection System	• Front-Load Automated Collection Truck • Alternative Fuels • Electric Powered • Hybrid Solution • Fleet Management – Telematics • Self Sealing Tires • Tire Pressure Monitoring • Self Driving Collection Trucks • Self Driving Transport Trucks • AI Based Cart Recognition	• Black Plastic Optical Sorter • Optimizing Existing Optical Sorters • Fully Automated MRF • Scalping Screen • Non-wrapping Screen • Artificial Intelligence and Robotics • Optibag Program • SCADA (Supervisory Control And Data Acquisition) • Auger Screen • UniSort 5.0 by Steinert • Michelin Tweel Airless Radial Tire • Automatic Switching Power Factor Correction • Levelling Devices • Ballistic Separator • Bag Breaker • Paper/Film Extractor • Optical Scale	• Right Material Mix • Standardized Signage • Back-Office System • Solar-Compacting Smart Public Space Bins • Interactive Sorting Systems • AI – Waste & Recycling Sorting • AI – Waste Management – Saskatchewan • GIS & Big Data • Electronics Recycling – ATM

Performance and Cost Evaluation Framework

- Given the current impacts on post-consumer commodity end markets and Ontario's transition to IPR by 2025, the Project Team identified four key criteria for evaluating the various technologies. These criteria are:
  - Improving Bale/Commodity Quality;
  - Measuring and Managing Contamination;
  - Time Required to Implement; and,
  - Cost/Payback Period
- In addition to these criteria, the Project Team recognizes that most public articles and vendor information are not likely to provide a balanced perspective; typically focusing on the benefits and opportunities. Where possible, the Project Team leveraged its existing knowledge to identify possible disadvantages/drawbacks.

Rationale for Evaluation Criteria

➢ Improving Bale/Commodity Quality

- China's National Sword and Blue Sky policy imposed strict requirements on post-consumer commodities imported into the country that were adopted by the rest of the world. This resulted in significant declines in commodity pricing, and in some extreme cases, disposal of baled materials. As a result, MRF operators implemented various measures including adding new equipment, slowing down lines, adding labour, and/or adding shifts.

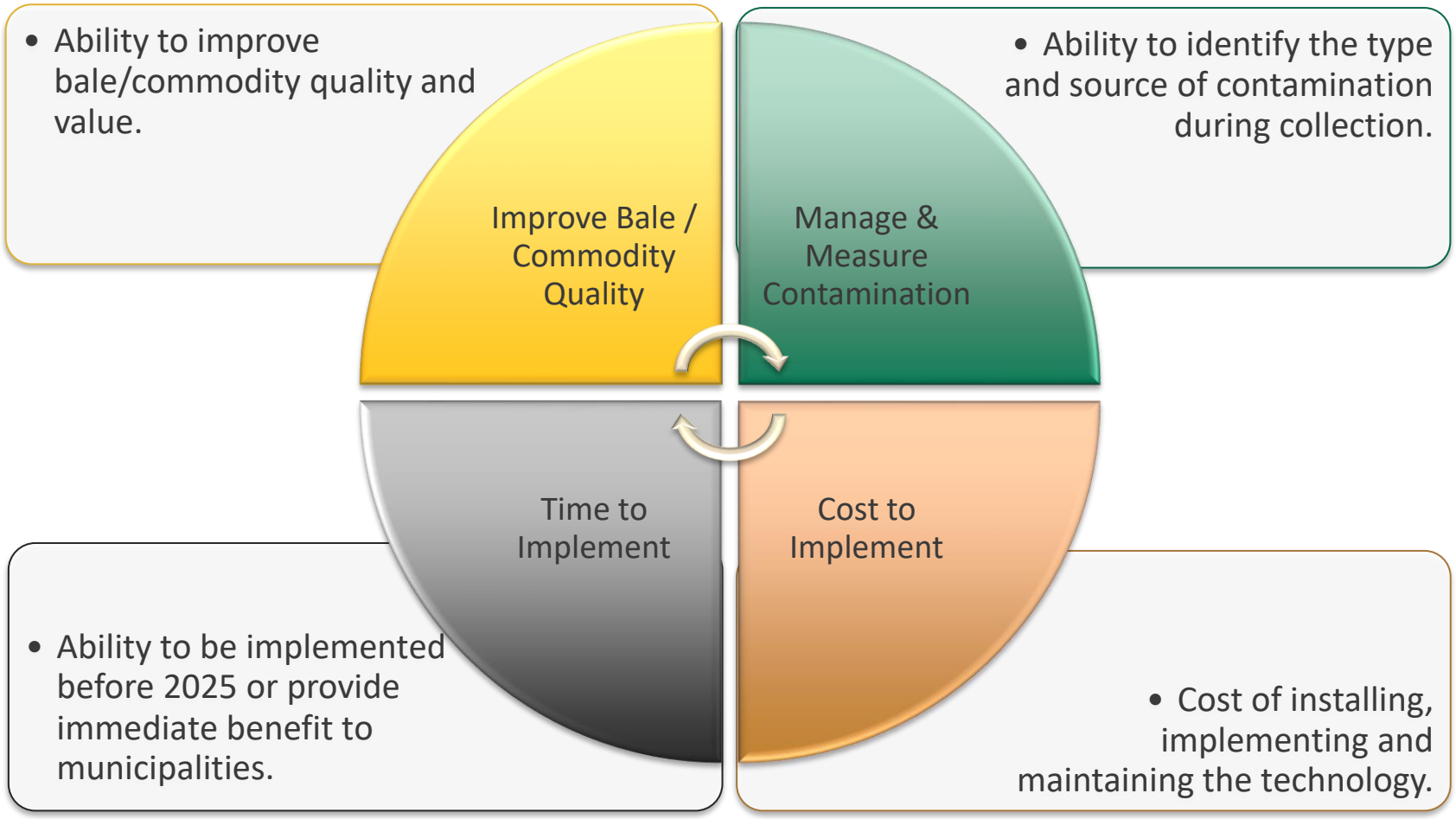
➢ Measuring and Managing Contamination

- Rising contamination levels placed in Blue Boxes and/or drop-off points have also resulted in increased collection and processing costs. There are several factors that contribute to increasing contamination levels ranging from illegal dumping to improper preparation of recyclable materials. Several technologies have been introduced to help municipalities identify the type and source of contamination to assist municipalities in providing targeted communications, or to more effectively enforce recycling policies.

Rationale of Evaluation Criteria (continued)

- **Time Required to Implement**
  - Recognizing Ontario will transition to IPR by 2025, its critical for municipalities that are considering these technologies to assess whether they have been proven and how long it will take to implement. Some technologies require a significant lead time and overhaul of infrastructure, while others can be installed or retrofitted into existing infrastructure.
- **Cost to Implement (Payback Period)**
  - In addition to timing considerations, the capital requirements as well as the payback period are key considerations for municipalities when assessing these technologies. While specific financials have not been obtained, an initial assessment was made based on estimates provided by the vendors or within articles.

Evaluation Criteria



Prioritized Shortlist

Given the evaluation criteria, the Steering Committee prioritized and short-listed the following technologies. Some of these technologies were already implemented by Ontario municipalities, such as the RFID and Non-Wrapping Screens; however, they were still prioritized to explore further enhancements and greater utilization of the technology.

1. RFID Equipped Trucks and Bins
2. In-Bin Remote Sensors and Cameras
3. Artificial Intelligence and Robotics
4. Optimizing Existing Optical Sorters
5. Black Plastic Optical Sorters
6. Front-Load Automated Collection Truck
7. Scalping Screen
8. Non-wrapping Screen

RFID Equipped Trucks and Bins

RFID Equipped Trucks and Bins Vendors

Click logos for company websites

AMCS Group	FleetMind	Routeware	Soft-Pak
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RFID Equipped Trucks and Bins

- Radio-frequency identification (RFID) technology consists of two main components: RFID tags and RFID readers. RFID tags, effectively a programmable digital serial number that consists of both a transmitter and a receiver that are attached to a waste or recycling container.
- When an RFID tag receives a broadcasted signal from an RFID reader, it transmits relevant information back to the reader. This technology has been used for decades, not only in waste management, but in various industries such as smart cards, clothing, transportation, etc.
- The value of RFID Technology in waste management is not the standalone technology, but the integration with other technologies such as GPS, scales, cameras, etc. to provide real-time data that can be used in education, service optimization, and enforcement. Municipalities such as Peel Region, Guelph and Bluewater are a few municipalities that have deployed these technologies.

RFID Component List

- Hardware
  - RFID Tag
  - RFID Reader
  - Reader Remote Antenna
  - Modem
  - GPS Module
  - On-Board Computer
  - Scale Integration
  - Camera Integration
  - Support Mobile Devices
- Software
  - Main System
  - Customer Database
  - Container Database
  - Work Order Repairs and Exchanges
  - Container Repair System
  - Billing System
  - Mapping Module
  - Live GPS Tracking

RFID Hardware Components

RFID Tags

RFID tags are fitted on the inside of the walls circling carts or on the outside of containers. They are read by RFID antennas installed on garbage truck lifters when serviced.

Location of RFID tags (green and red arrows)

RFID Antenna

RFID Antennas are installed on the hydraulic lifter and are used for automatic reading of RFID transponders fitted on waste bins and containers.

Visual & Audible Signaling Equipment

Alerts the workers with signals corresponding to a particular process (successful/failed reading, irregularity reports, blacklisted user).

RFID Components

Controller Unit

Installed in the rear side of the superstructure, the controller unit communicates with other system components then aggregates and relays all collected data to the central computer.

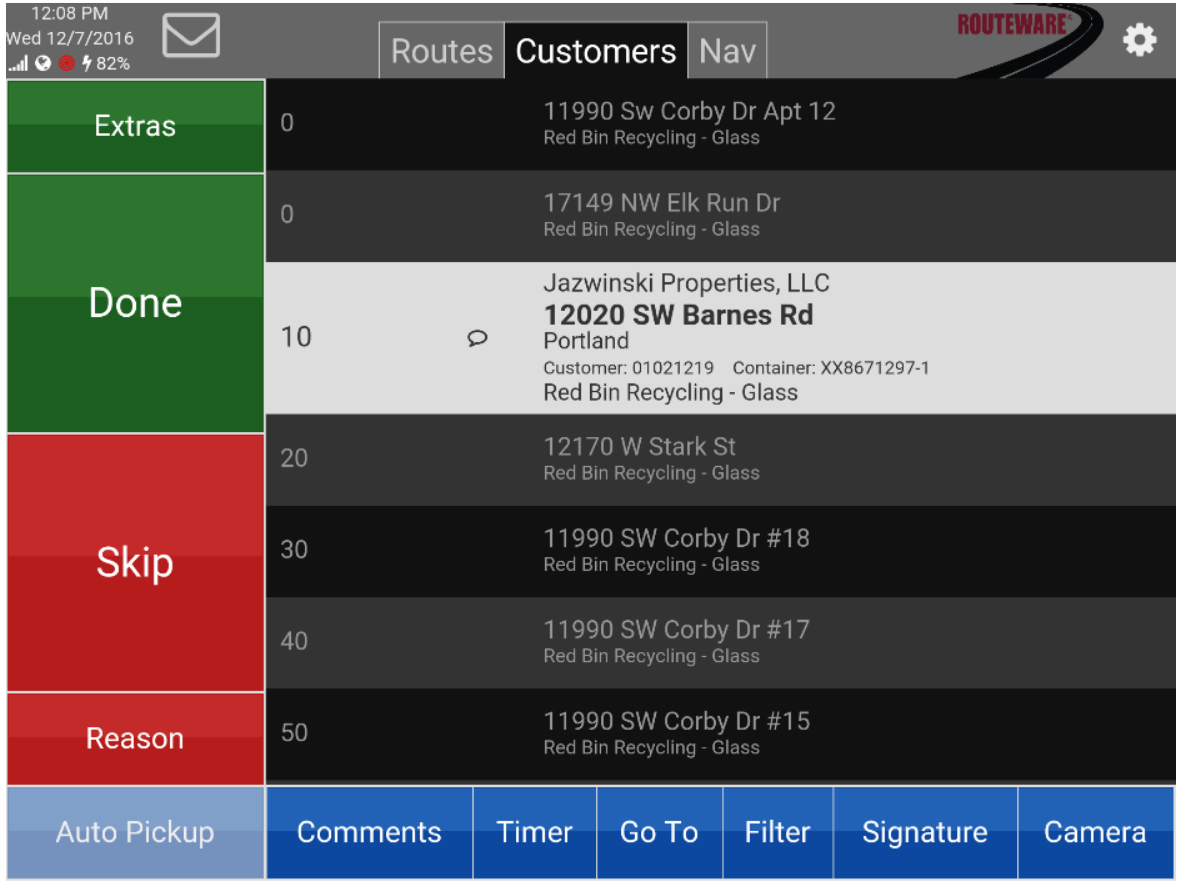
On-Board Computer System

Installed inside a vehicle's cockpit, the central computer controls overall operation of the entire system and enables storing, processing and wireless data transfer in real time. The On-Board Computer System stores the routes and all related event data (for example: pickups, skips, timers) in a SQL Server Express database. The system collects GPS location data and transmits event data and GPS data to the control centre.

RFID – How it Works

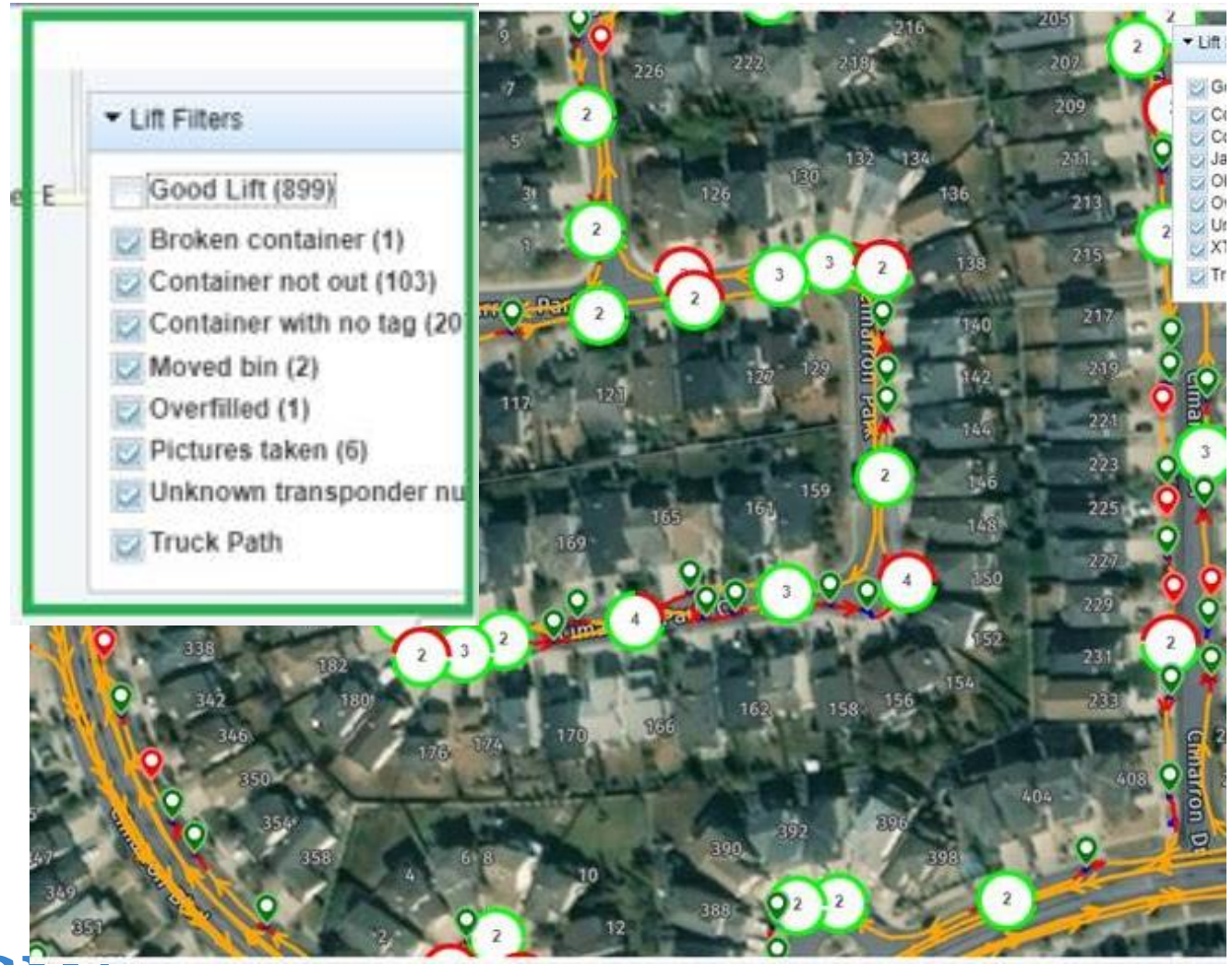
- RFID tags are affixed to all carts and containers that will be serviced.
- RFID readers are placed in the trucks as part of the On-Board Computer System.
- The RFID readers scan the tag's ID number, find the appropriate customer record in the On-Board Computer System, and automatically record the pickup on behalf of the driver.
- The database associates RFID chips with the customers' containers and pickups are automatically recorded on behalf of the driver.
- All RFID event information is captured on the on-board terminal and transmitted to the back-office system in real-time.
- If the cart does not have a RFID tag, the driver can make a visual determination of the correct address and select that address from the on-board computer. If the cart is at the wrong location, the driver can assign that cart to another address.
- RFID tags can be reassigned either remotely through vendors inventory management tools, or in the field through an RFID scanner that can communicate with the client's system.

RFID – In-Field Reporting



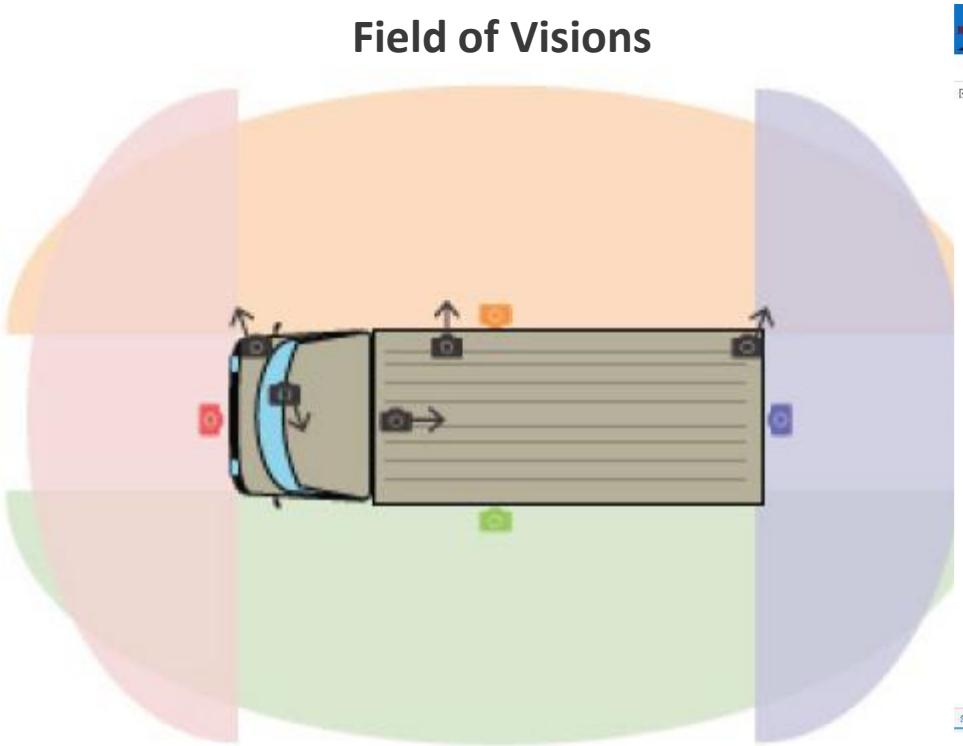
- The on-board computer system tracks both missed pickups and containers that were not set out. The user interface on the system has a large, red Skip button which the driver simply presses to indicate an inability to service the container. Users can assign a default reason associated with this button press (typically “Not Out” or “Blocked”).
- The pickups can be displayed in customer sequence as the route progresses. After each completed stop, the screen automatically advances to the next sequenced stop. The unit can also be set in Auto Pickup mode, where the pickup is automatically recorded without driver input.

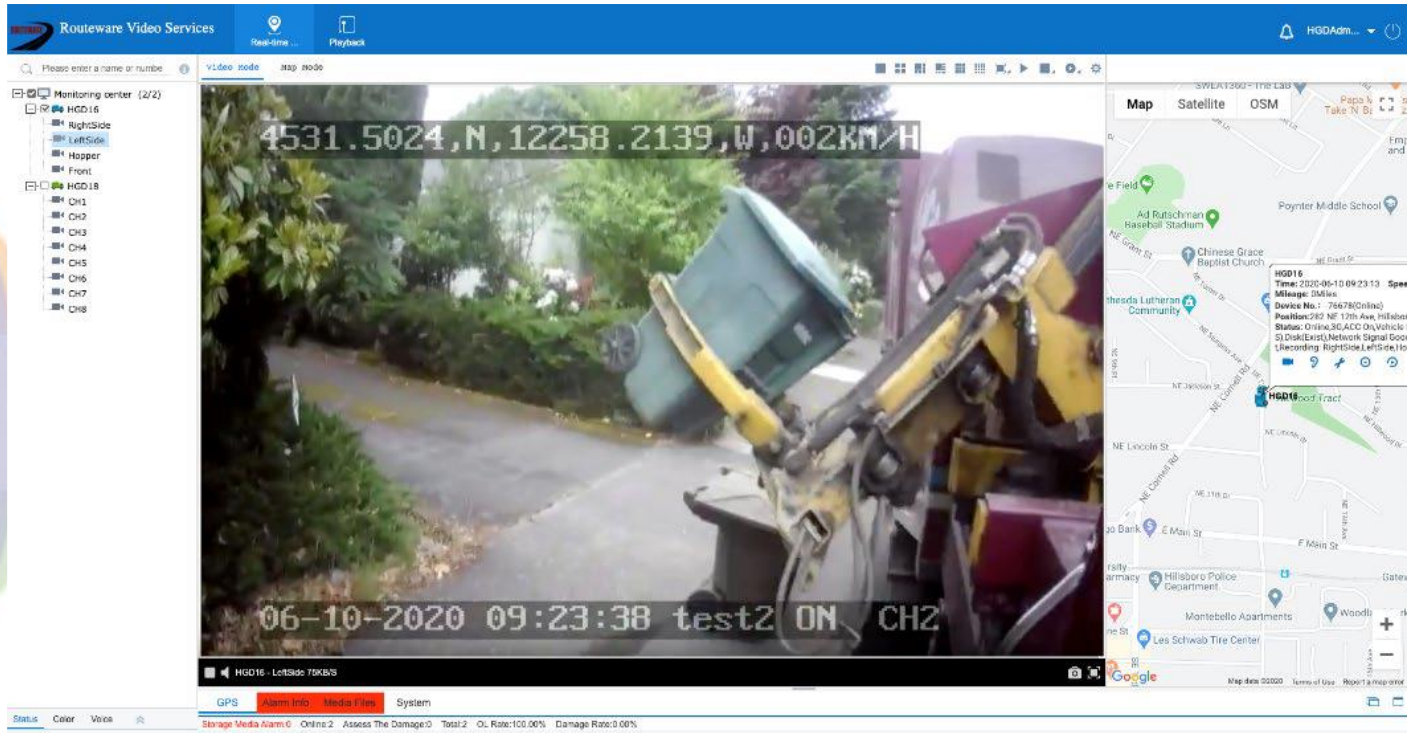
RFID – Tracking Issues



- The system allows users to customize a range of issues that may be encountered by drivers during collection. If an issue arises, the driver selects the appropriate issue using their on-board system.

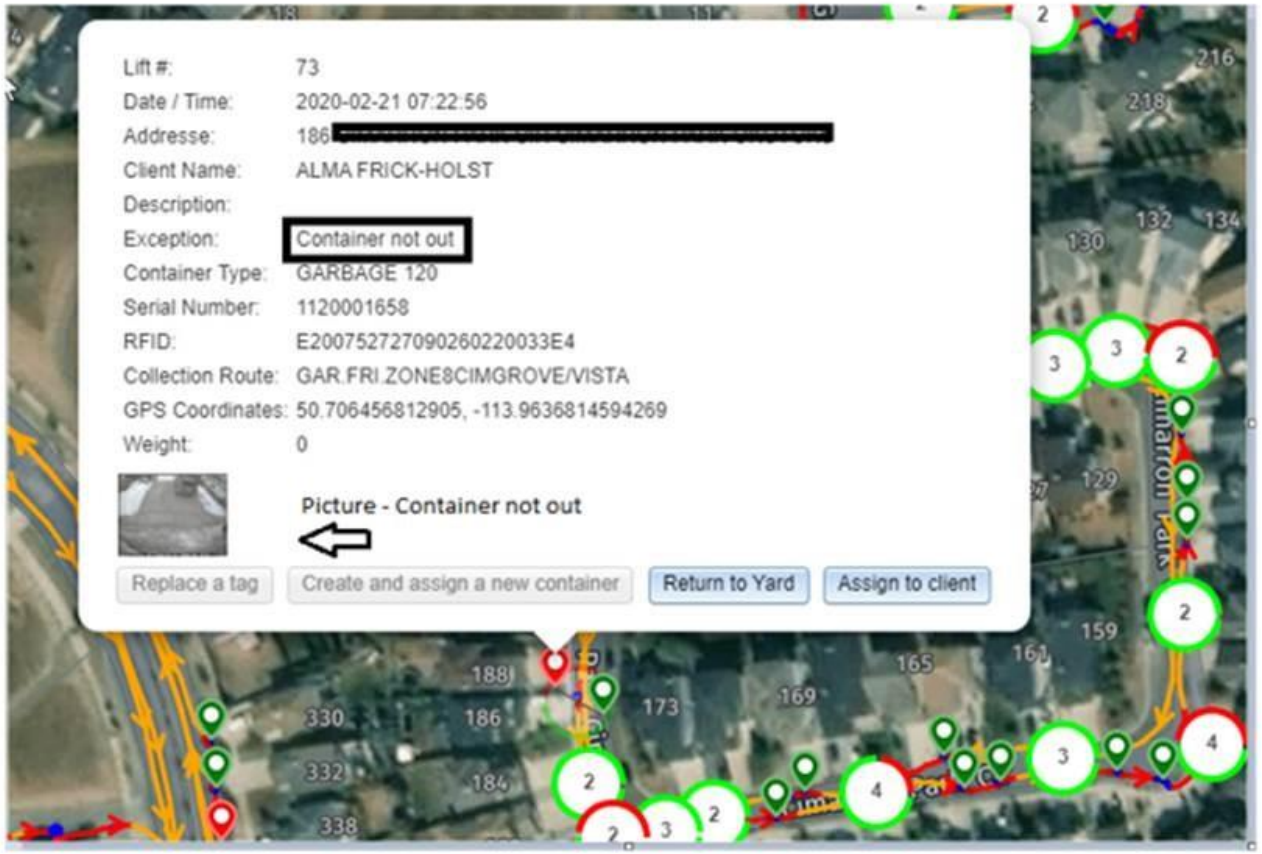
RFID – External Digital Cameras





New software can support and interface with external digital cameras, allowing the driver to document situations on-site in picture or video format. The pictures are saved with a timestamp, customer name and location (latitude and longitude). Pictures and video can provide necessary documentation of issues.

RFID – Documenting Issues



Pick up informations

Photographs provide additional documentation in the event a bin hasn't been set-out. These images can be reviewed to confirm if a bin was set-out or if there was a failed read.

Exception's picture

RFID – Documenting Issues (Continued)

- Not only can cameras be equipped to capture whether containers have been set-out, but cameras can also be placed in the hopper to identify contamination.
- If contamination has been identified, the driver can manually indicate the issue and the system can be triggered to automatically issue a letter to the resident.

RFID – Documenting Issues (Continued)

Plastic Bag (depot only) was identified in your **contaminated RECYCLING cart on 7/3/2020.** Please refer to the picture(s) on the reverse side of this letter.

The Regional District of Central Okanagan Waste Reduction Office and member municipalities are working very hard to eliminate the costly problem of contamination in yard waste and recycling carts and to prevent yard waste and recyclables from being put in the garbage cart. Each property owner is responsible for the contents of the municipally owned carts on their property.

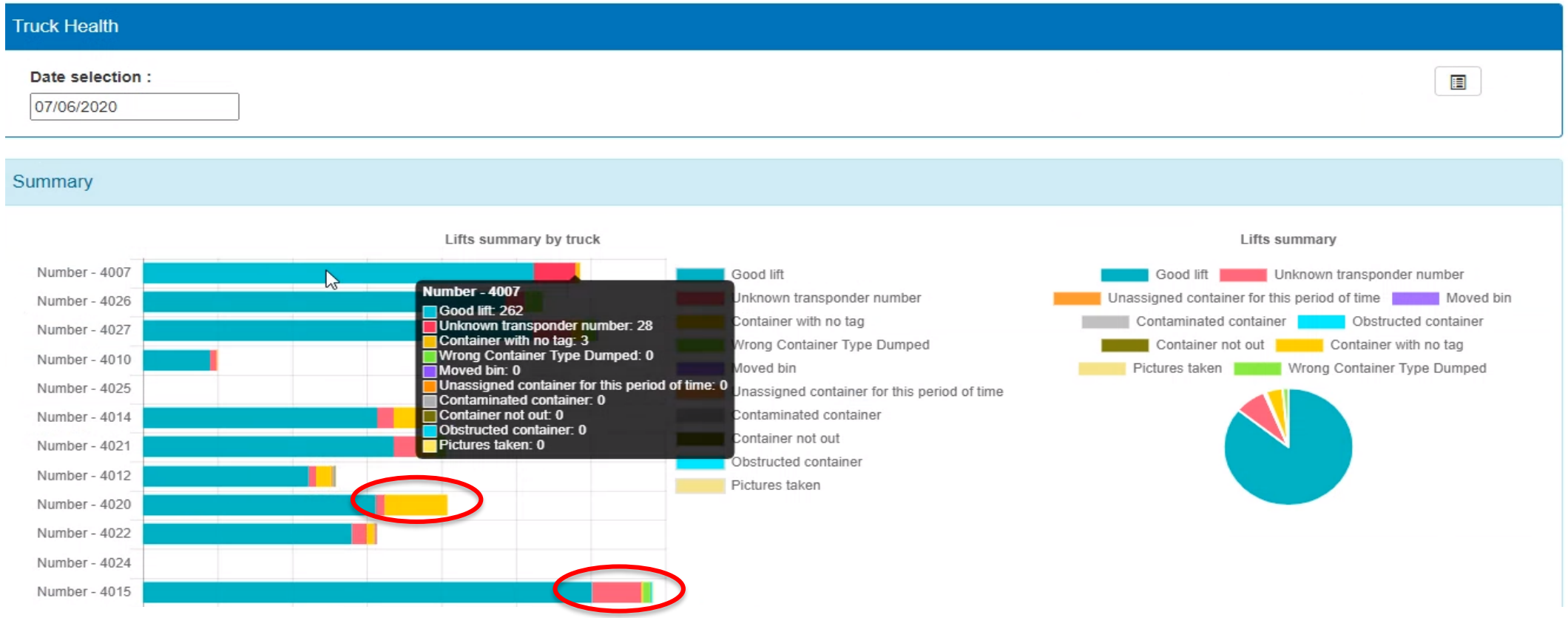
The following violations could result in a $150.00 fine.

Placing garbage or recyclables in a yard waste cart.
Placing yard waste or recyclables in a garbage cart.
Placing garbage or yard waste in a recyclables cart.
Placing depot only recyclables in a recycling cart.

Repeat Offenders may be fined for those offences listed above.

Included with this letter is a comprehensive guide to the materials that can and cannot be included in each of your carts. If you have any questions or require further information do not hesitate to call the Regional Waste Reduction Office 250-469-6250, visit our website rdco.com/recycle or download the RecycleCoach App for mobile devices.

RFID – Reporting Issues by Truck



- Users can also create reports that identifies issue by truck or route. This enables municipalities to allocate appropriate resources to tackle on-going issues. Using the example above, an issue classified as “Container with No Tag” may require immediate action in the field, while “Unknown Transponder Number” may be a failed read or incorrect read.

RFID – Optional Truck Features

Fork Scales on Commercial Front Load Trucks

- The On-Board Computer System has a serial cable connection to the scale meter provided by the scale vendor. The sensor is able to capture the weight of each lift and report that back to the central control server and the back-office dispatchers.
- Users have indicated that the reliability of the scales does vary depending on weather conditions and application. Typically, weights are averaged over multiple pick-ups (i.e. over a month) to determine an average weight to account for variances.

Body Scales

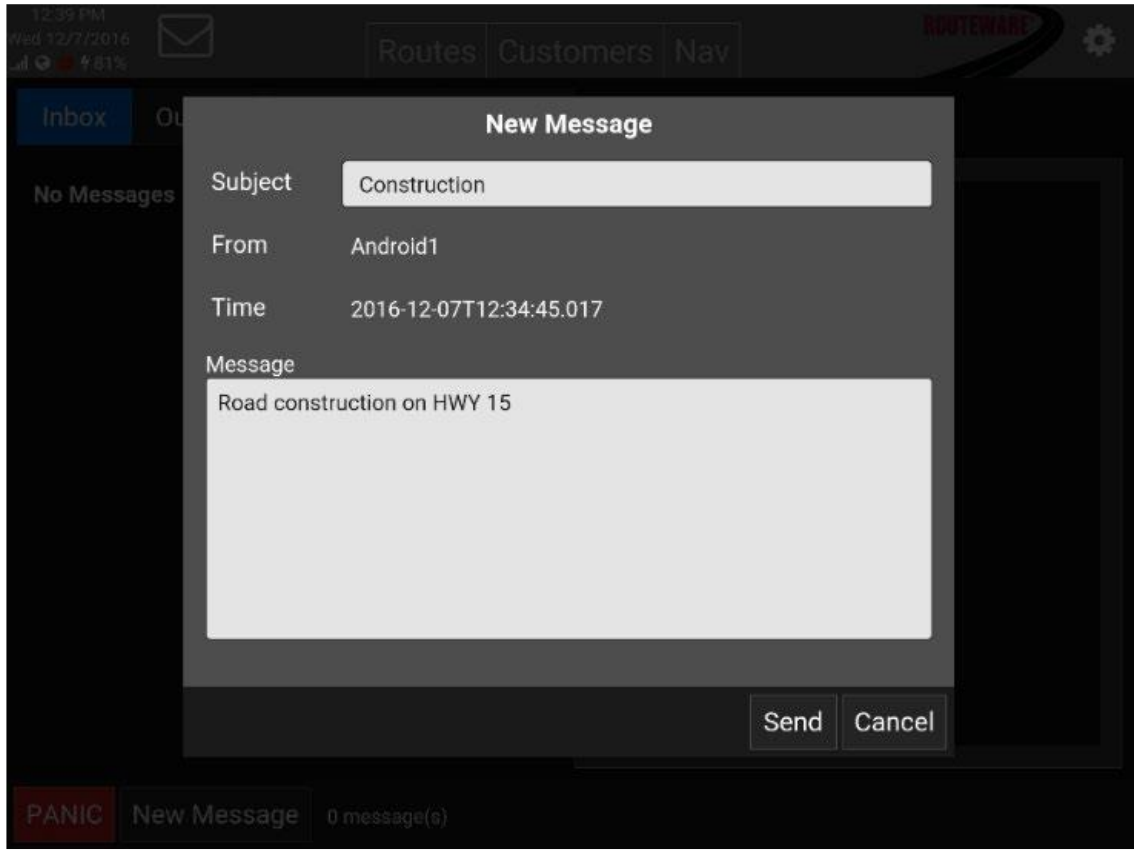
- Scale sensors built into the truck measures the overall vehicle weight. These are tied into the On-Board Computer System via a serial cable. Body scales provide an alternative to fork scales, and reduce the potential risk of damage or wear & tear associated with fork scales. The integration will capture the information and report it to back office dispatchers.

RFID – Additional Features

RFID systems include an On-Board Computer, a dashboard or tablet, that not only allows the driver to track whether a pick-up was good or not but also allows for direct messaging.

Driver Messaging is designed to replace cellular calls and two-way radios by giving the dispatcher and the driver an easy way to communicate with one another. These quick text messages can be sent from the control centre to the System, and vice versa. This also ensures the message was received, which may be missed when broadcasted over a radio.

Drivers can choose from a series of pre-set messages, then use the on-screen keyboard to complete it, or type a new message from scratch. The dispatcher can also broadcast a message to all drivers.



RFID Relevance for ON Municipalities

- RFID technology alone does not provide a significant value for municipalities. However, with accompanying GPS and camera technology it can play a vital role for municipalities to tackle contamination and improper set-outs at the curb.
- Cameras equipped on the truck and within the hopper can be used to document issues and enables municipalities to take appropriate actions to correct the behaviour. It also enables municipalities to implement Pay-As-You-Throw (PAYT) or Utility Rate based fees for waste collection.

RFID Lessons Learned

- As RFID systems, along with GPS and cameras track significant amounts of data from the field, it is critical for municipalities looking to deploy this technology to inform residents of how the data will be used to minimize privacy concerns.
- Areas with spotty cell reception can be problematic as users would lose real-time connectivity. However, data would not be lost but stored and then uploaded once a connection can be made.
- Installation costs of RFID tags on existing bins can be high due to the labour/staff required. Municipalities should consider these costs in addition to capital and operating costs.
- A growing number of devices use RFID tags, such as smart meters and 407 transponders, which will result in incorrect reads. Municipalities looking to implement RFID technology will need to allocate full-time staff to scrub the data to ensure data integrity. Ontario municipal representatives have indicated at least one full-time staff will be required to review data on an on-going basis to ensure familiarity and accuracy of the data tracked. This is especially critical during the initial roll-out of the system.

RFID Mobile Reader Specs

- **Environment:**
- Operating Temperature: -25°C to 55°C (-13° F to 131° F)
- Storage Temperature: -30ºC to 75ºC (-22° F to 167° F)
- Humidity: 10% to 90% (Non-condensing)
- Shock and Vibration: MIL-PRF-28800F, Class 2
- **Device Configuration:**
- Options for RF configuration, tag types, tag reporting, tag singulation, medium access, antenna configurations via: HTTP/HTTPS, RS-232, Intermec SmartSystems, Wavelink, Avalanche™ Client

- RF Antenna Connections: Four mono-static RF ports: FCC - Reverse SMA. ETSI Standard SMA, 30 dBm to 10 dBm RF power output software controlled.
- RFID Frequency Ranges: 860 - 960 MHz
- Internal power supply: 95-264 VAC auto ranging, 47-63 Hz
- Processor: Intel Celeron M 600 MHz
- Memory: 128 MB of DDR expandable to 1 GB, 1 GB Flash memory standard. Optional 40 GB hard drive.
- Connectivity: Ethernet: IPv4 & IPv6, Auto detect and selectable 10-100 Mbps full and half duplex. Optional 802.11 a/b/g Wi-Fi. USB for storage. RS-232 for peripheral devices.
- Network Services: HTTP/HTTPS Web server, SSH server, FTP server, Telnet server, Domain Name System (DNS), Simple Network Time Protocol (SNTP), Syslog, Server Message. Block (SMB/CIFS) Network File System (NFS)

RFID – Response Highlights

Question	Response
Components required to run system?	Base installation includes the on-board computer, wire harness, and integrated cellular modem.
Can you import and export data?	Reports can be exported to Excel, CSV, or PDF to aid in operational monitoring and review.
Cost range?	Truck equipment: ~$15,000 per truck Bin inventory system: ~$10,000 for 1st year; ~$3,000 per year after 1st year RFID Bluetooth Scanner and Phone:~ $2,500 per unit Mapping Software/License (location of pickups): ~$2,500 one-time fee Pathing Software: ~$500 per truck, one-time fee
What is the range of the system to read a bin?	~0 to 10-15 feet in ideal conditions.
Warranty	1-year warranty on hardware and software.
Technical support	Various support packages and user training is available.

In-Bin Remote Sensors and Cameras

In-Bin Remote Sensors and Cameras Vendors

Click logos for company websites

Compology	Recycle-Smart	Contelligent (Formerly OnePlus Systems)	Lidvizion
COMPOLOGY	RECYCLE SMART	Contelligent	LID VIZION™

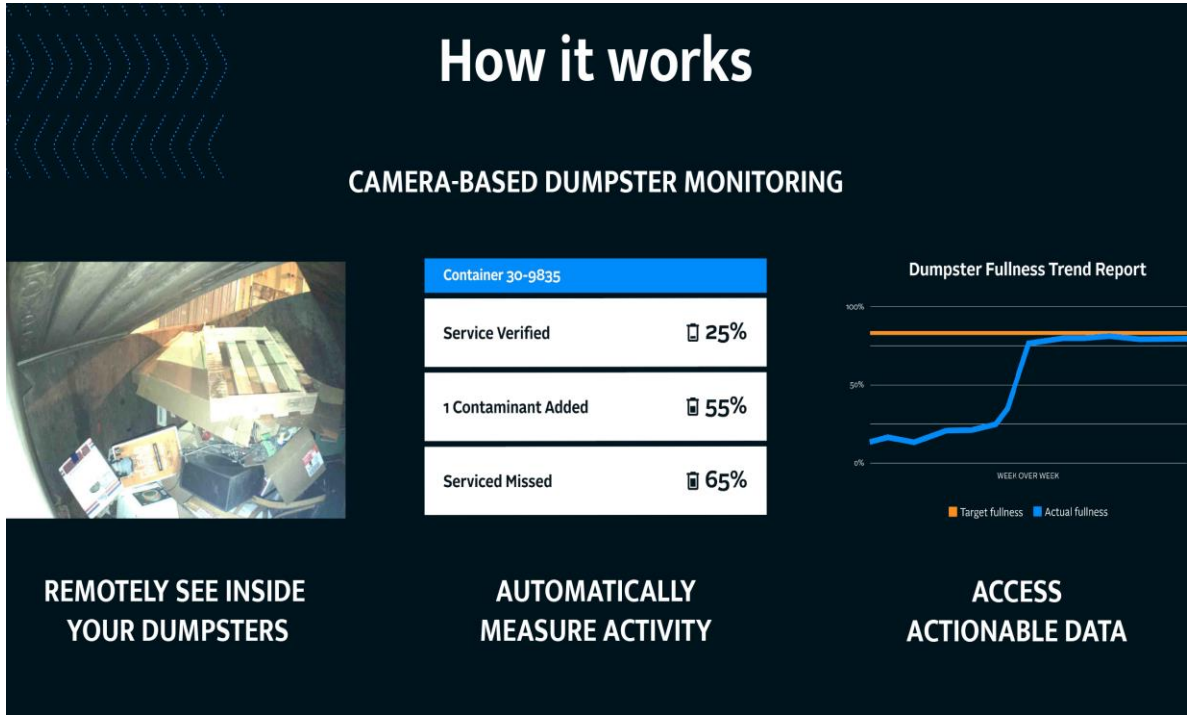
In-Bin Remote Sensors and Cameras

- Camera and sensors placed within the bins provide visibility in determining the fullness, as well as whether contamination has been placed in the bins. This avoids the need to “lift the lid” to look into containers.
- These cameras are also equipped with GPS and communicate with AI software to automatically detect contamination.

In-Bin Remote Sensors and Cameras – Components

- A camera is placed inside the bin with a robust plastic casing that is weatherproof, impact resistant, corrosion resistant, and waterproof.
- Wide angle, flash-enabled camera captures in-bin images.
- Advanced images and AI software, offer clear full pictures of in-container materials and identification of approximately 6 contamination types.
- AI software for in-bin cameras is still in development and do not appear to have the same capabilities as AI software used for robotics. However, vendors are investing in the technology and expect to see improvements over time.

In-Bin Remote Sensors and Cameras – How it works



- Sensors and cameras are placed inside waste/recycling bins and compactors to monitor fill rates and contamination levels on timed intervals. Cameras are typically designed to take 3 – 5 pictures a day but can be customized. The pictures are uploaded to the cloud, with automated alerts sent via email or text for bins to be serviced.
- Sensors also measure the temperature inside the container along with its GPS location and sends it to the server. This enables users to respond to potential bin fires. Tilt sensor captures pick-ups and drop-offs.
- Average battery life is around 5-years, assuming about 3 – 5 pictures a day. Increasing the frequency of the pictures will decrease the battery life.
- Data plans can be included within a monthly software subscription. Back-end software is hosted in the cloud.

In-Bin Remote Sensors and Cameras Reporting Capabilities

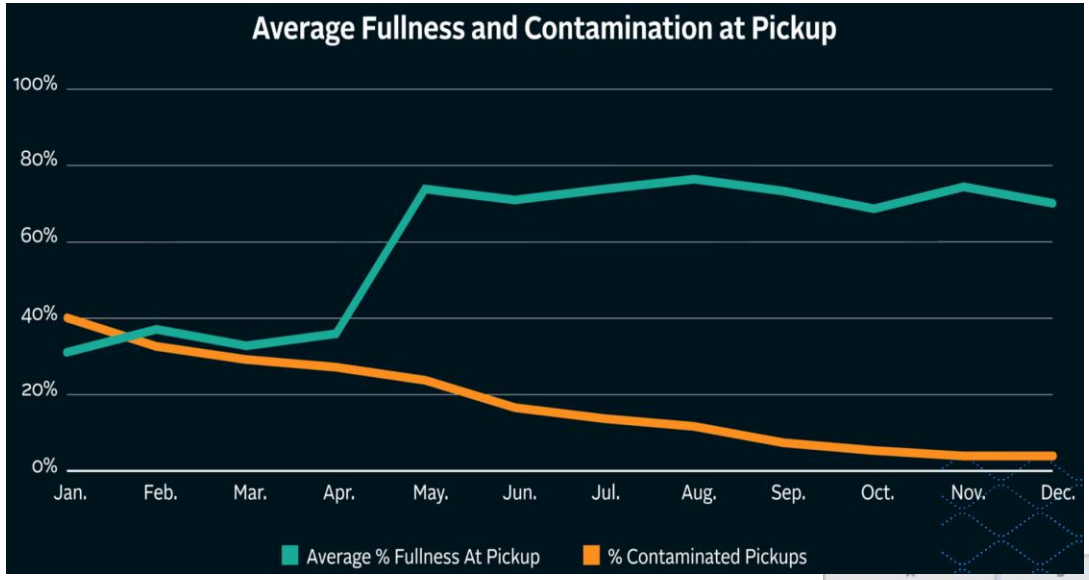
Web-Based Interface

- Allows customers to access data on a per container or per location basis across any timeframe. View full image history and activity feed. Download Excel versions of web reports along with any image at any time.

Customized Reports

- Create custom reports and dashboards to be automatically produced for any frequency.
- Review contamination audits.

In-Bin Remote Sensors and Cameras Reporting Capabilities



- Detailed reporting and analysis helps municipalities determine more efficient timing for pick-ups and take action against repeat offenders with contamination issues.
- Contamination is detected based on shape and pattern identification. Higher accuracy for more distinct and consistent shaped materials (i.e. propane tanks, black garbage bags).

Total Contamination: All Shifts											
Building Location	Content Type	Bags	Uncollapsed Cardboard in Recycling	Cardboard in Refuse	Bulky Items	Tanglers	E-Waste	Styrofoam	Propane Tanks	Wood	Total
Building B1	Recycle	0	189	0	1	0	0	15	0	0	205
Building B1	Refuse	0	0	23	5	1	0	0	0	0	29
Building B2	Recycle	0	7	0	0	0	0	0	0	0	7
Building B2	Refuse	0	0	6	0	0	0	2	0	0	8
Building B3	Recycle	1	49	0	10	2	0	1	0	0	63
Building B3	Refuse	0	0	10	4	2	0	0	6	1	23
Building B4/TC	Recycle	275	159	0	14	4	0	18	0	6	476
Building B4/TC	Refuse	0	0	56	5	2	0	10	0	0	73
Building B5	Recycle	3	157	0	3	0	0	2	0	1	166
Building B5	Refuse	0	0	5	0	0	0	0	0	0	5
Conference Ctr	Recycle	1	77	0	7	2	0	1	0	0	88
Conference Ctr	Refuse	0	0	19	0	1	0	0	0	0	20
	TOTAL	280	638	119	49	14	0	49	6	8	1163

In-Bin Remote Sensors and Camera Relevance for ON Municipalities

- In-Bin Sensors and Cameras are beneficial for municipalities that service multi-residential buildings or unstaffed drop-off depots with containers or compactors. These Sensors and Cameras are not recommended for use within carts.
- For both multi-residential buildings and drop-off depots, the cameras provide insight into disposal habits when it would not be practical to do it manually. In multi-residential buildings, daily messages can be provided to the property managers to address contamination placed in bins. Property managers can then investigate issues.
- For drop-off depots, drivers can be informed if contamination levels are high to ensure the load is sorted prior to be tipped at a MRF or rerouted altogether.

In-Bin Remote Sensors and Camera Lessons Learned

- While the systems can be effective, the AI technology is limited in its ability to recognize a wide range of contaminants. Some anecdotal information indicate the accuracy does vary between vendors from 50-90%; lower for bulkier items that have unique characteristics (e.g. chair, tables) and higher for materials with consistent shapes and colors (e.g. propane tanks, black bags).
- Vendors recommend staff review images to ensure the material in the bin is actual contamination.
- Scratching of the casing, as well as bulky items placed in front of the camera, will result in false-reads on contamination and/or fullness of the containers. A message is typically sent to the property manager or waste collector to inspect manually.
- For rural communities relying on unstaffed drop-off depots, stable cell reception can be the greater barrier to effectively use these cameras.

In-Bin Remote Sensors and Cameras Response Highlights

Question	Response
Durability of in-bin camera	Very durable hardware, built for 20 year useful life. Battery life expectancy approximately 5 years
Solar power panel	Currently not available, but battery could be charged by solar power
Data plans and connectivity	Data plans required, unless wifi is available. GPS, LTE-CATM1 (cell communication), 4g LTE compatible. Monthly plans range from $5-25 per month per device.
Number of pictures taken per day or triggered on action	Can be configured to take as many pictures as required but battery life will be compromised. Suggested 3-4 pictures per day
Items blocking camera	Camera has a wide angle lens, but if blocked will send an alert
Software accuracy detecting contamination	Varies by material types ~75-95% accuracy
Software	Software resides in the cloud. Included in package
Camera cost	~$75-$200/device

In-Bin Remote Sensors and Cameras Reporting Capabilities

Fullness	▪ Fullness by percent ▪ Volume by cubic yards ▪ Fullness at service and trends over time
Contents & Contamination	▪ Counts of 6+ categories of contaminants ▪ Type of contaminants ▪ Time window of contaminant addition ▪ Count of contaminants per cubic yard
Service Verification	▪ Count of service events by location, customer and container ▪ Timestamp of service and frequency of pickups ▪ Comparison against schedule ▪ Before/after images
Asset Management	▪ Number of assets deployed by location and by customer ▪ Total cubic yards by location and customer
Notifications	▪ Automated alerts about fullness and contamination levels ▪ Email and text ▪ Summary reporting via Excel and API

In-Bin Camera – Technical Specs

Dimensions	5” (H) x 7.25” (W) x 2” (D) 1.3 lbs
Sensing	GPS (3f accuracy) Wide-angle camera Accelerometer
Durability	IP67 weatherproofed Operational -20F to +185F Withstands 14,500 lbs crush force
Security	Security mounting bolts Password-protected activation
Power	5+ years battery life LiSoCl2 battery
Comm	CAT-M1 LTE Bluetooth NFC

Artificial Intelligence and Robotics in MRFs

Artificial Intelligence and Robotics Vendors

Click logos for the company's website

AMP Robotics	BHS – Max AI	Machinex – SamurAI
AMP ROBOTICS	MAX·AI	SAMURAI

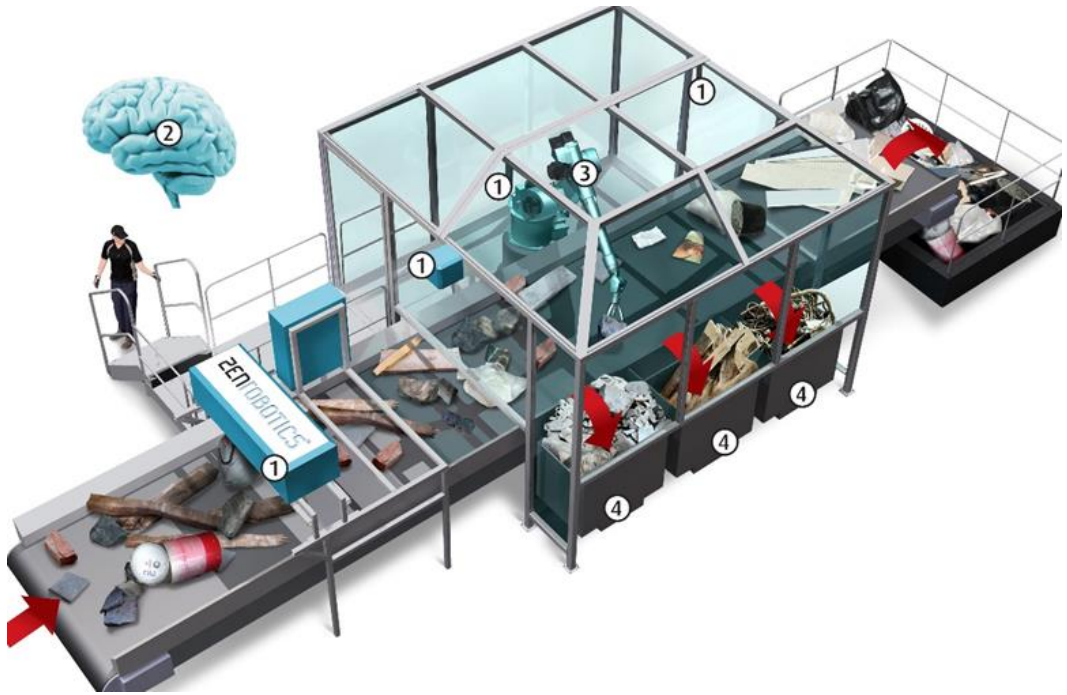
Van Dyk Recycling Solutions – RoBB AQC	Waste Robotics	ZENROBOTICS
VAN DYK recycling solutions	WASTE ROBOTICS	ZENROBOTICS

Artificial Intelligence and Robotics

Video Link: Click here

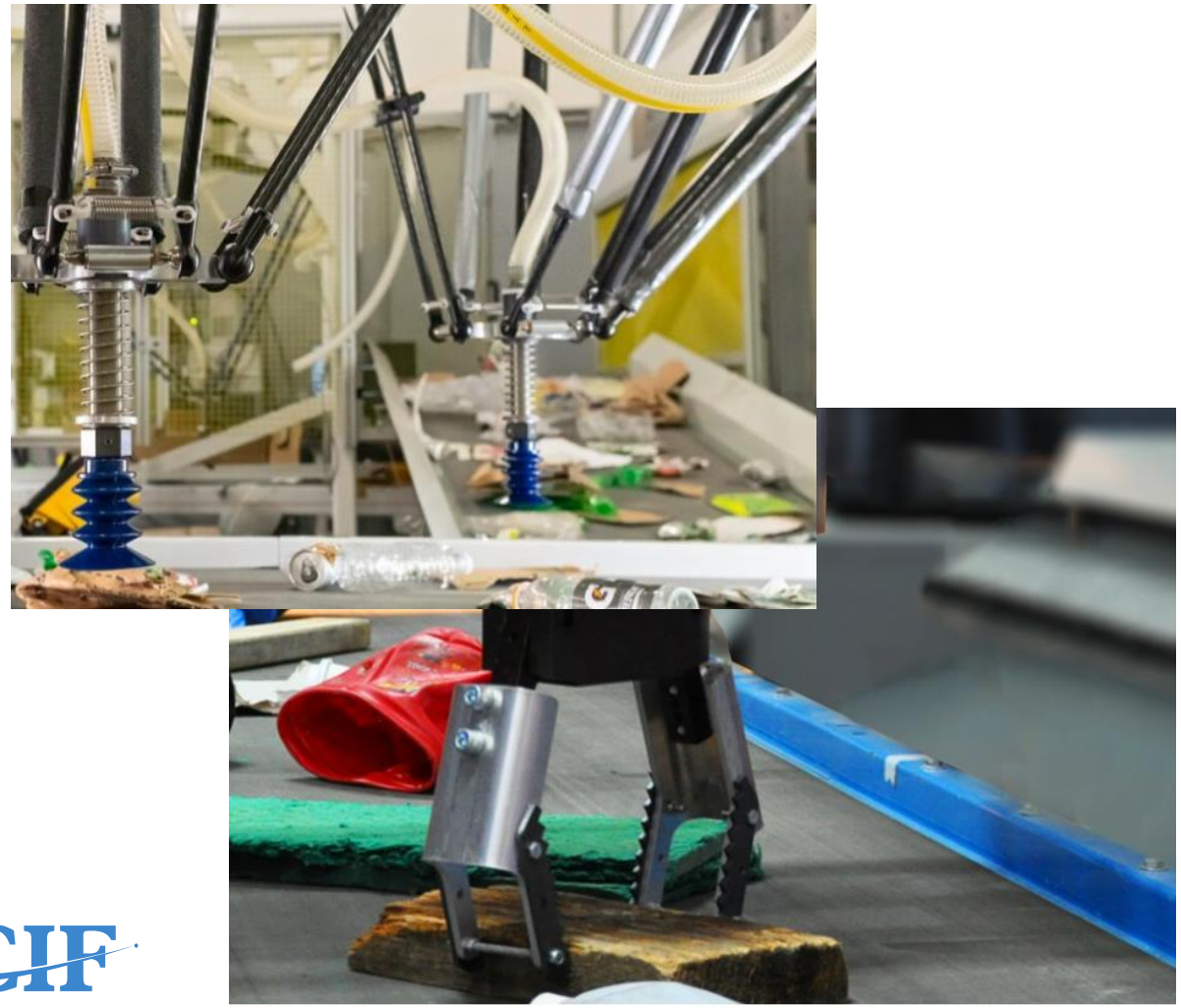
- Robotics combined with Artificial Intelligence (AI) and machine vision analyze and sort material streams to identify recyclables and other items for recovery.
- Combined with modern sensors, AI allows robots to identify objects based on various characteristics including material, shape, color or specific object type.
- Robots can be easily reprogrammed to adapt to changes in the waste stream and can be trained for new sorting tasks and waste streams.
- When one robot learns about a new packaging in one region of the world, all other connected robots become aware of the same knowledge.
- Several robots have been installed in Quebec, Manitoba, British Columbia and Ontario.

Artificial Intelligence and Robotics – How it Works



- AI and Robotic Systems consist of four key components:
  - **Sensor Module / Vision System (1)**
  - **AI / Computer Brain (2)**
  - **Robotic Arm (3)**
  - **Storage bins (4)**
- The **Sensor Module / Vision System (1)** acts as the eyes of system to capture data on the key characteristics (colour, shape, material or object type) of each material that passes under the system on a conveyor belt. This information is then analyzed by the **AI / Computer Brain (2)** linked to a neural network to determine whether a material should be targeted by the **Robotic Arm (3).** Once the **AI / Computer Brain (2)** recognizes the material it is targeted by the **Robotic Arm (3)** and placed in **Storage Bins (4)**.
- Since the Sensor Module / Vision System (1) and Robotic Arm (3) are installed overhead, it allows vendors to easily retrofit existing facilities (assuming appropriate height clearance) without significant operational changes, unlike optical sorters that need acceleration belts.
- Additionally, in the event there is a system failure or requires downtime, the overhead installation still allows for manual sorters to operate underneath the robotic arm. Note: Manual sorters cannot work underneath the robotic arm when system is operational.

Artificial Intelligence and Robotics –Components



- Robotic Arm (Suction / Gripper)
  - Most vendors provide robotic arms equipped with suction cups to pick up targeted materials. Some provide a gripper instead of a suction cup as it is more effective at picking up heavier items. Suction cups are recommended for Blue Box materials with a minimum size of 2” x 2” and maximum weight of 3 kg.
  - Once installed, these arms cannot be relocated with ease. However, they can be reprogrammed to target different materials or prioritize targeted materials, if targeting multiple materials (i.e. target highest value material first).

Artificial Intelligence and Robotics – Components

- Sensor Module / Vision System
  - The “vision” component of the system varies greatly from supplier to supplier and it forms the foundation of the system. It is typically a combination of 2D or 3D cameras, and sometime with near-infrared (NIR) scanners, combined with AI. These cameras and sensors enable the system to see multiple properties of materials (size, shape, colour, resin, etc.).
- Computer Network
  - Many of the systems are connected in the cloud enabling each robot installed anywhere in the world to share their knowledge. When one robot learns about a new packaging in a region of the world, all other connected robots become aware of the same knowledge. It makes them super sorters.

Artificial Intelligence and Robotics Relevance for ON Municipalities

- The AI and Robotic systems typically have a range of 60 – 90 picks per minute and should be used as quality control after the main sorting of materials. Most vendors do not recommend using AI and Robotics system at pre-sort stations due to the uneven burden depths and bulky items.
- Some vendors allow for a single vision system to connect with up to 10 robotic arms; however, the greater the number of the arms connected to a single vision system the lower the efficiency of the arms further away from the visions due to materials rolling.
- AI and Robotics can play a vital role in cleaning up commodities that require higher purity levels as it can remove film, fibre, plastics, etc.

AI and Robotics – Response Highlights

Question	Response
Weather conditions	No noticeable impact on wet (snow or rain) materials.
Partially covered materials	If the robots can see a portion of an item, they can typically identify it
Capture and purity rate	Capture and purity is ~95%
Maximum weight per lift	Large variation dependent on model 0.5kg up to 30kg
Pre-sort activities/contaminants	Most models can be programmed to target contaminants and other small materials; however, it is not recommended by most vendors to be used at pre-sort.
Plastic film/grocery bags	Systems can remove plastic film and bags
Picks per minute (ppm)	Large range depending on weight of item – min 25 ppm – max 90 ppm
Speed of belt	200 – 400 feet per min
Identification accuracy	90%+
Retrieval success rate	~90 - 95%
Leasing options	Most vendors offer leasing options that vary in time/cost

Optical Sorters (Optimizing Existing Optical Sorters and Black Plastic Sorters)

Optical Sorters Vendors

Click the logo for the company's website

Machinex	MSS Optical	NRT Sorters	Pellenc ST

Redwave	Steinert Global	TOMRA

Optimizing Existing Optical Sorters

- Initial investments in optical sorters are significant as they consist of multiple hardware components including scanner boxes, acceleration belts, air compressors, and valve blocks. The effectiveness of the optical sorter relies heavily on the software, the “brain” of optical sorters to recognize the changing mix of materials scanned by the optical sorters. As the packaging mix changes, the software must also be updated to adapt and learn of these changes. Most vendors will push (include) software updates through their preventative maintenance inspections (PMI). However, over time hardware upgrades may also be necessary.
- All vendors have indicated they can provide upgrades to individual hardware components, mostly the CPU or the controller. With higher resolution scanners, the optical sorter can improve its ability to recognize materials.

Optimizing Existing Optical Sorters

- Machinex has developed the Optical Sorter MACH Hyspec®.
- Using technology made more efficient by a high-speed, short wave infra-red (SWIR) hyperspectral detection system, the MACH Hyspec® can sort different types of material, such as plastics (PET, HDPE, PVC' LDPE' PP PS, etc.) and fiber products.
- It also includes carton container detection, wood product recognition, wood by grade (natural versus painted), color recognition and metal detection.
- The MACH Hyspec® can be used in different types of material recovery facilities, such as single-stream, construction and demolition, municipal solid waste, plastic recycling, and other applications.

Optimizing Existing Optical Sorters

- Machinex MACH Hyspec® Optical Sorter
- Video Link: Click here

Optical Sorters – Technical Specs

- TOMRA AutoSort 1000
  - Width 1,800mm
  - Length Belt 5,000mm
  - Length 7,400mm
  - Weight 190kg
  - Power Consumption 1.5kW
- TOMRA AutoSort 1400
  - Width 1,800mm
  - Length Belt 5,000mm
  - Length 7,400mm
  - Weight 215kg
  - Power Consumption 1.6kW
- TOMRA AutoSort 2000
  - Width 2,800mm
  - Length Belt 5,000mm
  - Length 7,400mm
  - Weight 270kg
  - Power Consumption 1.7kW
- TOMRA AutoSort 1400
  - Width 3,600mm
  - Length Belt 5,000mm
  - Length 7,400mm
  - Weight 300kg
  - Power Consumption 1.9kW
- MACH Hyspec
  - 3D volumetric detection depth up to 430 mm: Increased product recognition
  - MACH fast detection & analysis : Outstanding accuracy & capacity
  - Static acquisition system (no moving parts): Superior reliability & stability

Optical Sorters – Technical Specs

- Pellenc 1G
  - 1 – 2 scanner (s)
  - 1 biplexor spectrometer
  - Material and color sorting
- Pellenc 2G
  - 1-2 scanner(s)
  - 1-2 spectrometer(s)
  - No biplexor
  - 2 signals composition
- Pellenc 3g
  - Scanner box - includes scanner and spectrometer
  - 3 signals composition

Optimizing Optical Sorters – Response Highlights

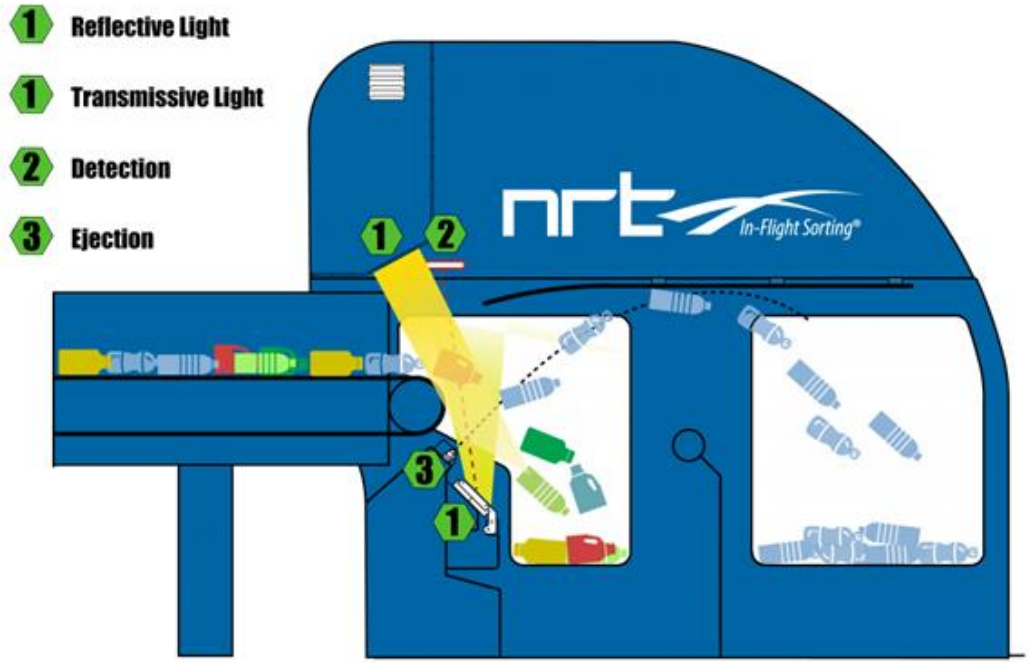
Question	Response
Which hardware component can you upgrade?	Most components do not need, or typically do not get upgraded. For the Inductive Sensor, a metal detector can typically be added to existing optics.
Which software components can you upgrade?	Various components of software can be updated depending on the original model. With the advances in technology, programming options and reporting options are possible upgrades.
What is the cost to buy a new unit? (will vary by size)	A new optical unit can range anywhere from $250K to $450K CAD depending on the size, features etc. This is a price for the unit itself and does not include the speed belt, ejection box, infeed or outfeed conveyors or compressor.
What is the cost of a typical upgrade?	Capability as it pertains to upgrading/updating existing machines is case specific. Rough estimates range from $25 – 50K.

Black Plastic Optical Sorters

- Black plastics represent a significant recovery challenge for MRF operations. It is often discussed as a “type” of plastic (i.e. PET, HDPE), but black plastics are made from multiple resins, which creates further confusion and challenges to recycle them.
- Traditional optical sorters use near-infrared (NIR) to detect the resin of a plastic by shining a light onto each item and reading the reflection back; however, black materials, not just plastics, absorb light rather than reflect light.
- To overcome this challenge, National Recovery Technologies (NRT), STEINERT and TOMRA have all developed optical sorting technology to identify black plastics in three different ways. These vendors have approached the problem in their own ways, using Transmissive Light and In-Flight Sorting, Laser Object Detection (LOD) and Hyper Spectral Imaging (HSI).

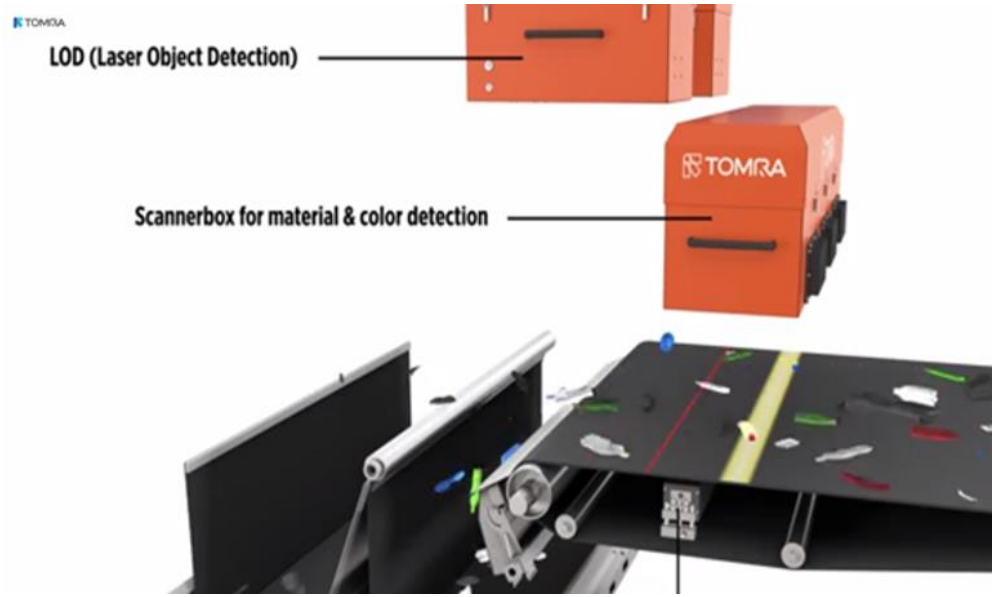
Black Plastic Optical Sorters

- The NRT ColorPlus™ Imaging System is an advanced image processing sorting system designed to target and sort materials based on precision color analysis and sophisticated object recognition.
- The technology uses in-flight recognition which means it would not have the issue with the black plastic resting against the black belt. The technology was available as of late 2016. Models designed for MRFs are unable to sort by resin; however, specific models are designed to sort by resin but require the materials to be flaked.



Black Plastic Optical Sorters

Steinert uses HSI sensors which are mounted over the conveyor belt near its end, beside the NIR sensors. These sensors have a much finer resolution measuring 256 points in the spectrum rather than the usual 16. Black plastic can be identified while on the conveyer belt and be ejected as it falls off the belt to a separate collection bin using an Air Ejection system.



Similarly, TOMRA uses LOD which is an add-on to its existing NIR to aid in the detection of black plastics. It claims it can boost final product purity by as much as four percent without compromising circuit productivity and is designed to be easily retrofitted into existing optical machines.

Black Plastic Optical Sorters – Technical Specs

- Steinert UniSort BlackEye
  - Special solutions for black polyolefins, polystyrene and PVC
  - High performance, throughputs of 1 to 6 tonnes/hour with belt sorting machines
  - All core combinations of plastic sorting systems from a single source
- TOMRA AutoSort Black 1200
  - Laser Object Detection (LOD) recognizes a materials spectral and spatial characteristics.
  - Foreground detection technology ensures the laser beam only identifies material above the belt, reducing background noise.
  - Can be installed on existing optical sorters.
- NRT Colour Plus
  - In-Flight Sorting® provides industry-leading purity and hit rates
  - High-speed identification with throughput rates up to 16,000 lb/hr
  - Low maintenance requirements, self-cleaning optical path
  - Remote diagnostics, adjustments and upgrades
  - Width sizes from 24″ to 108″

Black Plastic Optical Sorters – Response Highlights

Question	Response
Can the Black Plastic scanner be installed on existing optical sorters?	TOMRA and Steinert system can be added to existing optical sorters. NRT requires a new optical sorter.
What is the accuracy of it recognizing black plastics?	Foreground detection technology ensures the laser beam only identifies material above the belt, reducing background noise and giving operations the flexibility to use any type of belt feeder for the circuit. No specific data was provided on the accuracy of these systems within MRFs.
Can it identify the resin type?	Capable of identifying whole black plastics but not able to differentiate by resin type.
What materials should it be used to target?	Can be used to target almost any material.

Front-Load Automated Collection

Front-Load Automated Collection

The Curotto Can

Front-Load Automated Collection (Curotto Can)

- The Curotto Can allows for fully automated collection using a front-loader platform, as opposed to the traditional side loading.
- Designed to be an attachment, the Curotto Can can be disconnected allowing for servicing of front-load bin used in multi-residential and commercial buildings. It provides flexibility for collectors to service both single-family homes and multi-residential buildings.

Key Benefits

- It provides multiple benefits including:
  - Easier to align arm with carts reducing time per stop.
  - Allows to spread materials within the hopper.
  - Higher load capacity compared to automatic side-loaders due to arm placed in front, as opposed to behind the cab.
  - Low lift-over height allows for manual loading.
  - Increased visibility as driver can see into the hopper.
  - Reduce health-and-safety issues as all actions are in-front of the driver.
  - Allows for dumped materials to be recovered (i.e. contamination, bins).

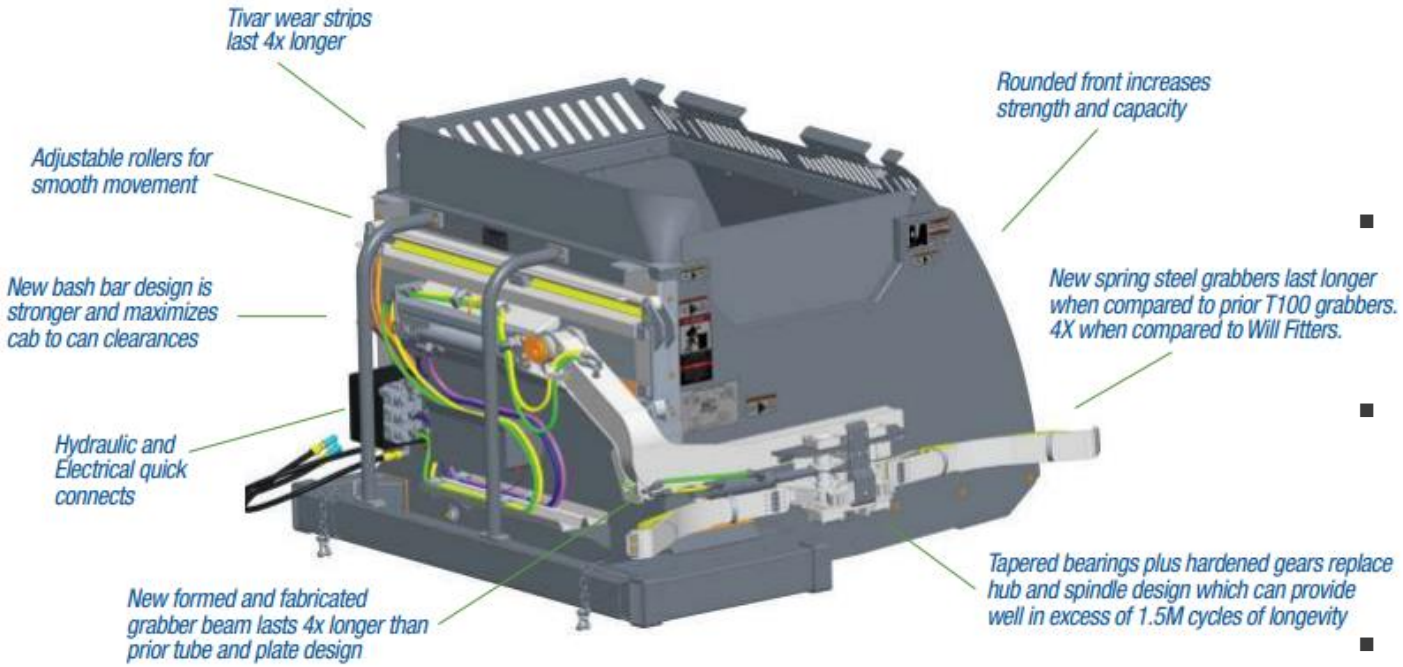
Known Issues or Concerns

- Front load arms are not designed to carry loads for extended periods. Arms and forks show stress marks. Cylinders absorb the bouncing and wear out early.
- Arm does not reach as far as side loader.
- Dumping height is a problem in mature neighbourhoods with trees and power lines in the air.
- Difficult to operate in cul-de-sac because of the vehicle length.
- Limited to collecting one material at a time (no co-collection).

Relevance for Ontario Municipalities.

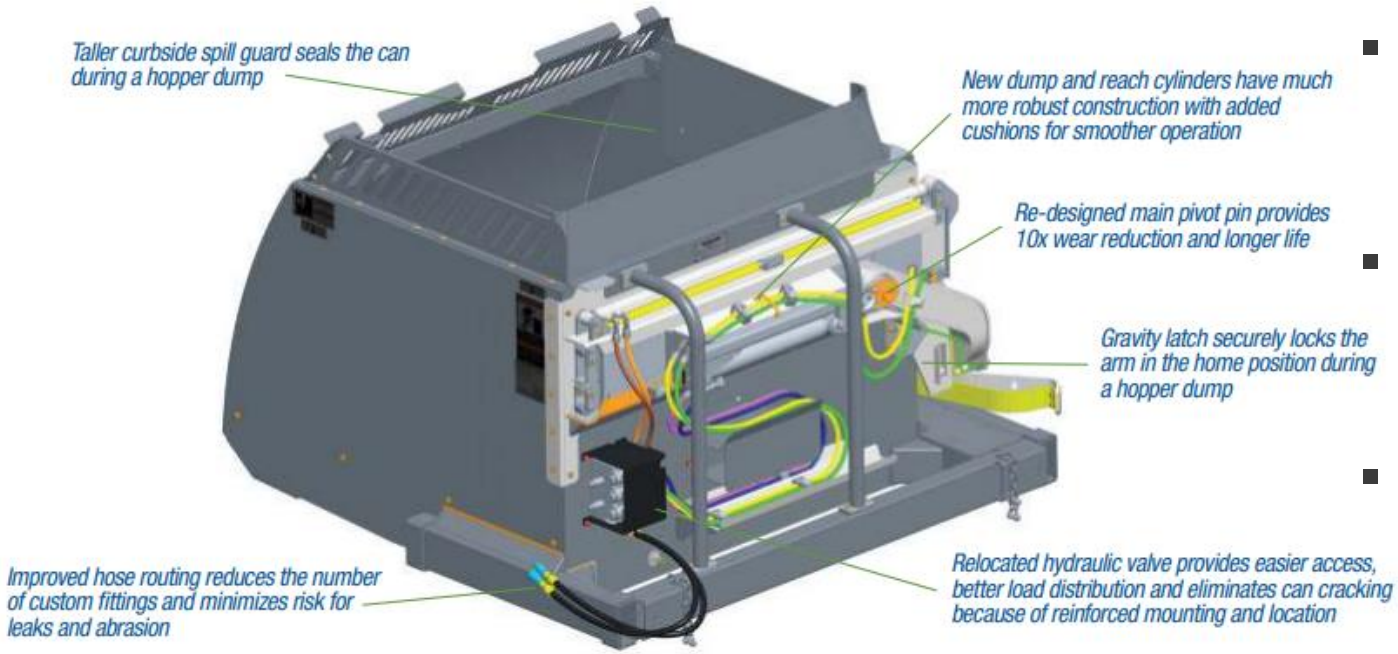
- Curotto Cans are primarily used by single-stream cart based programs. In Ontario, some municipalities have purchased Curotto Cans as a back-up to their side-loading trucks. This enables the municipality the flexibility to service front-load bins when not in use, and can be utilized in the event one of their side-loading trucks breaks down.
- Single-stream cart based Ontario municipalities that are considering providing collection services to PROs post-transition should consider investing in Curotto Cans as a way of optimizing collection operations, and reducing contamination given the greater visibility for drivers. Municipalities with both front-load bins (multi-family or IC&I sites), and single-stream cart based collection will benefit the most from purchasing a Curotto Can.

Technical Specifications



- Dimensions:
  - Overall Size 55"H x 64"W x 81.75"L
  - Inside Height 45.88"
  - Lifting Pocket 6"H x 3"W x 0.25" thick high-strength steel
  - Weight 848 kg (1870 lbs)
- Capacity
  - Carts 32 to 96 gal.
  - Lift Capacity ~227 kg (500 lbs).
  - Volume 3.5 m^3 (4.6 cubic yards)
- Cycle Time
  - Full Slide Extend 2.5 seconds
  - Full Slide Retract 1.5 seconds
  - Dump 2.0 seconds
  - Dump Return 1.2 seconds
- Control System
  - Externally mounted curbside and/or streetside joystick-type cab; optional curbsideaccessible switch bank mounts to cab interior

Technical Specifications Continued



- Hydraulic System
  - Pressure 2000 psi
- Slide
  - Bore 1.5"
  - Stroke 54"
  - Shaft Diameter 1"
- Dump
  - Bore 2.5"
  - Stroke 14"
  - Shaft Diameter 1.5"
- Grab Cylinder
  - Bore 1.5"
  - Stroke 7"
  - Shaft Diameter 1"
- Induction-hardened, ground and polished chrome rods

Scalping/Polishing Screens and Non-Wrapping Screens

MRF Equipment Vendors

Click the logo for the company's website

BHS	CP Group	Machinex

Stadler	Van Dyk Recycling Solutions

Scalping Screens

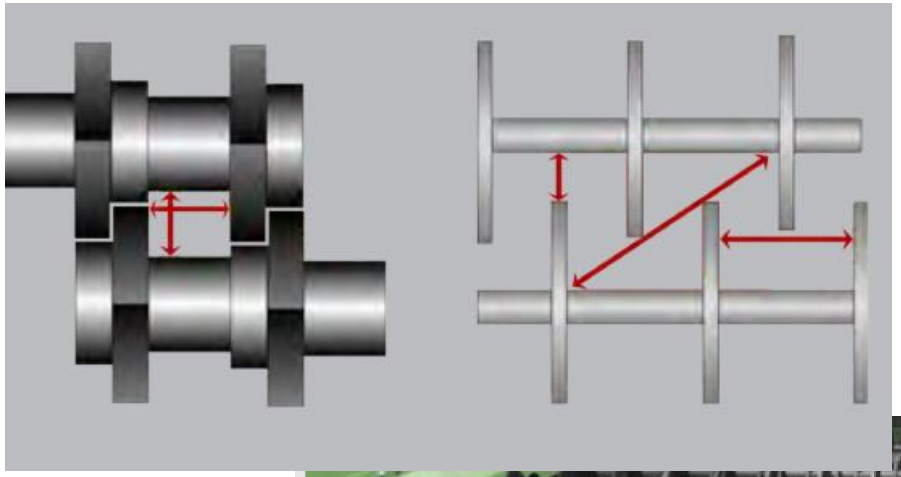
- Scalping screens are designed to remove small fibres, containers and other fines from the system to improve the marketability of commodities. It is typically used to clean-up fibre materials in single-stream programs.
- These screens will play a larger role in a position after the OCC screen in newer plant designs for Ontario but they can be installed in front of, over or under another piece of equipment to remove glass and fine particles.
- Due to the aggressive agitation in scalping screen, fines are dislodged from the overs improving the quality.
- Highlights & Benefits
  - Removes glass and fine particles early in the system to minimize belt wear
  - Prevents the material from becoming contaminated and protects rubber discs from glass abrasion
  - Extremely strong and durable equipment
- Width from 60'' up to 96'' (1500 mm to 2400 mm)

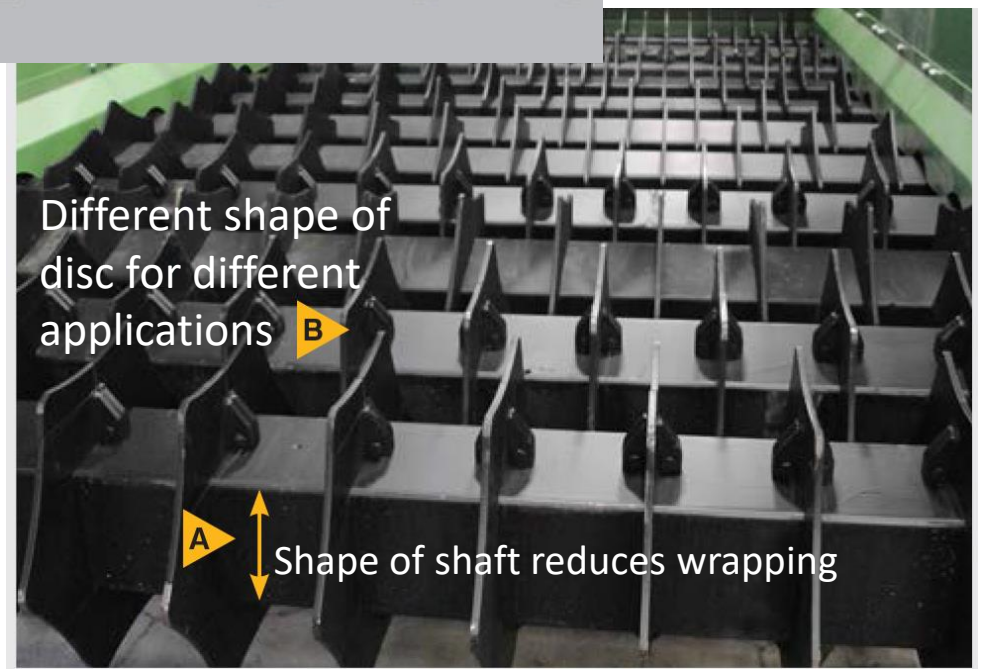
Scalping Screens

- Construction and Features
  - A 5” minus screen equipped with highly abrasion-resistant metal discs
  - Tilted screen surface
  - Adjustable speed ensured by a variable frequency drive
  - Larger square-shaped shaft to reduce wrapping
  - Shape of the disc according to application
- Applications
  - Single-Stream, Fibers, Containers, Construction and Demolition

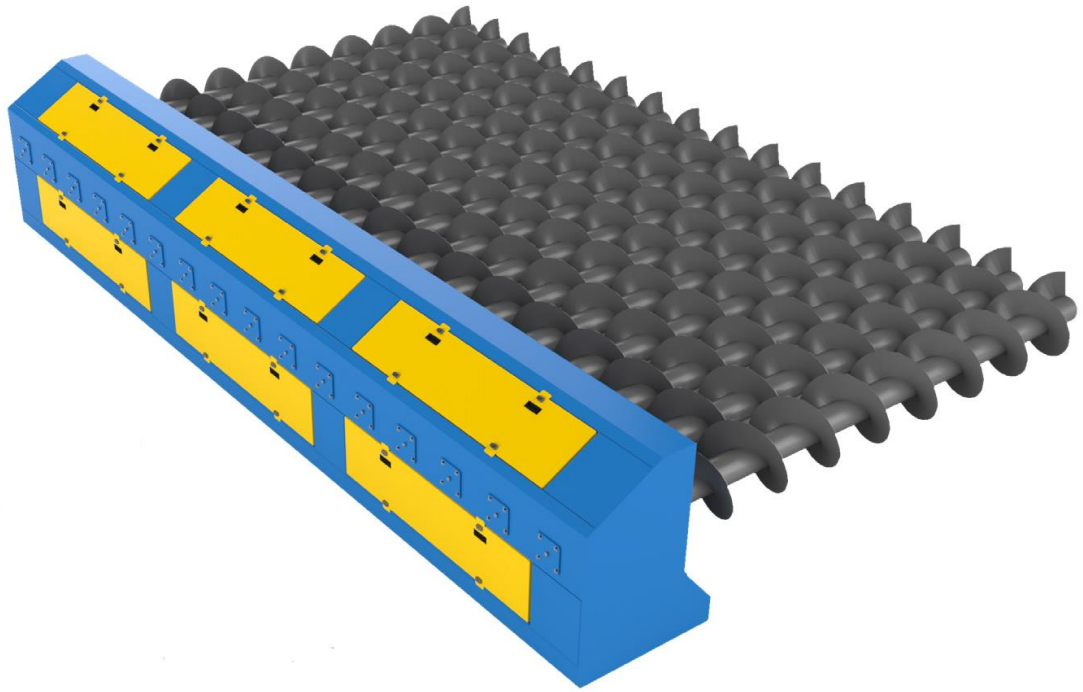
New Disc Screen Design (consistent spacing)

Conventional Disc Screen (inconsistent spacing)





Auger Screens

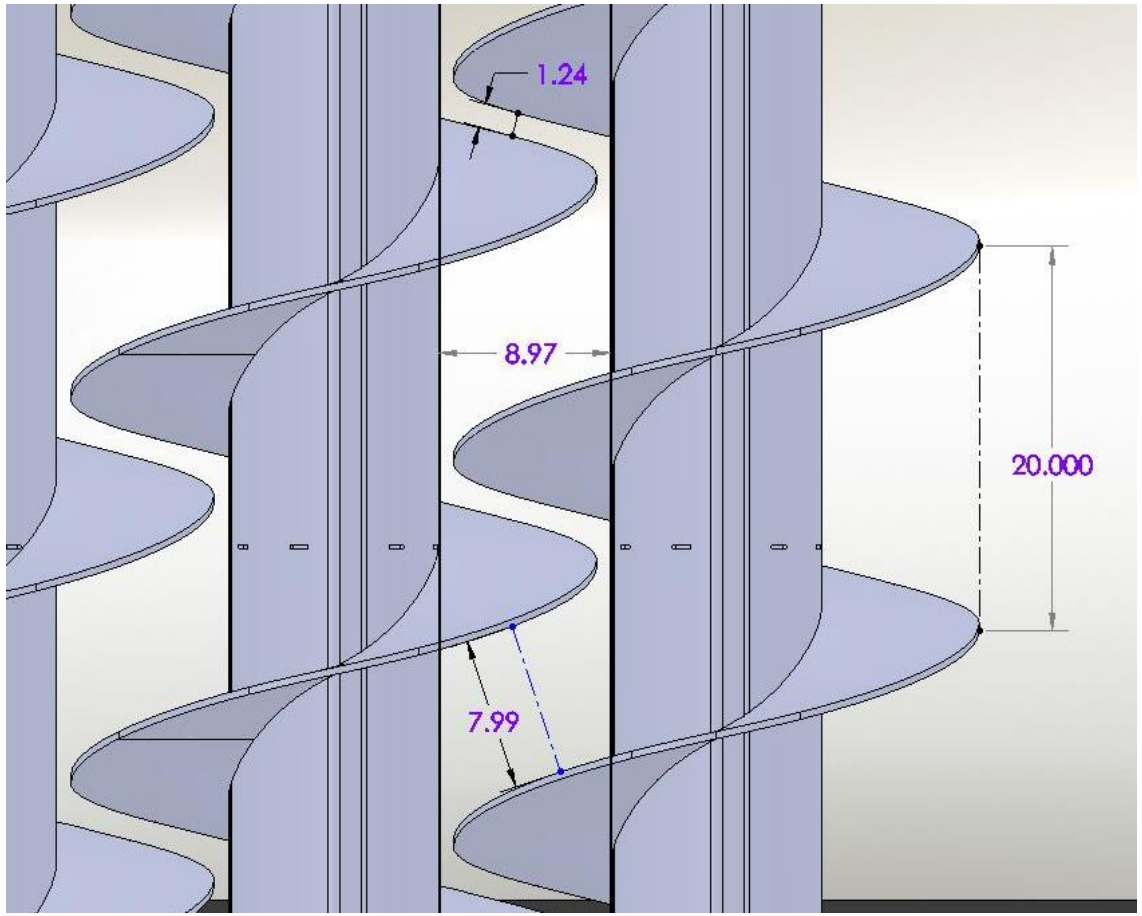


The CP Auger Screen™ sizes material by using a series of cantilevered augers that do not wrap or jam, requiring very low-maintenance. It has the ability to sort three fractions; Overs, Unders and Sides.

Built with low-wear technology, it maintains reliable sizing at high volumes.

- Features:
  - Low maintenance, minimal wear
  - Reliable screening quality
  - High volume
  - Reduces manual presorters
  - Produces three cuts: Overs, Unders, and Sides
  - Used as scalping machine
  - Helps to capture small OCC

Auger Screens – How it works



Multiple Sizes

- 8” openings are used in front of traditional presort or postsort
- Decreases amount of material seen by sorters, increases efficiency
- Removes small fraction from sorters, increases safety
- Decreases amount of manual sorters needed, only see the “Big Uglies”
- 5” openings are used as a scalping machine
- Creates homogenous sized streams to properly feed downstream machines
- Captures small OCC (Amazon effect) in one place for better recovery of OCC

Auger Screens – Technical Specs

- Rotors per Deck 5
- Rotor Lengths 96", 120"
- Drive Chain drive with #80 (1” pitch) roller chain

- Motor 7.5 HP 3-phase helical bevel gear motor
- Speed 115 RPM nominal rotor speed, adjustable between 58-173RPM
- Opening Sizes 3”-6” x 8” primary; 2”-4” x 5” scalping

Screening Drums / Trommel Screen

- Stadler has been providing customers with Screening Drums/Trommel Screen to improve material sizing and to remove contaminants prior to manual handling. Depending on the space available, a Screening Drum can sort into multiple size fractions combining multiple sort stations into one.
- In most MRFs it is used prior to the presort station removing fine as one sort, and containers with recyclable paper as another sort that fall through the screen plates. Large OCC and bulky items come out the other end of Screening Drum to a QC station where bulky items are removed from OCC.

Screening Drums / Trommel Screen

Video Link: Click here

Relevance for Ontario Municipalities

- Given current market conditions, the ability to manage contamination and improve material quality will be critical for MRFs to be competitive when transitioned. Additionally, as sorting staff are already concerned with COVID-19, the ability to reduce the direct manual handling of materials will help maintain existing staff. Scalping Screens, Auger Screens, and Screening Drums provide robust steel screens that are designed to maximize agitation and improve material separation. This will enable sorters and equipment to have greater visibility of materials and reduce handling of contamination.

Scalping Screens – Response Highlights

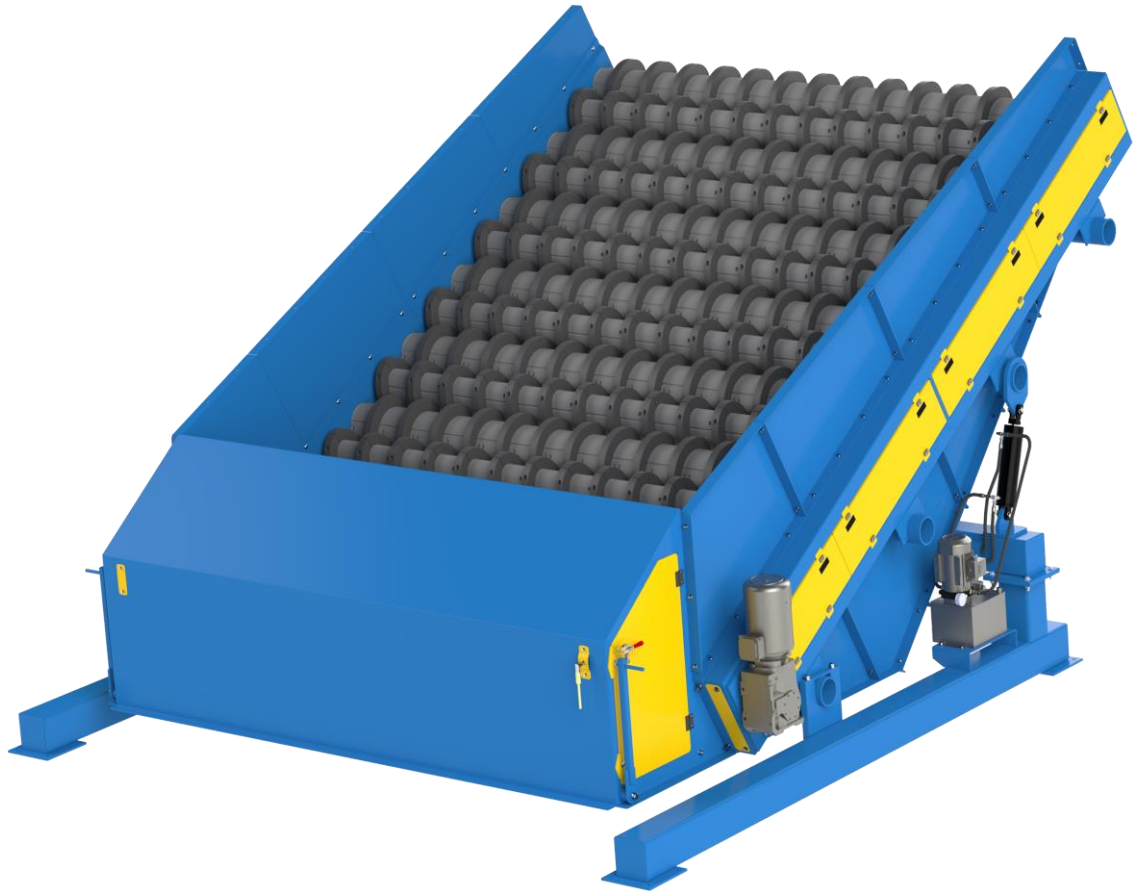
Question	Response
What is the estimated annual maintenance cost for these equipment (maintenance, replacement parts)?	A scalping screen requires minimal maintenance on an annual basis. The shafts are designed with a configuration to minimize wrapping, and the discs are steel. Some scalping screens in the industry are rubber and require frequent replacement to obtain the desired gap and screening efficiency.
What is the ideal mix of materials for it to have a high accuracy and efficiency?	A scalping screen is often added near the front end of a single stream system, typically after the pre-sort and OCC screen. Therefore, the material that hits the screen ranges anywhere between 0-12”. If there was too much big material going over the screen it would hinder the efficiency, also the overall tonnage would influence the efficiency.
Can it handle plastic bags?	Yes.
What is the cost for this system?	Machinex builds two standard widths of scalping screens, 72” wide and 96” wide. They both are in the $100K CAD range for the screen only. That does not include structure, controls or any type of integration into the system.

Non-Wrapping Screens

Non-Wrapping Screens

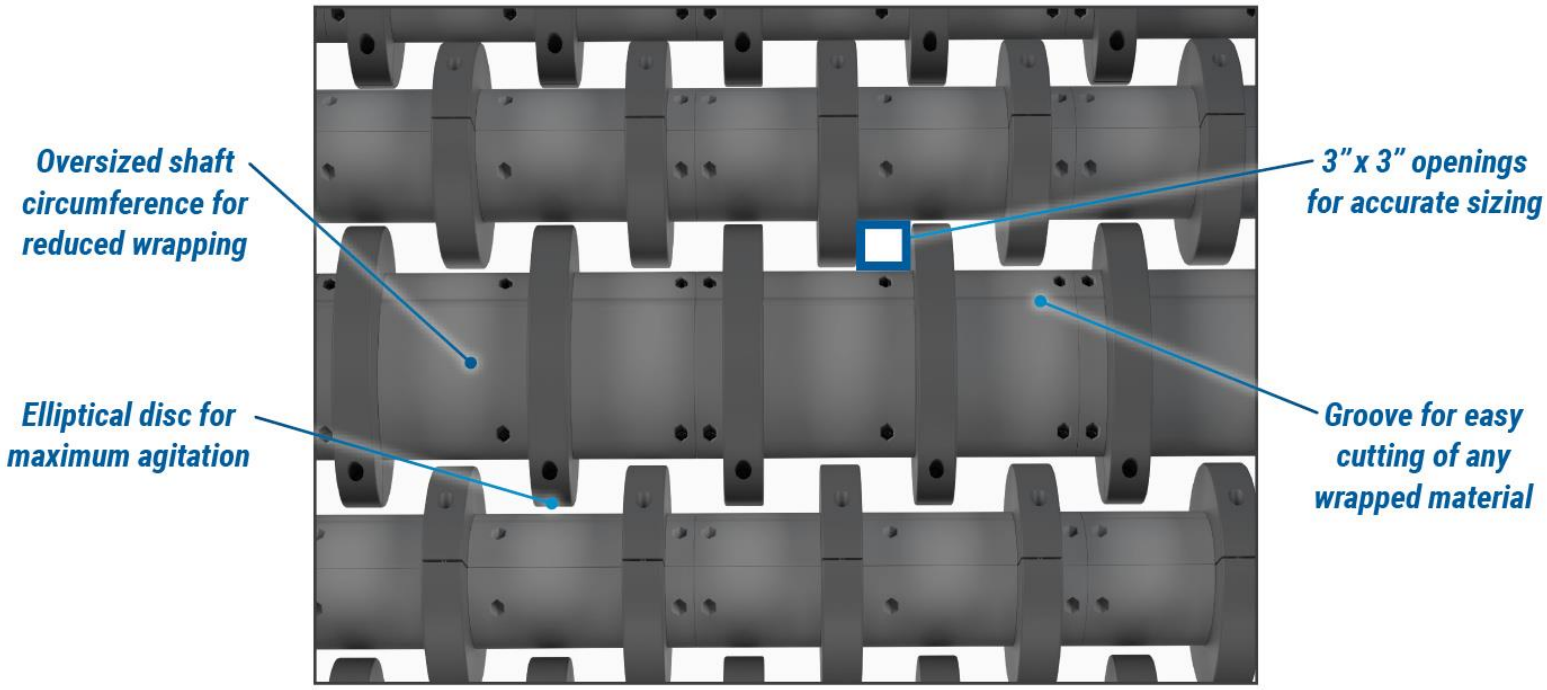
Flexible packaging, “tanglers” and film tend to wrap around standard screen shafts. As these materials wrap around the screen shafts, it increases the contamination of the Overs.

Non-wrapping screens have high-agitation discs and extra-large rotor shafts to mitigate wrapping and reduce jamming. It can run at peak performance for every shift, the result is higher quality paper and container streams.



Non-Wrapping Screens

- Adding the non-wrapping screen. Process at a high throughput (up to 50 tph) Divert 95% with virtually no wrapping or cleaning needs.
- Easily change screening size to increase system flexibility.
- Achieve high purity with aggressive agitation.



Non-Wrapping Screens

- No wrapping of film, tape or textile.
- High throughput: material is screened in a thin layer over the screen deck.
- High purity through aggressive agitation.
- An additional advantage is the fine dispersion of the material and loosening of the fraction, which makes sorting overs easier and better in the next sorting process. Unlike sorting with a drum screen, there is no sausage formation.
- The modular construction of the screen (1 module is 1.5 metres) means that the Non-Wrapping screen can be built in almost any existing situation.
- Low energy consumption.
- Standard use of high quality parts such as shafts, bearings, drives and motors.
- The patented disc Lubo quick connect system is standard. This system allows fast changing of star shafts without dismounting bearings, drives, sprocket and chains.
- The frequency-controlled range of speeds means that the sorting size can be easily adjusted (within certain limits)

Anti-Wrapping StarScreen – Technical Specs

- Screen size
  - 40 - 50 mm*
  - 40 - 75 mm
  - 40 - 100 mm
  - 40 - 125 mm
  - 40 - 150 mm
- Screen lengths These can be built up in modules for each type. The section length is 1,524 mm.
- Screen deck widths
  - 1,240 mm
  - 1,640 mm
- Star type 550 AWS
- Drive 1 motor SEW 7.5 kW per 3,048 mm
- Speed control frequency regulators
- Total machine width
  - 2,130 mm *
  - 2,530 mm
- Total machine height 2,292 mm
- Side wall thickness 6 mm
- Spacer diameter
  - 457 mm *
  - 406.4 mm
  - 355.6 mm
- Inspection / access door 1,000 x 700 mm

* - Denote standard installation.

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