# Technical and Environmental Performance of Material Recovery Facility for Separately Collected Packaging Waste

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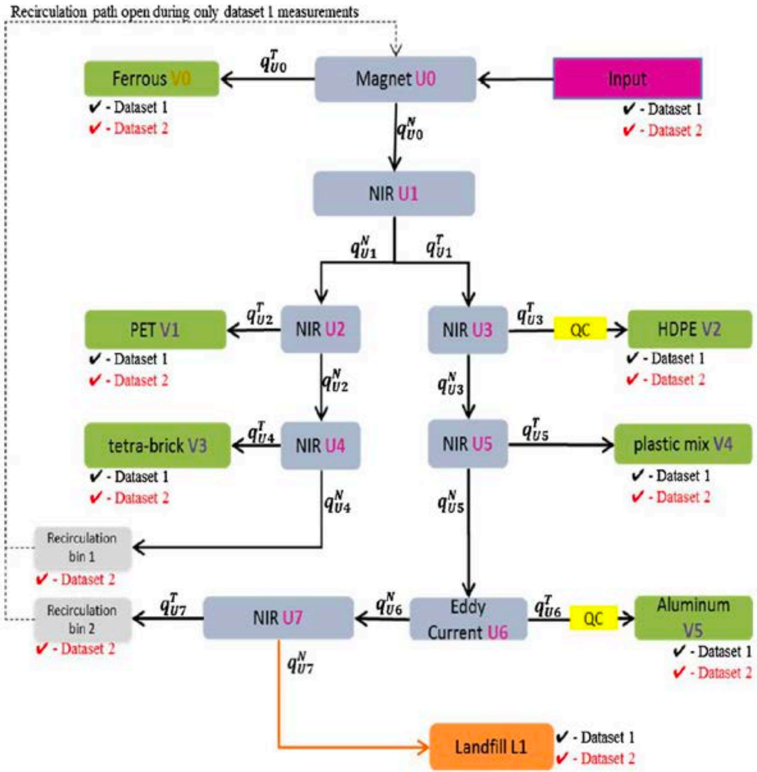
# Introduction

- Material Recovery Facilities (MRF) separate the different waste fractions according to their main physical properties (Tanguay-Rioux et al., 2021)

- They often determine the amount of collected recyclable material that can be recovered for recycling (Pressley et al., 2015)

# Introduction

- Mathematical models have been developed to assess the performance and design of material separation systems – efficiencies can be captured through experimental methods / physical modelling (Wolf, 2003)



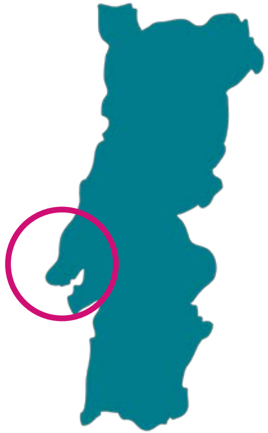

*Representation of light-packaging recovery section of MRF facility as a network of multi-output units*
*Source: Ip et al., 2018*

# Introduction

- Industry surveys and benchmarks for MRFs are scarce and data on process efficiency are mostly unavailable (Mastellone et al., 2017)
- High quality data are required to ensure a reliable assessment of the technical and environmental performance of a MRF (Ardolino et al., 2017), such as:

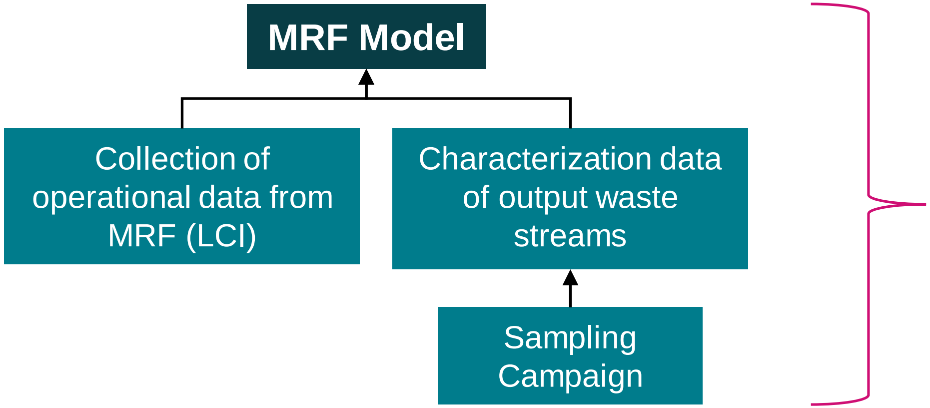
| | | |
|---|---|---|
| Waste composition | Impurities | Sorting technology |
| Purity targets | Equipment performance | Properties of final recovered material |
| Residual contaminants | Direct emissions | Fuel and energy consumptions |

# Introduction



**OBJECTIVE**

To evaluate the overall environmental impacts related to the sorting of separately collected packaging in a MRF by Life Cycle Assessment (LCA), using operational and experimental data.




Compare the environmental performance of two scenarios, with and without recirculation of waste in the MRF

*How much do we gain from recirculating and if these benefits offset the increased operational impacts?*

# Methodology

- A MRF model was developed by resorting to the partition coefficients obtained from the sampling campaign in a MRF. It involved the characterization of the output streams:

Ferrous metals

Non-ferrous metals

Beverage cartons

HDPE

Recirculation material

PET

Plastic film

Mixed plastics

Residual waste

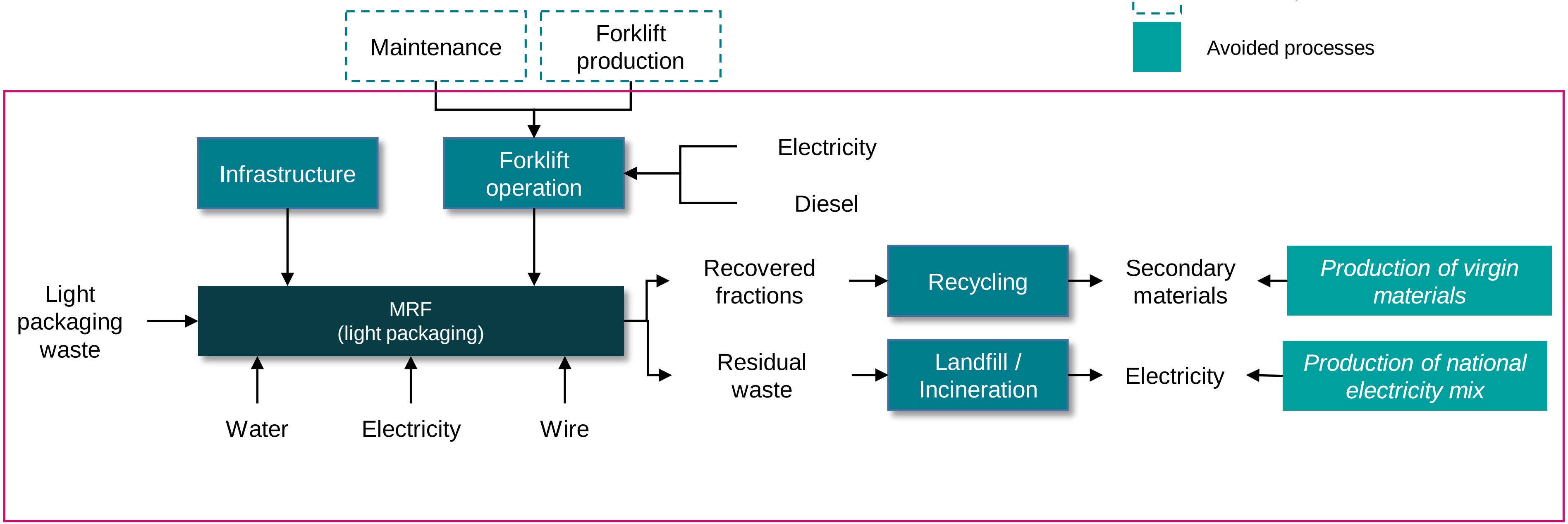
# Methodology

- These streams were obtained after the facility was emptied and then operated for one hour with a regular quantity of input (batch test).
- Samples were then collected from each output stream and characterized by material type.
- This campaign allowed to obtain reliable data for the mass flows of the different materials throughout the stages of the sorting process and to obtain a set of partition coefficients for each of the outputs of a plant as a function of the input stream.

# Methodology (LCA)

**Functional unit: 1 kg of processed waste**

System boundaries
Foreground processes
Background processes
Excluded processes
Avoided processes

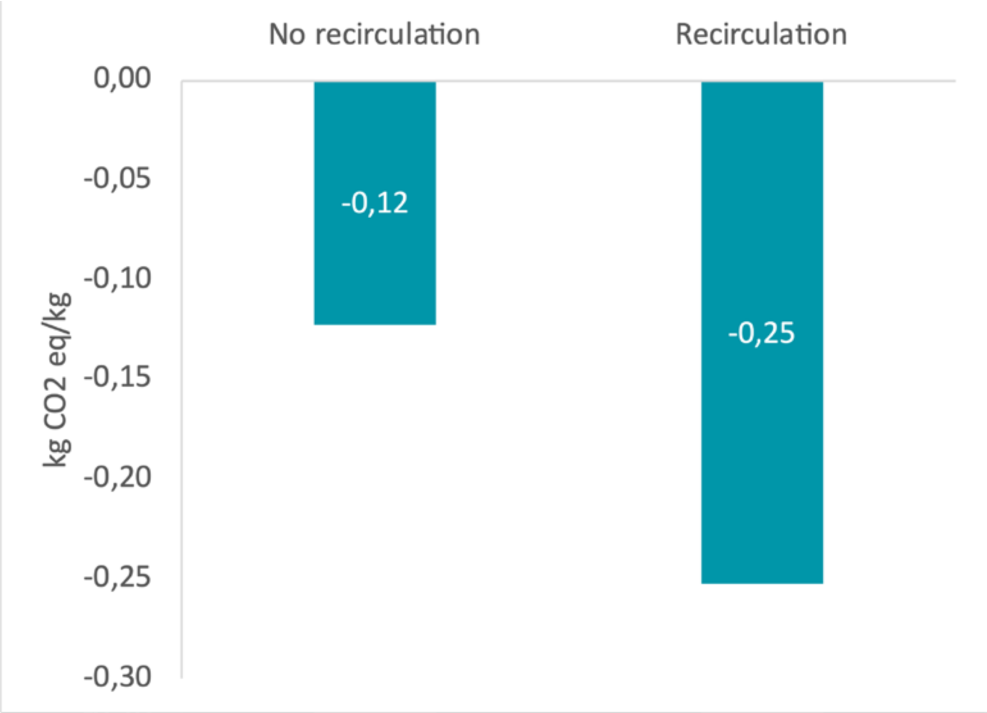


# Methodology

## Life cycle inventory of MRF (1 tonne of processed waste)

| Inputs | Unit | Value |
|---|---|---|
| Diesel consumption by forklifts and shovel wheel loaders | kg | 0,498 |
| Wire for baling | kg | 1,738 |
| Infrastructure of MRF | p | 2,12E-06 |
| Operation of forklifts and shovel wheel loaders | hr | 0,102 |
| Water consumption | m3 | 0,018 |
| Electricity consumption by forklifts | kWh | 0,654 |
| Electricity consumption by sorting lines | kWh | 49,269 |

# Results




*Method: ReCiPe 2016 Midpoint (H) V1.05 / World (2010) H*

- The increased output from recirculation more than compensates for the increased environmental impacts of the facility in the category of global warming

# Results

| Impact Category | Unit | No Recirculation | Recirculation |
|---|---|---|---|
| Global warming | kg CO2 eq | -0,122 | -0,252 |
| Stratospheric ozone depletion | kg CFC11 eq | 0,000 | 0,000 |
| Ionizing radiation | kBq Co-60 eq | -0,001 | 0,000 |
| Ozone formation, Human health | kg NOx eq | -0,002 | -0,001 |
| Fine particulate matter formation | kg PM2.5 eq | -0,001 | -0,001 |
| Ozone formation, Terrestrial ecosystems | kg NOx eq | -0,002 | -0,001 |
| Terrestrial acidification | kg SO2 eq | -0,002 | -0,001 |
| Freshwater eutrophication | kg P eq | 0,000 | 0,000 |
| Marine eutrophication | kg N eq | 0,000 | 0,000 |
| Terrestrial ecotoxicity | kg 1,4-DCB | -1,190 | -0,932 |
| Freshwater ecotoxicity | kg 1,4-DCB | 0,001 | 0,000 |
| Marine ecotoxicity | kg 1,4-DCB | 0,000 | 0,000 |
| Human carcinogenic toxicity | kg 1,4-DCB | 0,042 | 0,036 |
| Human non-carcinogenic toxicity | kg 1,4-DCB | -0,106 | -0,097 |
| Land use | m2a crop eq | -0,065 | -0,063 |
| Mineral resource scarcity | kg Cu eq | -0,007 | -0,006 |
| Fossil resource scarcity | kg oil eq | -0,332 | -0,263 |
| Water consumption | m3 | -5,983 | -2,612 |

*Method: ReCiPe 2016 Midpoint (H) V1.05 / World (2010) H*

- The increased output from recirculation more than compensates for the increased environmental impacts of the facility in the category of global warming
- In the remaining categories the results are either negative or the net benefits are small

# Results

- There is an increase of 17% of recovered materials, but the recirculation rate is 24%, i.e. the throughput increases by this value.
- In the case of global warming, the benefit from recirculation results from the substitution of virgin materials, but more significantly from the avoided emissions from burning the residual fraction of plastics.
- The most valuable materials are already collected in the first round (e.g., PET, HDPE, metals), and, contrarily, there is a significant increase in the typically non-target materials, namely film, mixed plastics and beverage cartons.
- Recirculation compensates for the material substitution alone, but its benefits are even more significant if it allows to divert plastic waste from waste-to-energy.
- These results might not hold to older or less efficient MRF, with higher energy footprints (more than 49 kWh/t) and higher electricity emission factors.

# Final Remarks

- The used coefficients are static and are restrained to a specific waste composition and operating conditions, but some deviations are expected with varying waste composition and flow rate.
- It was assumed that all the materials recovered in the MRF were effectively recycled, which in some specific cases can be an overestimation (e.g. mixed plastics).
- Future work will focus on a similar question but at the collection stage, which will further help to understand the trade-off between higher recycling rates and the environmental impacts related to fuel consumption, vehicle use, among other.
- Together, the results of the two studies will help to weigh the environment burden between the collection and the sorting stage.
- A more detailed analysis of the disposal options for residual waste, and avoided emissions associated with the recovered materials is essential to ensure a deeper understanding of the role of MRFs in MSW management.

# References

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# THANK YOU FOR YOUR ATTENTION

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