The Future of Waste Management

In Milan and beyond

Presented by:

Gabriele Coppa
Mathieu Echevin
Gabriele Ghilotti
Connor van Heulen
Edoardo Sibilla
Jule Jessen



Università Commerciale
Luigi Bocconi



POLITECNICO
MILANO 1863

Introduction

Why does waste matter?

A global challenge for the environment and for resources

2.1 bn

tonnes of municipal waste

generated worldwide (2023)

→ 3.8 bn

projected by 2050 (UNEP)

1 **Growing volumes**
Population growth, urbanisation and consumption keep increasing the waste we produce.

2 **Environmental impacts**
Landfills and poor management pollutes air, water and soil and realeases GHG.

3 **Lost resources**
Most of what we throw away could be reused or recycled, but it ends up lost.

Waste is already a major challenge, but new technologies and regulations are emerging to tackle it

Frameworks and Regulations

R-Strategies: From Waste to Resources

The 10R framework identifies strategies to retain resources and product value, ordered broadly from higher to lower circularity.

Refuse (R0)	Avoid unnecessary products and materials.
Rethink (R1)	Use products more intensively, e.g. through sharing.
Reduce (R2)	Minimize resource consumption and waste generation.
Reuse (R3)	Use products again for their original purpose.
Repair (R4)	Fix damaged products to extend their lifespan.

Refurbish (R5)	Restore or upgrade existing products.
Remanufacture (R6)	Rebuild products using recovered components.
Repurpose (R7)	Give products or components a new function.
Recycle (R8)	Process waste into secondary raw materials.
Recover (R9)	Recover energy from waste.

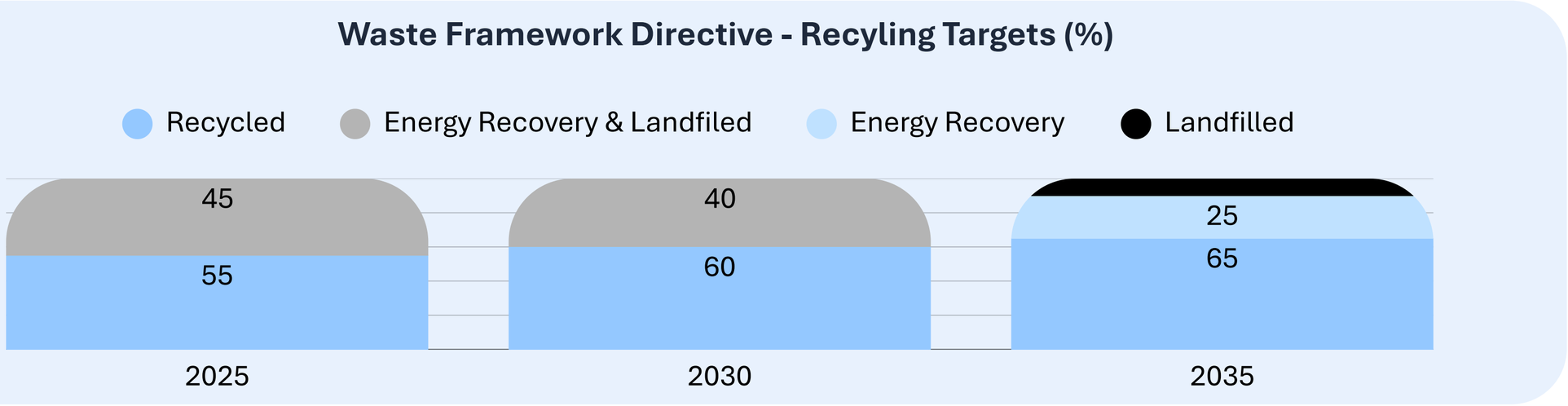
Our challenge: enabling the transition of the municipal mixed residual waste stream from energy recovery to material recycling through advanced waste sorting

Source: https://www.pbl.nl/en/publications/circular-economy-measuring-innovation-in-product-chains

Frameworks and Regulations

EU Regulations: Driving the Transition to Circularity

EU legislation establishes increasingly ambitious recycling targets, encouraging the recovery of valuable materials from municipal waste.



Landfill Directive
<= 10% landfilled by 2035

Packaging Regulation
Packaging recyclability targets from 2030

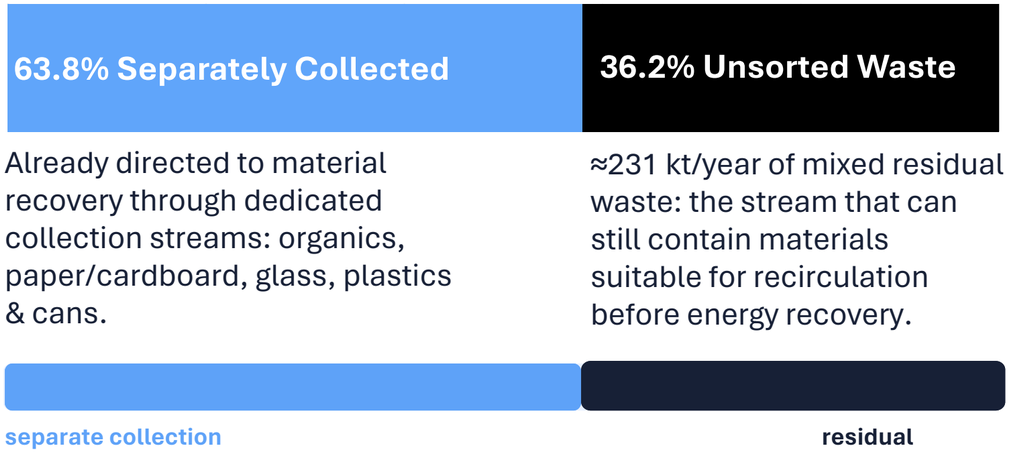
Sources: EU Directives 2018/851, 2018/850; Regulation 2025/40

Milan's waste profile

Milan’s municipal waste collection

≈638 kt/year

Total urban waste collected in the city



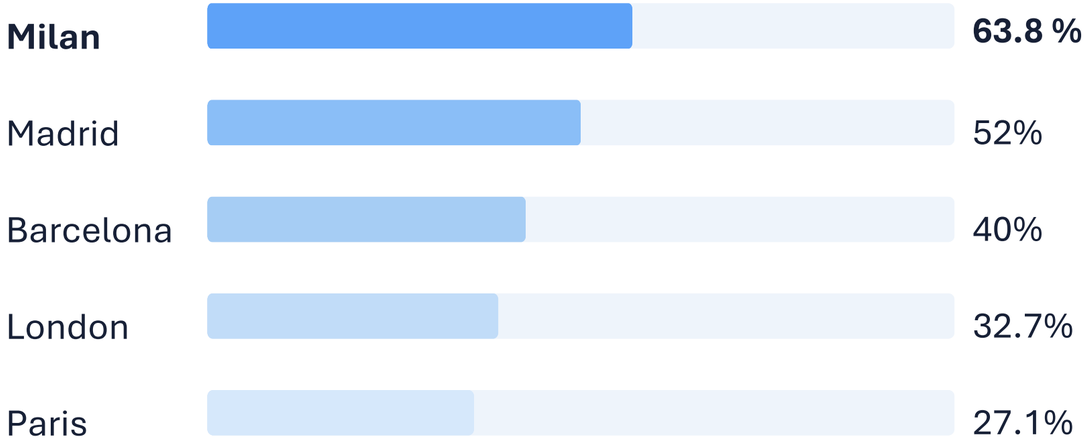
Already directed to material recovery through dedicated collection streams: organics, paper/cardboard, glass, plastics & cans.

≈231 kt/year of mixed residual waste: the stream that can still contain materials suitable for recirculation before energy recovery.

Separate collection rates: Milan vs major European cities

≈64% separate collection

Milan is already a benchmark, but the remaining 36.2% is still a large technical and economic challenge.



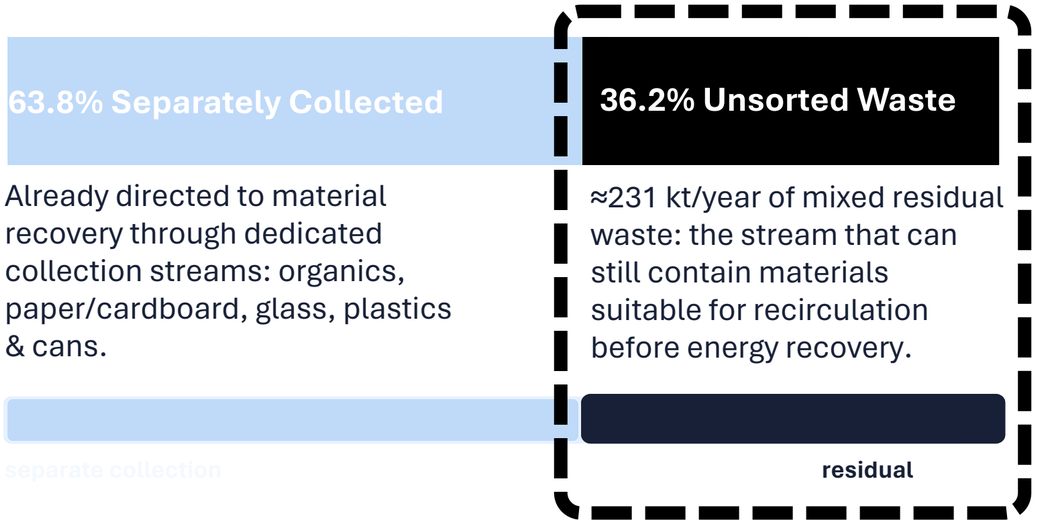
Milan’s separation performance is already high, especially when compared to major European cities, but the residual fraction still contains valuable materials that could be recirculated.

Milan's waste profile

Milan’s municipal waste collection

≈638 kt/year

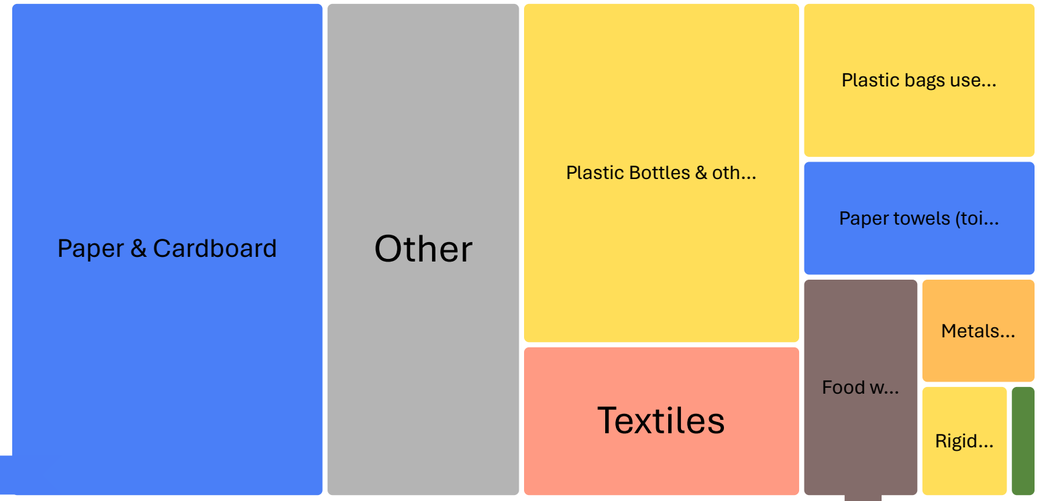
Total urban waste collected in the city



Milan’s *undifferentiated* municipal waste collection

≈231 kt/year

Residual Waste Fractions



Paper & Cardboard represent the largest individual fraction at 31% of the residual waste stream. This is closely followed by the **Other** & **Plastic Bottles & other plastic packaging** streams at 19%.

Organic waste represents roughly **5.1%** of the total residual waste stream. This is a unique characteristic of Milan when compared to other large cities, like Rome (27.8%) and Berlin (38%).

AMSA, A2A, CONAI and WtE: roles in the current system

A roadmap of Milan's waste route: who manages collection, where materials go, and what happens to the residual fraction



A2A Group

Parent group of AMSA and wider waste/energy utility. It frames the industrial infrastructure, but waste does not physically pass through A2A as a step.

AMSA

Local operator responsible for municipal collection and urban hygiene in Milan. It manages separate streams and the mixed residual fraction.

Material route → CONAI and material-specific consortia

Packaging materials with sufficient quality move through the CONAI system and dedicated consortia for paper, plastics, glass and other streams. Value depends on tonnes accepted and purity.

Residual route → third-party Waste-to-Energy operator

Mixed residual waste that is not materially recovered is sent to an external incinerator. The route recovers energy, but the material is no longer recirculated and treatment costs remain.

AMSA, A2A, CONAI and WtE: roles in the current system

A roadmap of Milan's waste route: who manages collection, where materials go, and what happens to the residual fraction



A2A Group

Parent group of AMSA and wider waste/energy utility. It frames the industrial infrastructure, but waste does not physically pass through A2A as a step.

AMSA

Local operator responsible for municipal collection and urban hygiene in Milan. It manages separate streams and the mixed residual fraction.

Material route → CONAI and material-specific consortia

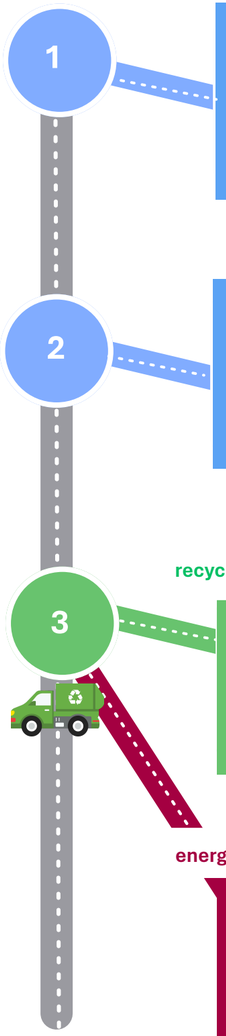
Packaging materials with sufficient quality move through the CONAI system and dedicated consortia for paper, plastics, glass and other streams. Value depends on tonnes accepted and purity.

Residual route → third-party Waste-to-Energy operator

Mixed residual waste that is not materially recovered is sent to an external incinerator. The route recovers energy, but the material is no longer recirculated and treatment costs remain.

AMSA, A2A, CONAI and WtE: roles in the current system

A roadmap of Milan's waste route: who manages collection, where materials go, and what happens to the residual fraction



A2A Group

Parent group of AMSA and wider waste/energy utility. It frames the industrial infrastructure, but waste does not physically pass through A2A as a step.

AMSA

Local operator responsible for municipal collection and urban hygiene in Milan. It manages separate streams and the mixed residual fraction.

Material route → CONAI and material-specific consortia

Packaging materials with sufficient quality move through the CONAI system and dedicated consortia for paper, plastics, glass and other streams. Value depends on tonnes accepted and purity.

Residual route → third-party Waste-to-Energy operator

Mixed residual waste that is not materially recovered is sent to an external incinerator. The route recovers energy, but the material is no longer recirculated and treatment costs remain.

The Project Challenge

Can Milan turn residual waste into recoverable value?

231,000

tonnes / year

of mixed residual waste in Milan

1. **Economic viability**
   Can automated sorting generate enough value to justify the investment and operating costs?
2. **Benefits for Milan**
   How much material could be recovered, and what enviornmental and scoial benefits could follow?
3. **Transferable decision tool**
   How do waste composition, energy prices and material renumeration change the result?

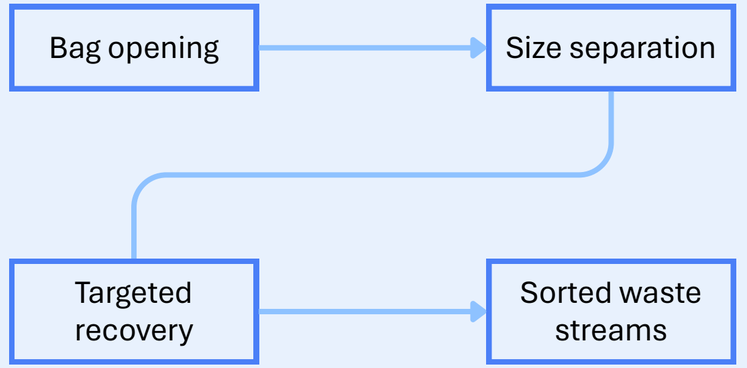
Our approach: A modular techno-economic EXCEL model developed in cooperation with Amsa and A2A

From individual technologies to an integrated system

We researched the following technologies ...

- Bag Opener
- Ballistic Separator
- Trommel Screen
- Air classification
- Ferro-magnets
- Eddy Current magent
- Spectroscopy
- AI Vision

...and used some of them to create an integrated sorting line model

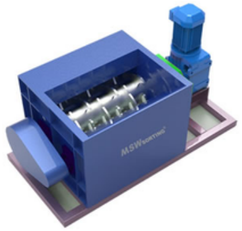


By combining complementary technologies in sequence, the model can evaluate recovery across the entire waste stream.

We first **assessed technologies individually** based on BREFs and additional innovation we found during our research. While the **results were promising**, we quickly realized that each technology addressed only a part of Milan's residual waste issue. Since no single technology can sort every material, we **combined some of them** to address the whole stream.

Modelling of Pre-sorting Technologies

Technologies review



Bag opener

Opens incoming waste bags through controlled pulling and shearing, exposing the contents for downstream sorting. In the model, it is the first preparation step before size separation

Trommel screen

Separates waste by particle size into coarse, oversize and undersize streams. Larger recyclable items tend to remain in the larger fractions, while smaller organics and fines concentrate in the undersize stream



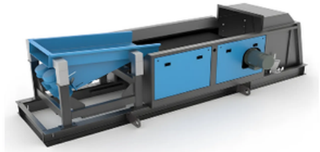


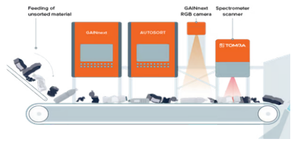
Ferro-magnets

An overband magnet extracts ferrous metals such as iron and steel from the conveyor

Eddy-Current

Separates non-ferrous metals by inducing circulating electrical currents





Spectroscopy

Identifies materials from their near-infrared spectral signature and uses air jets to eject targeted items

AI Vision + Robotic Arm

Uses AI-based visual recognition to identify target objects and a robotic arm to physically pick them from the conveyor



Each technology was modelled as an individual processing step using a small set of operational and economic parameters: throughput/capacity, material-specific recovery efficiency, CAPEX, OPEX, electricity consumption, depreciation life and physical life.

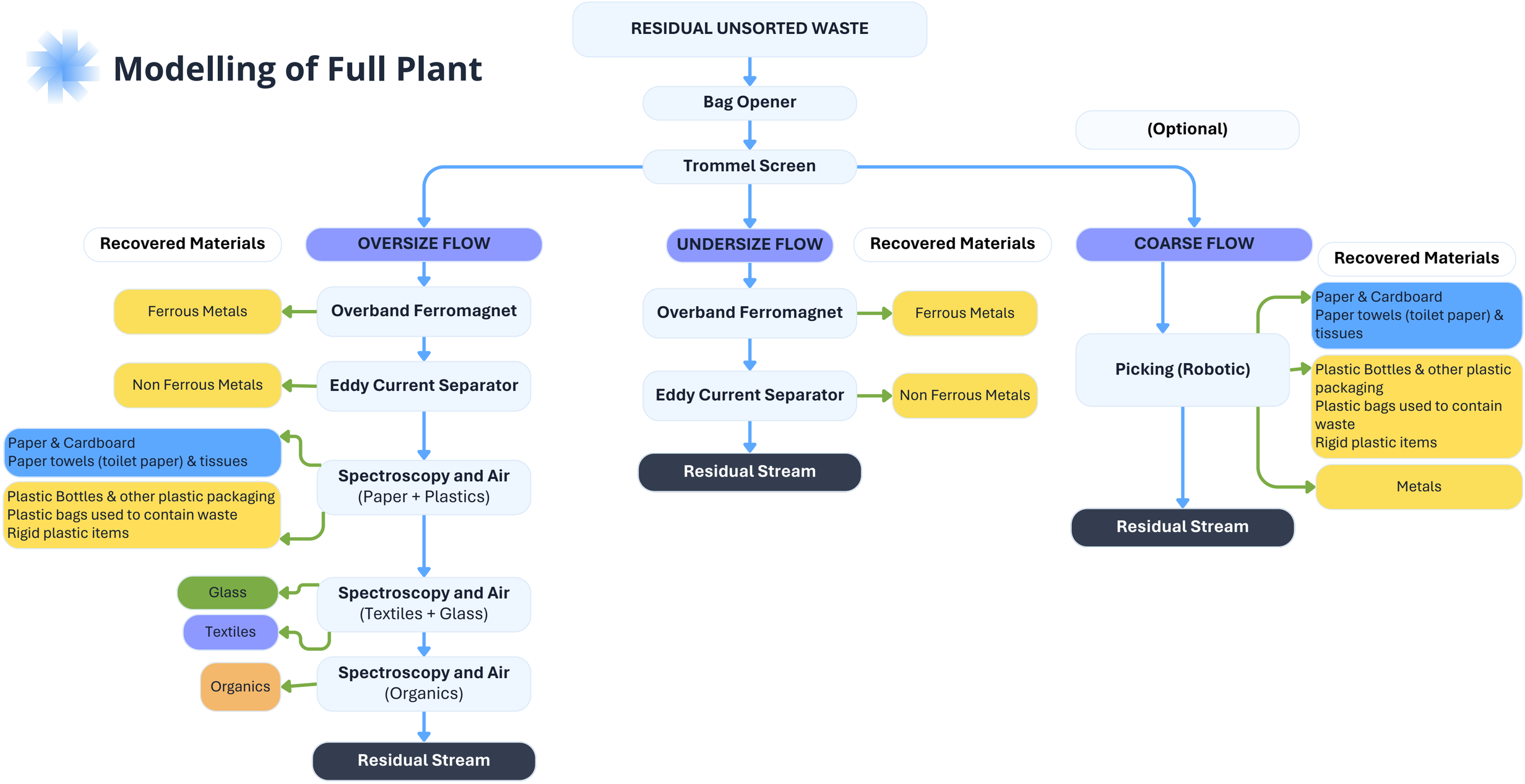
The recovered quantity from each step is calculated from the waste entering that technology and its recovery efficiency, while the remaining material is passed to the next stage

Plant level verifications with A2A

01 **Capacity**
Operating hours
Machine processing capacity…

02 **Layout**
Space needed
Conveyor belts
Plant Layout

Modelling of Full Plant



Overall Model Results

Up to

64 Kt

of Waste Recovered per year

(28%)

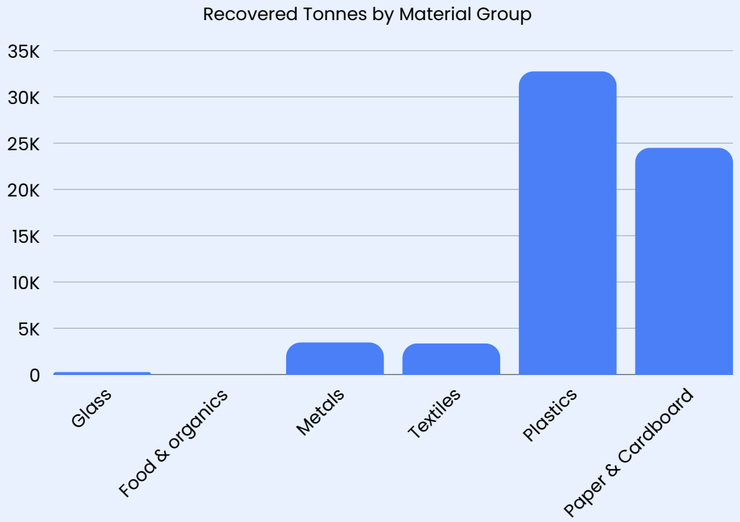
120 Kt

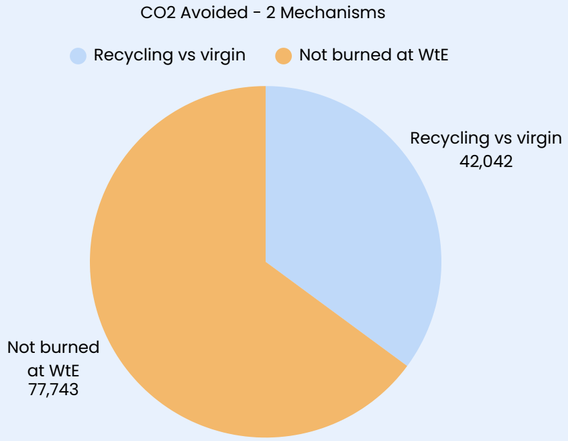
of CO2 Saved per year

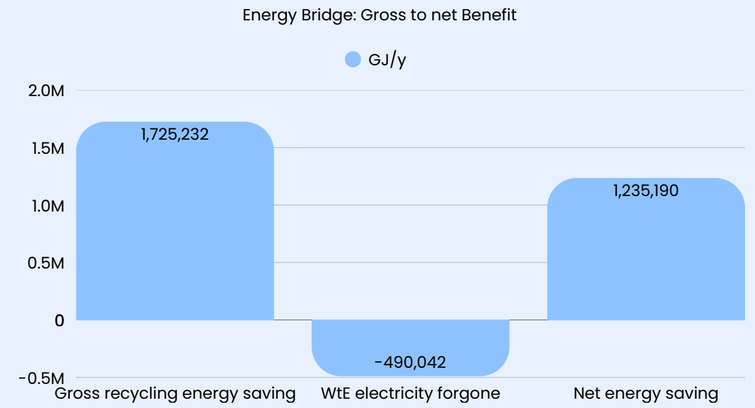
About these numbers

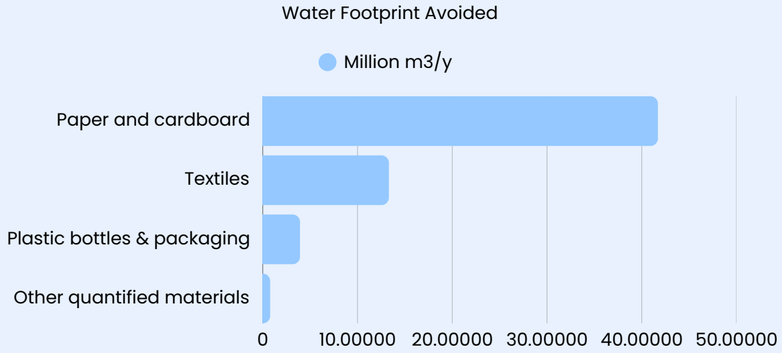
Savings were derived from usage figures assigned to life-cycle stages in Ansys Granta.

Key Environmental Benefits









Zooming in: AI in Bulk Waste Management

Stat Sheet: AI Robotic Sorter

Cost Structure: Installation + Annual Lease

Simple efficiency: 76%

PPM: ~52.5 PPM

Weight per Pick: 28.57g



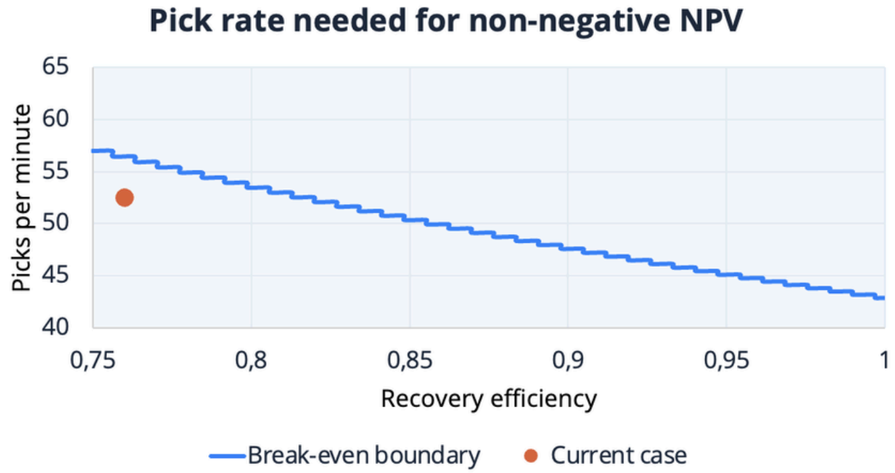
Tech overview

An AI robotic sorter combines a 3D vision system, AI categorisation and a robotic arm. It identifies individual items on the belt and picks selected plastics, metals or fibre, and is remotely monitored.

Currently, AI is usually employed in quality control and last chance recovery lines. Could it also be used for bulk waste recovery?

Our Implementation

AI Sorters at the end of a mixed coarse waste stream, with one dimension exceeding 20cm in length, approx. 60.000 tonnes/year, picking only metals, plastics and paper.



Our Findings

At current prices, AI robotic sorters are **not yet economically viable for bulk waste management**.

Recovery efficiency would have to increase to 83%, or the PPM would have to increase to roughly 57. This asessment does not include **plant-level costs & recyclability**, which are significant variables.

Thank You



Università Commerciale
Luigi Bocconi



POLITECNICO
MILANO 1863