# prMRF: Automating Decentralized Material Recovery from Municipal Solid Waste

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## Abstract

The Portable, Robotic Material Recovery Facility (prMRF) is a newly developed solution designed to enhance waste sorting and material recovery at a local scale. The prMRF is housed within a standard container box, integrating advanced artificial intelligence and robotic technologies to enable decentralized waste processing with industrial-level efficiency. This innovation is particularly valuable for locations that generate significant amounts of urban waste, such as ports, airports, stadiums, malls, and skyscrapers, as well as small or less accessible regions such as islands and rural territories.

**Figure1**. External view of the containerized portable, robotic Material Recovery Facility (prMRF)

Equipped with modern artificial intelligence-based computer vision [1], the prMRF ensures reliable waste identification, localization, and categorization. The AI system, trained on millions of waste images, accurately maps waste items to their respective material categories. Hyperspectral waste categorization allows the system to analyze chemical properties, improving material recognition beyond standard visual assessment. By combining RGB and hyperspectral imaging, the system achieves 99% accuracy in categorization, ensuring exceptionally high purity of recovered recyclables. Additionally, with a processing speed of 10 frames per second, the system ensures rapid and accurate waste identification.

To enhance sorting efficiency and adaptability, the prMRF integrates innovative robotic waste recovery technology. It features new low-cost robotic waste pickers designed for affordability without compromising performance [2]. Piston-driven vacuum grippers enable fast and effective material collection, reducing cycle time. Modular grippers can be easily swapped to accommodate different waste compositions, increasing operational flexibility. Furthermore, each robotic picker is serviceable for maintenance while the prMRF continues to operate, ensuring uninterrupted waste processing.

**Figure2**. AI-powered robotic material recovery inside the prMRF.

These state-of-the-art technological components allow the prMRF to achieve significant operational benefits. It provides industrial-level efficiency, matching the sorting performance of central Material Recovery Facilities (MRFs) with high throughput and accuracy. By eliminating the need to transport waste to central MRFs, it significantly reduces logistics costs, making recycling more economically viable for local entities. The prMRF can be deployed directly at waste generation points, enabling small and remote communities to efficiently manage and process recyclables. Additionally, by processing fresh and non-compacted waste, it enhances the quality of recovered materials, increasing their market value and recyclability.

Overall, the prMRF sets a new standard for decentralized waste management, demonstrating its feasibility as a scalable and efficient alternative to traditional MRFs. Its adoption can lead to transformative policy developments at local, national, and European Union levels, supporting circular economy goals, reducing carbon emissions associated with waste transportation, and fostering sustainable urban environments. By empowering communities with localized waste processing solutions, the prMRF paves the way for a cleaner and more resource-efficient future.

## References

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