Recycling Plastics from Residual Municipal Solid Waste

Final Report of the MSWPlast Project

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ISBN 978-951-38-8803-9

VTT Technology 439

ISSN-L 2242-1211
ISSN 2242-122X (Online)
DOI: 10.32040/2242-122X.2025.T439

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Preface

Finland faces challenges with low recycling rates for both municipal solid waste (MSW) and plastic packaging waste. The majority of plastics in municipal solid waste ultimately end up in mixed fractions diverted to incineration. Consequently, this contributes to emissions, climate change, and the depletion of non-renewable material resources.

Due to upcoming legislative revisions in the EU, which introduce mandatory recycled content targets for plastic packaging, the demand for plastic waste feedstock in the recycling industry is expected to increase. Sorting of plastics from residual MSW is expected to display an enormous potential for plastics recycling: approximately 17 % of residual municipal solid waste consists of plastics, and it is estimated that as little as a quarter of the plastic packaging waste in Finland is captured in separate collection, with the rest ending up in the residual waste.

However, little is known about the polymer composition of residual municipal solid waste. Current technologies are unable to recycle mixed plastics streams without prior separation of polymers. Additionally, not all plastic items are monomaterials, and certain polymers have a higher market demand for recycling.

The project demonstrated industrial post-sorting of residual municipal solid waste in Finland - that mixed plastics can be sorted from the waste, sorted and washed for recycling. The MSWPlast project conducted a pilot sorting trial, with industrial sorting of more than 500 tonnes of residual municipal solid waste. The sorting trial provided data for modelling and material samples for analyzing the recycling potential. Results indicate a promising recycling potential for plastics in residual municipal solid waste.

MSWPlast was a Business Finland funded co-research project, starting in January 2023 and continuing until April 2025. The project was coordinated by VTT, with research partner Finnish Environment Institute (Syke), and industrial partners Borealis, Remeo and Vantaan Energia. The project was part of the SPIRIT ecosystem led by Borealis.

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1 Introduction

Plastic consumption has increased significantly over the past 20 years. It is noteworthy that although the awareness on sustainability and recycling has increased significantly, most waste plastics still end up in the residual waste destined for incineration. This causes emissions and contributes to climate change, while also consuming fossil material resources. In addition, Finland struggles to meet the recycling targets set in legislation for plastic packaging waste.

A more economical and sustainable solution would be to increase the volumes of plastic recycling. Finland is currently expanding its plastic recycling capacity, which then requires availability of waste feedstock for recycling.

The MSWPlast project studied the potential for sorting plastics from mixed wastes, aiming to increase plastics recycling while reducing environmental impacts from incineration. A large-scale sorting trial conducted at Remeo's sorting plant indicated there is significant potential for post-sorting in Finland.

The MSWPlast co-research project demonstrated industrial post-sorting of residual municipal solid waste (MSW) in Finland - that mixed plastics can be sorted from the waste, sorted and washed for recycling. Expected impact of the project was the following:

- reduce the volume of plastics lost from the economy
- increase plastics recycling rates
- reduce imports of fossil feedstock for plastics production
- increase knowledge on post-sorting – supported by data
- systemic concept to support current recycling system

1.1 Research objectives and their implementation

The specific objectives and their implementation were as follows:

1) The demonstration of the sorting of residual MSW was done through a large-scale sorting trial, further described in Section 2 and Appendix A.
2) The collected data was used for modelling further analysis of the potential capture rates at a MSW sorting facility, further described in Section 4.
3) The recyclability of the plastics segregated in the sorting trial was studied, further described in Section 5 and Appendix C.
4) The recyclability of the segregated plastics through chemical and mechanical routes is discussed in Section 6.

5) An assessment of the impacts of the removal of the plastic fraction from residual MSW on waste incineration and recycling rates in Finland, further described in Section 7.1 and Appendix D.
6) A systemic concept for introducing post-sorting into existing recycling value chains, as described in Section 7.2 and Appendix E.
7) Mapping of the current European and Finnish policy framework in relation to mechanical separation of plastics from residual MSW, identifying key requirements and potential barriers for setting up post-sorting of plastic waste in Finland, further described in Section 8 and in a separate report[1].
8) Widespread dissemination to increase the knowledge around the Finnish potential for separating plastics for recycling from residual MSW.

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[1] Salmenperä H, Turunen T, Markuksela A, & Lukka S. (2025) Ohjauskeinot muovien erotteluun sekajätteestä. http://hdl.handle.net/10138/595265

2 Sorting trial

The sorting trial was conducted in September 2023. During the trial, 512 tonnes of MSW from households and service sector companies was collected by Remeo in municipalities in Southern Finland (Helsinki metropolitan area, Kouvola, Lappeenranta, Seinäjoki, Tampere, Turku and Uusikaupunki).

The sorting trial is described in Figure 1. First, the organic fraction is separated using a bag opener, rough pre-crushing (Tana Shark 400DT) and Tana X553T disc sieve (> 80 mm), resulting in a fine fraction of 181 tonnes and a coarse fraction of 331 tonnes, that is suitable for industrial sorting.

The coarse fraction underwent an industrial sorting process, including pre-crushing and sieving for separating the fines. Metals were separated through magnetic and eddy current separation. The 2D and 3D fractions were separated through ballistic separation and then sorted via multiple optical separators (NIRs) for sorting targeted materials. The final outputs were clear LDPE, colored LDPE and 3D plastics, as well as LDPE and 3D rejects. Finally, the reject is crushed producing the SRF fraction. The sorting trial is described in more detail in Annex A.

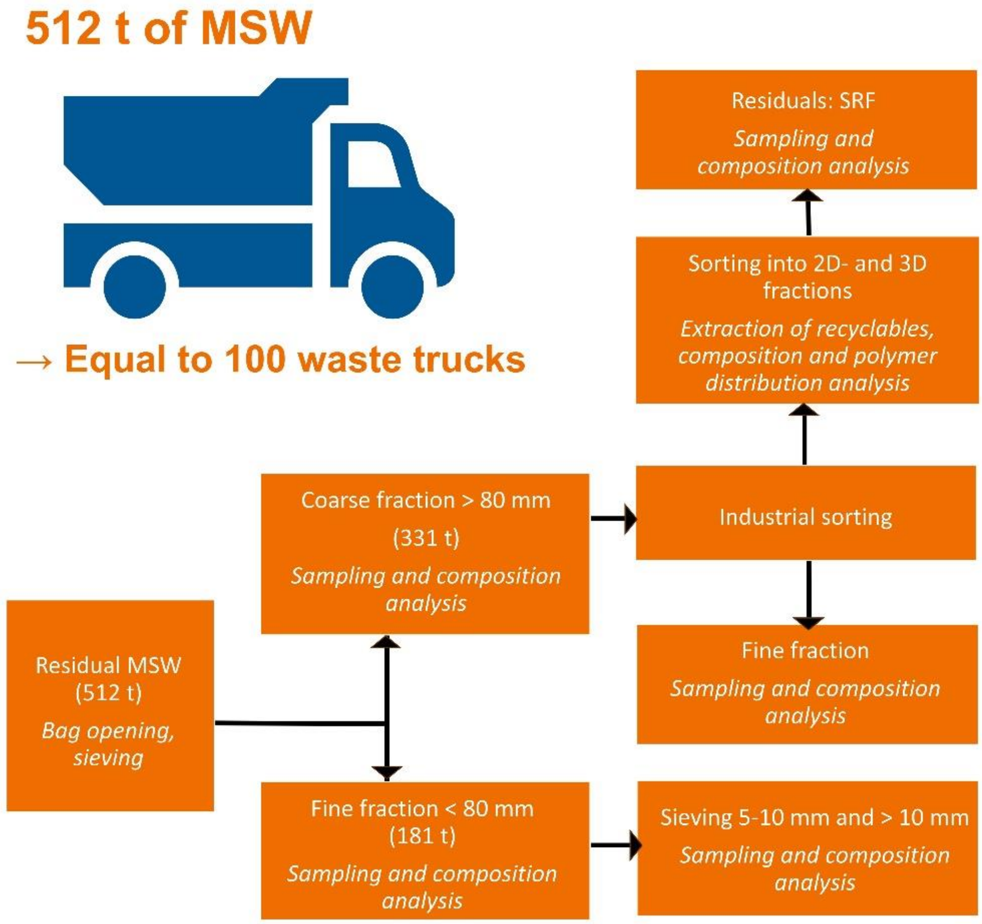

Figure 1. Description of the MSW sorting trial and processing steps.

3 International benchmarking

3.1 European facilities for industrial post-sorting

A study was conducted with the objective to better understand the operational environment for post-sorting facilities in operation in Europe and the reasons behind the investments in post-sorting of MSW in certain regions. Further, key topics to gain knowledge in was the ownership and responsibilities of the waste, and how costs are divided between actors. Finally, the processes, technologies, and sorting efficiencies were studied to form a general understanding of the process in practice. The following operating post-sorting facilities were visited during the project (see Appendix B for more detailed reports of the site visits):

- Brista post-sorting facility in Märsta, Stockholm County, Sweden
- Svensk Plaståtervinning plastic sorting facility in Motala, Sweden
- ROAF post-sorting facility in Lillestrøm, Norway
- AVR post-sorting facility in Rotterdam, the Netherlands
- Attero post-sorting facility in Wijster, the Netherlands
- Salpakierto post-sorting facility in Lahti, Finland

International benchmarking showed that residual MSW offers a significant source of waste plastic for recycling. Separation of the plastics fraction from residual MSW creates business opportunities for the plastics industry and reduces the demand for virgin raw materials in plastics production.

The international benchmarking further shows that a modern separation plant can efficiently sort most materials from mixed waste. The most commonly sorted materials include plastic, metals and beverage cartons and although other materials could be separated, there is currently no market demand for other materials separated from the residual waste. The organic-rich fine fraction that is separated is utilized in biogas production.

All visited facilities showed high sorting efficiencies and reported a good market for their output materials. A key reason for the good market demand for post-sorted plastics was highlighted to be the high polymer purity. Plastics can be obtained with very high yields or very high purity, commonly approx. 70 – 80 % of the plastics were separated with a polymer purity of approx. 95 % of the target polymers. Figure 2 presents a generalization of the processes at a post-sorting facility.

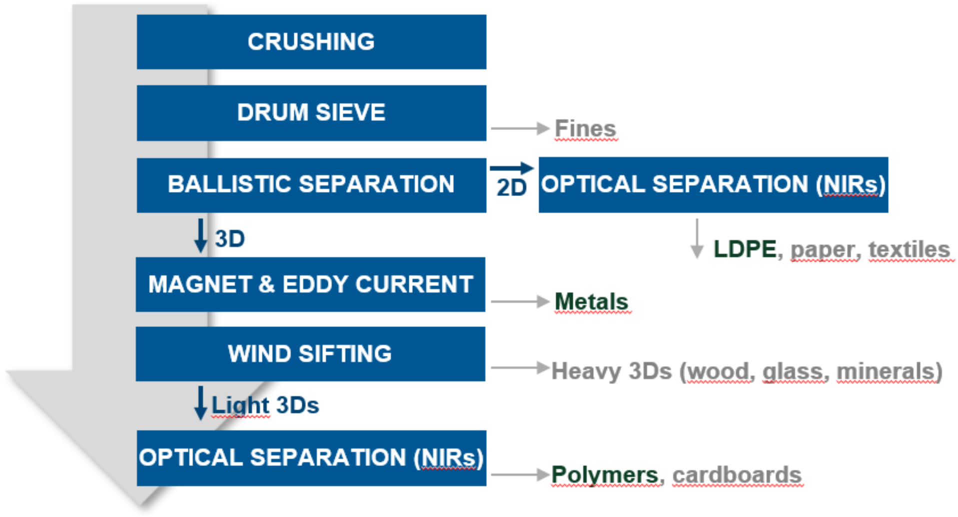

Figure 2. Generalisation of the processes at a post-sorting facility

Key enablers for the post-sorting business showed to be the division of costs between stakeholders – the sorters acquired both gate fees and additional input from the Producer Responsibility Organization for packaging (PRO) for the sorted and/or recycled plastic packaging waste. Further drivers for post-sorting in the international context was e.g. legislation related to incineration of mixed or recyclable wastes, emissions trading system (ETS) for mass incineration and strategies on circularity and carbon neutrality.

3.2 Operational environment in selected EU countries

The review of selected EU countries (the Netherlands, Latvia, Lithuania, Poland, Slovenia and Estonia) focused on countries with varying performances concerning their recycling rate. In general, all countries had similar problems and drivers in increasing their national recycling rate for plastic waste regardless of their performance. Good and promising measures have been implemented in all selected countries.

The reviews show that the lack of clear division and organisation of waste management responsibilities can cause problems in increasing recycling in practice. Cooperation between municipalities as well as between municipalities, producers, and producer responsibility organisations often need to be developed.

The results showed that in some countries mixed waste was subject to post-sorting, but in some cases the used technology is outdated. Manual sorting of mixed waste also arises certain social problems. The biggest issue with waste management investments is naturally the arrangement of financing, despite the existing national support systems in use. Most of the countries studied have insufficient capacity for recycling plastics, particularly the fractions that are more difficult to recycle. Plastic waste is exported for example to Asia. Additionally, the undercapacity of waste incineration is a common problem for the countries of southern Europe. Mixed waste is exported to other parts of Europe for incineration, and landfilling is still relatively common in some countries.

In many EU countries, good recycling rates have also been achieved with co-mingled collection of clean waste fractions, which is not in use in Finland. Co-mingled collection requires post-separation infrastructure but could be a cost-effective collection method in Finland's sparsely populated areas and long-distance areas. The reviewed countries also utilise different kind of economic instruments and e.g. ecomodulated fees in producer responsibility, but there is limited information about the effectiveness of these instruments.

The review showed that the calculation of the recycling rate and the comparison of countries is not necessarily justified, as waste monitoring and statistics and calculation methods also differ from country to country.

Considering potential Finnish exports, there is a need for functioning concepts and operating models of division of responsibilities. A need for technological solutions for separate collection (PAYT solutions, electronic waste data and related services and smart waste collection solutions) was identified. . There would also seem to be export potential in terms of modern and efficient sorting communication aimed at citizens.

More details on the waste management in selected EU countries is found in a separate report by the MSWPlast project[2].

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[2] Salmenperä H, Turunen T, Markuksela A, & Lukka S. (2025) Ohjauskeinot muovien erotteluun sekajätteestä. http://hdl.handle.net/10138/595265

3.3 Separation of plastics from residual MSW for recycling in Finland

Plastics are today separated from MSW in Lahti region by Salpakierto. This is done in addition and parallel to the separate collection of plastic packaging waste. A fraction consisting mixed PE, PP, PS and PET plastics is sorted out from residual MSW and it is sent to the producer responsibility organisation for further treatment. Today only 20-30 % of the plastics in the residual MSW is separated, corresponding about 1500 t/a. However, according to Salpakierto, there is notable potential to increase the share of separated plastic through new demand (e.g. chemical recycling) and improved sorting technology[3].

Vantaan Energia has announced plans to invest in a facility for residual MSW sorting with capacity to annually deliver 18 kt of plastic waste for recycling[4] . In addition, there are other preliminary plans to utilise plastics sorted from residual MSW, e.g. Syklo and Neste[5].

Between 2016 and 2020, Fortum Recycling & Waste carried out industrial post-sorting of residual MSW at its sorting and recycling plant in Riihimäki. Experience showed that with the technology used, the solution was unnecessarily expensive, and the plastics separated from mixed waste were also significantly more contaminated than separately collected plastics[6].

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[3] Interview and email correspondence with Salpakierto in 2024 and 2025.

[4] Suomi tarvitsee myös sekajätteen laitosmaista lajittelua päästäkseen EU:n kierrätystavoitteisiin - Vantaan Energia

[5] Muovifoorumi 2024, 23.10.2024, Helsinki. https://ym.fi/-/muovifoorumi-2024-kurkotti-muovin-kiertotalouden-tulevaisuuteen

- Eero Martikainen, Syklo Oy: Muovihaasteista mahdollisuuksiin
- Maria Puustinen, Neste Oyj: Kemiallinen kierrätys kierrätysasteen kasvattajana

[6] Fortum Recycling & Waste ja Sumi: Muovipakkausten kierrätystavoitteet voidaan saavuttaa nykytoimia tehostamalla - Sumi Oy

4 Simulation modelling

This section focuses on the creation of a near infrared (NIR) algorithm to predict the outgoing kilograms of plastic waste based on the sorter's NIR data, as well as simulation modelling of a sensor-based sorting (SBS) unit.

4.1 NIR to kilogram algorithm

During the sorting trial, NIR data was collected for the incoming waste. In addition to this, the outgoing fractions were weighed. We made a data and sample collection scheme for the LDPE fraction during the pilot. Every 3 hours, the facility was stopped, and the LDPE output fractions were weighed. This generated 10 data points with cumulatively increasing mass. Since the weighing times were known, NIR data until each stop was gathered and added up. These data points were fed to a machine learning model which found a linear relationship between the variables. The NIR to kilogram model was very accurate; even with only 10 data points, we could predict the output mass to below 5 % average error (see Figure 3).

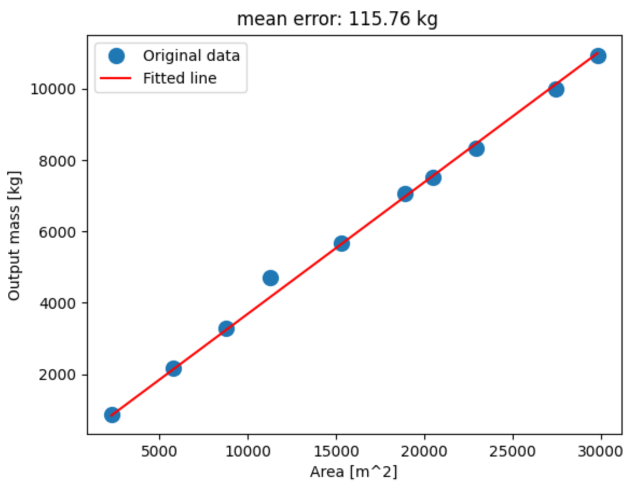

Figure 3. Results of the machine learning model.

4.2 SBS simulation modelling

A simulation model of an SBS unit for the NIR sorter was built. NIR can identify different polymers based on their electromagnetic reflectance spectrum in the near infrared range due to the presence of organic molecules which abundantly absorb radiation in this region. However, identification is only one of the steps in automatic SBS.

SBS consists of 4 phases: presentation, detection (or identification), data processing and separation. Presentation is the means of how the material is moved to detection; in plastic waste sorting, a feeding system connected to a conveyor belt is used. Detection and data processing are the NIR spectrum gathering and the algorithmic identification based on it; the NIR sensor is located above the conveyor belt. Separation is the means of how the material under identification is then divided; most often in the case of plastic sorting it is done using a pneumatic air actuator, located at the end of the conveyor belt.

Much of the research in the literature has focused on detection and data processing, while data on the other two have remained relatively scarce. However, recent studies have shown that occupation density, i.e. how much of the conveyor belt is covered, and input material purity have a great effect on the sorting performance[7]. Occupation density is correlated with throughput rate, i.e. the speed at which the material is fed, which has also been shown to have a similar effect[8]. Since these effects can be quantified very accurately using the data from SBS units, this data can also be used to build a simulation model of the SBS unit, which is what WP1 focused on. When the project started, no such research had been conducted. During the project an article was published outlining a digital twin of SBS[9]. However, no real-life validation was done for the model; thus, we focused our efforts on 1) developing a methodology for building a robust and accurate SBS simulation model, 2) collecting data for fitting this model, and 3) verifying the approach using real life sorting scenarios.

We collaborated with the University of Leoben's Chair of Waste Processing Technology and Waste Management for data collection. In this study, we used their NIR hyperspectral camera -based SBS unit that has been used in similar research. The data collection involved using washed and shredded (< 30 mm) PET and PP

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[7] Küppers, B., Seidler, I., Koinig, G. R., Pomberger, R., & Vollprecht, D. (2020). Influence of throughput rate and input composition on sensor-based sorting efficiency. *Detritus*, 9, 59–67. https://doi.org/10.31025/2611-4135/2020.13906

[8] Küppers B, Schlögl S, Friedrich K, Lederle L, Pichler C, Freil J, Pomberger R, & Vollprecht D. (2020) Influence of material alterations and machine impairment on throughput related sensor-based sorting performance. *Waste Management & Research*. 2020;39(1):122-129. doi:10.1177/0734242X20936745

[9] Kroell N, Maghmoumi A, Dietl T, Chen X, Küppers B, Scherling T, Feil A, & Greiff K. (2024) Towards digital twins of waste sorting plants: Developing data-driven process models of industrial-scale sensor-based sorting units by combining machine learning with near-infrared-based process monitoring. *Resources, Conservation and Recycling*, 200, https://doi.org/10.1016/j.resconrec.2023.107257.

particles, sourced from post-consumer plastic packaging waste. This material was used to generate samples with different compositions. These samples were fed to the SBS unit with different throughput rates, and the resulting material fractions (the eject and the reject) were analyzed. These sorting trials were conducted multiple times, and the average results were used to fit the simulation model; in total, 196 trials were realized.

The simulation model was built using discrete event simulation principles. A simplified schematic of an SBS unit is shown in Figure 4 (left). There are 4 elements, i.e. 3 material feeds (input, eject and reject), all with two properties: *throughput rate* and *composition*; and 1 SBS unit, with a property *target materials*. The SBS attempts to move the target material(s) to the eject fraction. In essence, the SBS unit is a function that splits the input material to two fractions, with its performance based on the two properties of the input. These SBS units can be linked together to form different sorting setups: an example of this is seen in Figure 4 (right). The simulation model was accompanied by a graphical user interface. A screen capture of the tool is shown in Figure 5. The tool can be used to easily design different sorting scenarios and viewing the sorting performance.

For validating the simulation model, we performed two validation sorting scenarios, which correspond to the one in Figure 4 (right). Two experiments, with different input purity and throughput rate, were conducted 3 times, and the average result was compared to the prediction made by the simulation. The results indicate that the simulation model could very accurately predict the purity and throughput of the cleaned PET and PP products as well as the intermediate steps, with an average error of 2.8 – 3.5 % and 2.4 – 21.6 kg/h, respectively.[10]

[10] A journal article has been submitted about the work: “Simulating sensor-based sorting for plastic waste management: Methodology and validation” by T. Sormunen, G. Koinig, P. Räsänen, A. Wallin

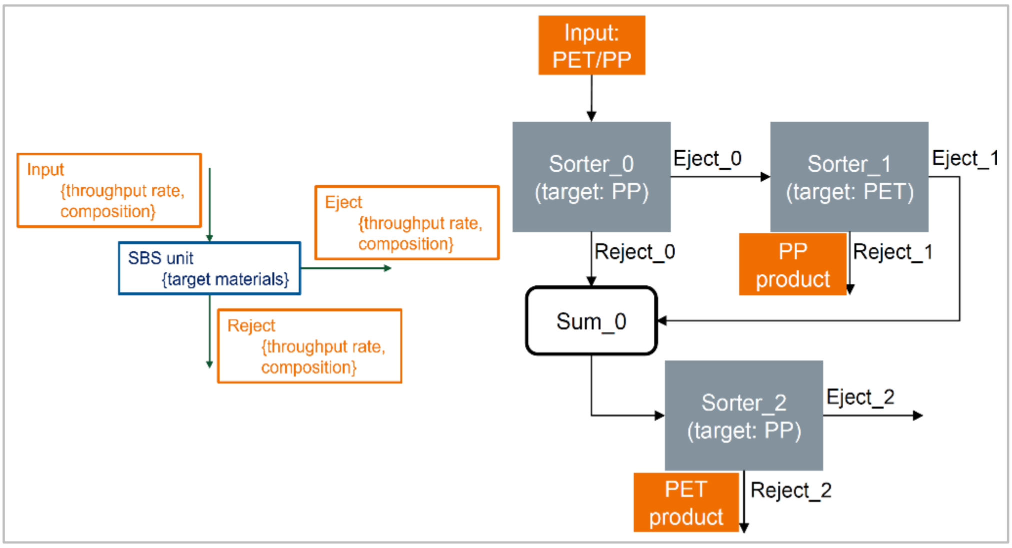


Figure 4. Left: A schematic of an SBS unit. Right: An example of a three-step sorting process to sort a mixture of PET and PP to clean products.

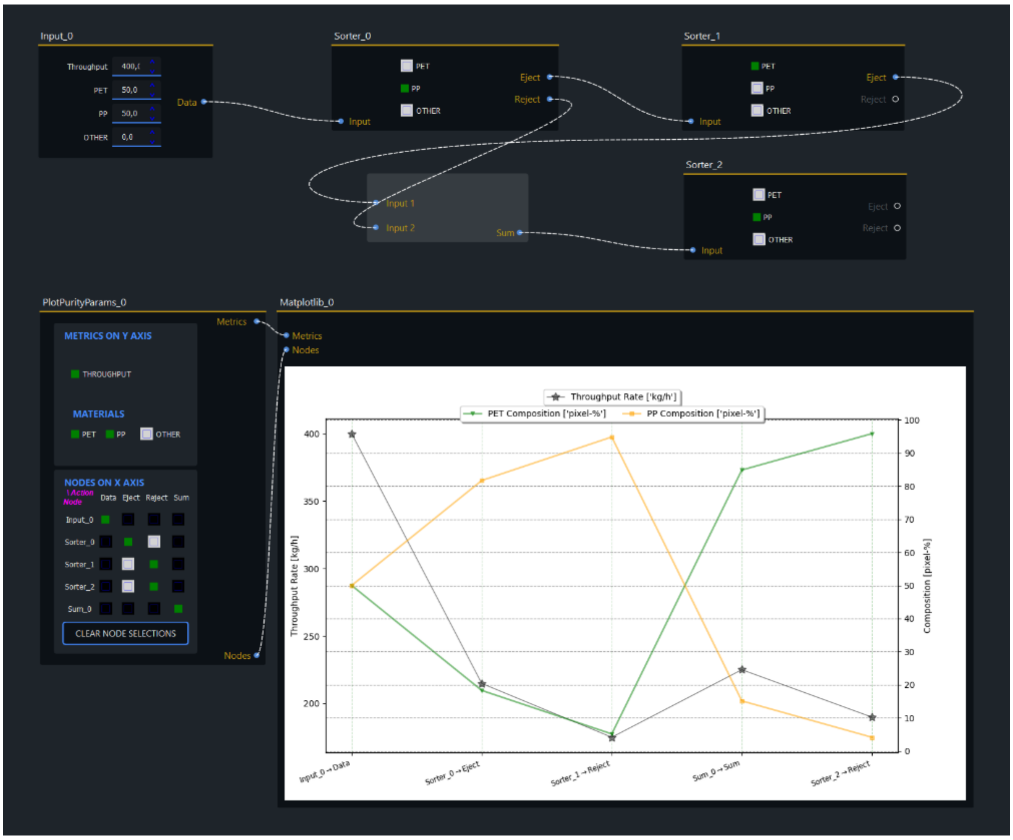


Figure 5. Screen capture of the graphical user interface of the SBS simulation modelling tool.

5 Mechanical recycling tests

For this study, the main objective was to assess the recyclability and to establish a technical concept for mechanical recycling of polyethylene (PE) fractions sorted from MSW.

The main tasks encompassed: (1) optimized laboratory-scale washing of sorted PE fractions, (2) compositional analysis of the feedstock, (3) upgrading and in-line characterization of sorted and washed LDPE fractions using VTT's advanced pilot-scale mechanical recycling line, and (4) characterization of the upgraded plastic compounds and demonstration of film processability by mono-layer cast film extrusion and biaxial stretching. More details on the mechanical recycling tests are documented in Appendix C.

5.1 Laboratory-scale washing

The washing trials for the sorted 2D LDPE plastics was planned to be conducted at VTT, focusing on the non-shredded LDPE clear and LDPE colored fractions from the sorting trial. The laboratory scale washing was realized in an IBC container with hot water and no detergent. However, it was concluded that the washing efficiency was inadequate.

Due to the challenges with the washing trials, optimized washing was performed at National Test Centre Circular Plastics (NTCP) in the Netherlands as a part of researcher exchange. The material was shredded into 50 mm flakes before washing, and both colored and clear LDPE streams were mixed to yield enough material for extrusion. After some test runs, the method chosen was the hot wash with detergent, and this procedure was used for washing of a bigger batch of LDPE at NTCP (Figure 6).

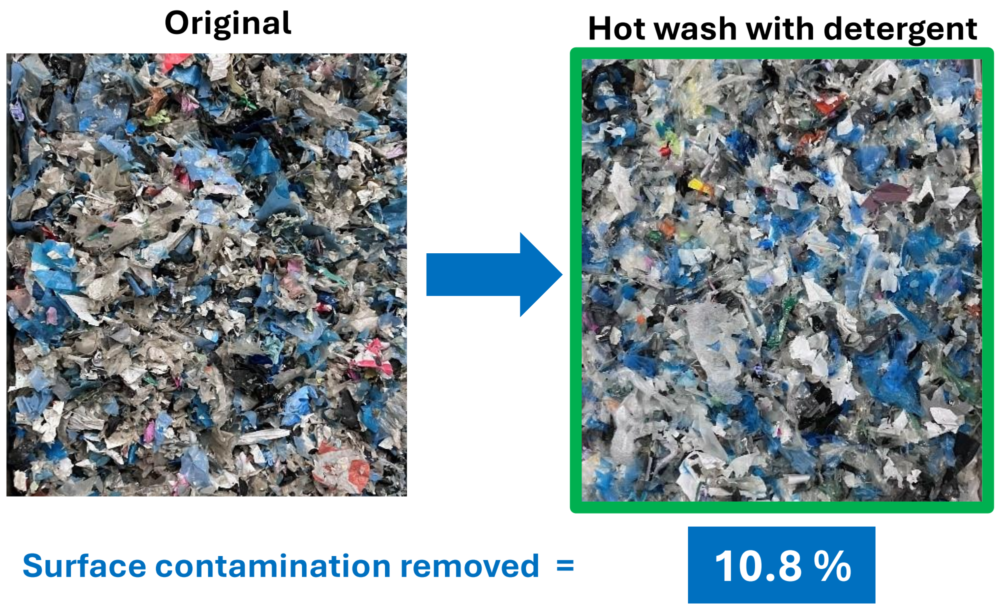


Figure 6. Optimized washing at NTCP. The pictures show the original shredded feedstock (after washing at VTT) and the feedstock after washing at NTCP.

Before upgrading and mechanical recycling demonstration, characterization of the sorted 2D LDPE plastic film fraction was performed to elucidate the composition and heterogeneity of the r-PE plastic fraction. This confirmed the presence of mainly L-/LDPE in the sorted 2D LDPE fraction, however, some minor polymer contaminants including PP, PA and PET, as well as organic mass, such as cellulosics, VOCs, waxes, and moisture were also detected.

5.2 Upgrading of sorted and washed PE fraction

Re-processing and upgrading of the shredded and washed 2D LDPE fraction were performed at VTT by using an in-line instrumented advanced mechanical recycling line. The mechanical recycling and upgrading process is depicted in Figure 7, showing the different processing steps from the upgrading trials. Based on the feedstock compositional analyses, the main approach for the material upgrading was to blend the sorted and washed 2D LDPE with virgin L-/LDPE and additives to reach suitable properties for the film demonstration. Various formulations for the material upgrading with 40-50% recycled content were established.

Continuous melt filtering of r-LDPE waste feedstock allowed significant amounts of metals (e.g. Al foil) and other impurities (such as cellulosics, non-melted polymers and rubbers, dirt) to be removed during the extrusion processing.

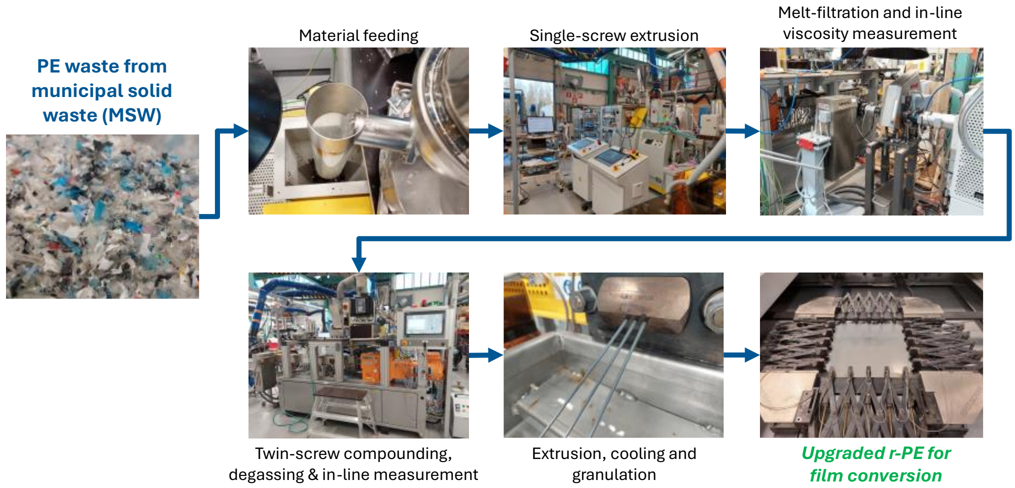


Figure 7. Pilot-scale advanced mechanical recycling of flexible PE plastics from MSW.

5.3 Film processability assessment

Film demonstrations, including mono-layer cast film extrusion and laboratory-scale biaxial stretching, were performed using the upgraded r-PE blends. The upgraded r-PE showed good processability in thin biaxially stretched films with basic mechanical characteristics comparable to those of a virgin LDPE, though with greater variability (Figure 8). Reducing the film thickness may lead to easier breakage due to impurities in r-PE. Therefore, further improvements in upgraded r-PE quality are still desirable, as impurities, mostly cellulosics, dirt and gels, are present in the films (see the optical microscopy images in Figure 8). This can potentially be achieved through a combination of improved sorting, washing, and industrial scale melt filtration with a self-cleaning filter design.

In conclusion, the material demonstration showed the potential of mechanical recycling of LDPE plastic fractions sorted from MSW, with potential applications envisioned in both mono- and co-extruded film products. Further improvements in the feedstock quality are however desirable, including e.g. further removal of labels, adhesives, and inks in the washing step, and improved separation of metals and rubbers in the pre-treatment.

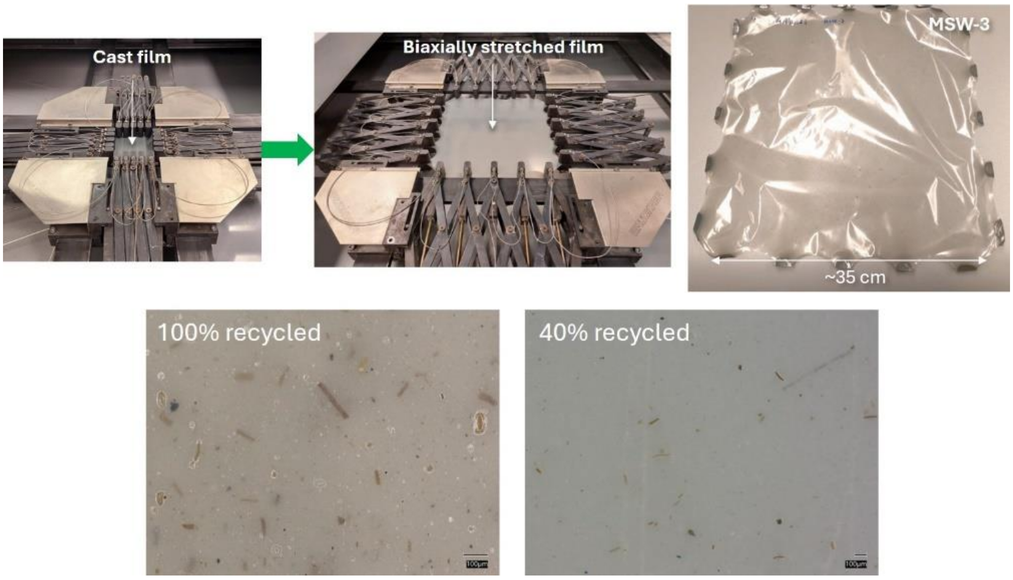


Figure 8. Top: Biaxial stretching of the mono-layer cast films produced from upgraded LDPE waste. The photograph on the right exemplifies a biaxially stretched film with 40% recycled content (3.5 x 3.5 stretch ratio). Bottom: Optical microscopy of biaxially stretched films.

6 Recyclability and efficiency

6.1 Quality of plastics separated form MSW

Experiences from the Netherlands, Sweden and Norway suggest that modern sorting plants are able to effectively separate plastics from mixed waste. The most important factor for the yield and quality of industrial sorting is the number and configuration of NIR sorters and the design of the plant, not so much the source or purity of the plastic to be sorted. The pre-processing steps play an important part: for example, the input material should be well spread on the conveyor belts to allow for accurate separation via pneumatic air.

The plastics separated from residual waste are dirtier than plastic packaging waste that is separated at source and collected in a designated separate collection system. However, with modern washing processes, for example hot water washing, the washing result is sufficient for mechanical recycling. Even with a lighter wash, the separated plastics could potentially be used as feedstock for chemical recycling. In the end, the recyclability of plastics separated from mixed waste does not differ from that of separately collected plastics.

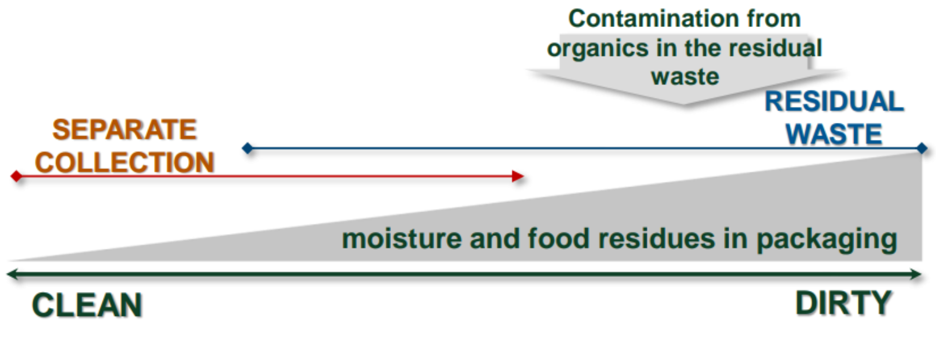


Figure 9. Plastic waste in the residual fraction is more contaminated by moisture and food residues, as well as from organics in the residual waste than plastic waste that is collected in a designated separate collection system.

6.2 Plastic types identified in the MSW sorting trial

In the sorting trial, the plastic types were determined by NIR identification of the 2D fraction (films) and 3D fraction (rigids). The plastic type data was based on the surface areas of NIR identification of the plastic objects on the conveyor belt after ballistic sorting. This method did not identify possible multi-layer plastics, which creates notable uncertainty to the assessment of recyclability. It has been reported that the 2D plastics fraction of MSW can contain 10 – 20 % multilayer plastics, which would increase the PET and PA contents[11].

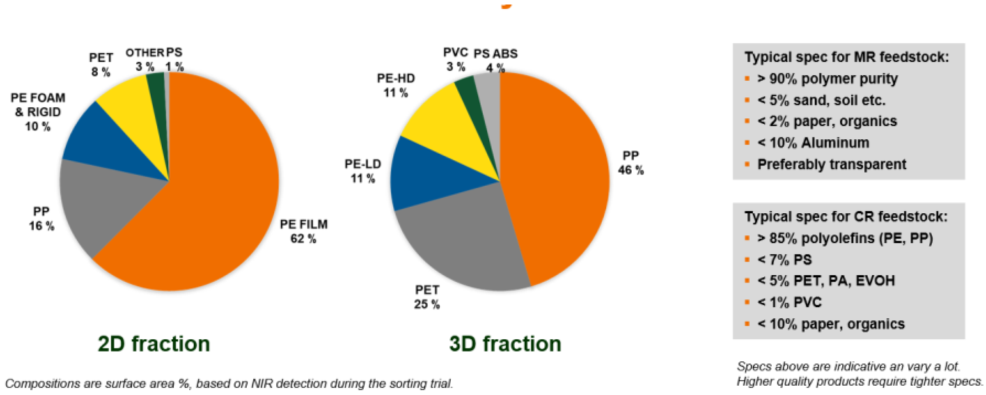


Figure 10. Plastic types of the industrial sorting trial based on NIR surface area identification of the 2D fraction (films) and 3D fraction (rigids). On the right typical specifications for feedstocks for mechanical and chemical recycling is presented.

The results indicate that the 2D fraction largely consists of polyethylene, with a total polyolefin content of 88 %, which closely aligns with the typical specifications for feedstocks used in pyrolysis-based chemical recycling. The PET content slightly exceeds the usual specifications, suggesting that an additional sorting step may be necessary, especially as PET often is present also in multi-layer structures. Moreover, the high polyethylene content of the 2D fraction could make it an attractive source for mechanical recycling after further sorting and washing.

VTT carried out hyperspectral analysis of shredded and fines samples collected during the sorting trial; in the case of SRF (which is the resulting reject of all NIR sorting steps), both washed and non-washed SRF were studied. NIR hyperspectral imaging allows for evaluating composition of waste plastics much like NIR spectroscopy, but instead of measuring a single point it measures an area (see Figure 11). Thus, we can get a surface area -based estimation of different plastics in a fraction. These results are seen in Table 1. As can be seen, SRF, fines, and clean SRF (weighted average) are all very rich in commercial packaging plastics

[11] AMI Feedstocks for Plastics Recycling Conference. 4.6.2024, Brussels, Belgium. Presentation by Alec Walker-Love (CEFLEX): *Insights from a multi-country study of plastic packaging waste*.

(PE, PP, PET). If the cellulosics were filtered out, this material could potentially be a viable feedstock for chemical recycling.

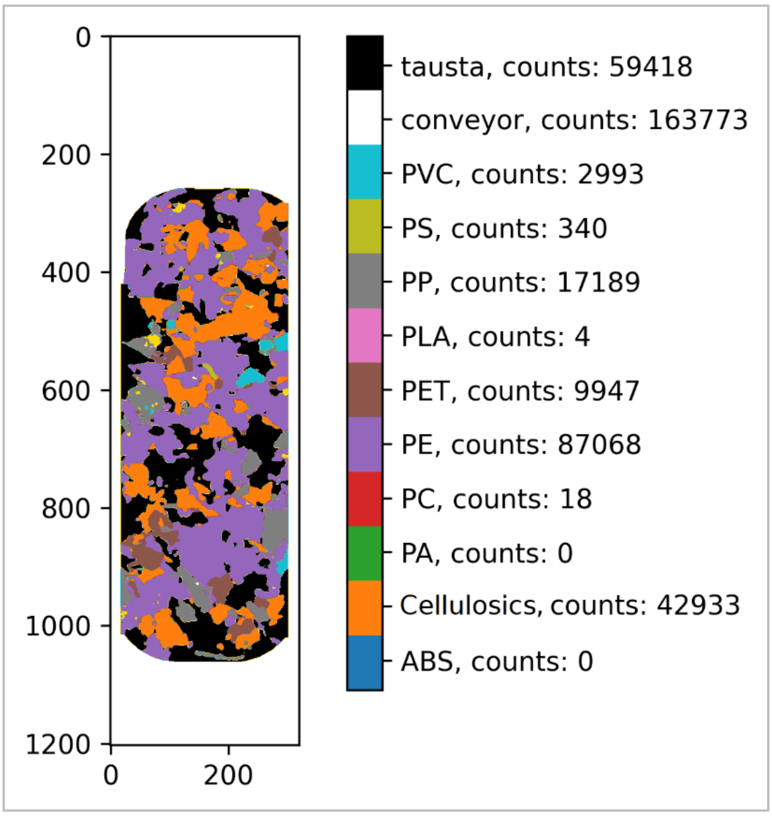


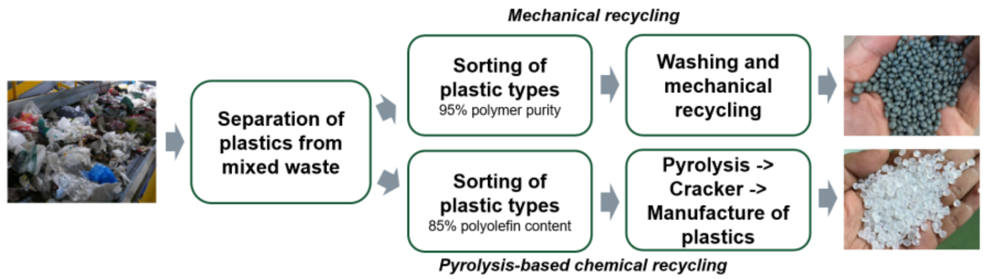
Figure 11. Illustration of hyperspectral analysis results of a single small SRF subsample. The analysis counts pixels belonging to each identified category, which are transformed to surface areas and further to surface area percentages.

Table 1. Results of the hyperspectral analysis of different fractions. The final column, "Clean SRF, weighted average" contains the two previous columns, Clean SRF float and sink fraction, averaged by their weight.

	Surface area percentage of each material				
Material	**SRF**	**Fines**	**Clean SRF, float fraction**	**Clean SRF, sink fraction**	**Clean SRF, weighted average**
PE	61,0	64,2	77,3	16,5	74,5
Cellulosics (paper, cardboard…)	23,2	7,0	3,6	29,1	4,7
PP	7,9	11,8	12,4	0,6	11,9
PET	4,8	11,8	3,2	43,2	5,1
Other	3,1	5,1	3,5	10,6	3,8

6.3 Assessment of yields for mechanical and chemical recycling routes

An important information in assessing recyclability is the plastic-to-plastic recycling yield indicating the material efficiency, CO_2 emissions and economic feasibility of the recycling route. Figure 12 shows an assessment for a recycling yields for mechanical and pyrolysis-based chemical recycling of plastics in MSW using modern state-of-the-art technologies. It is based on the knowledge available in public literature and info received during the project visits and interviews.



100 kg of mixed waste plastic	Yield % / kg remaining	Yield % / kg remaining	Yield % / kg remaining	Estimated total yield %*
Mechanical recycling	90% / 90 kg	70% / 63 kg	95% / 60 kg	**approx. 60%**
Chemical recycling	90% / 90 kg	90% / 72 kg	50% / 36 kg	**approx. 35%**

Figure 12. An assessment for recycling yields or plastics in MSW using modern state-of-the-art technologies. From clean dry plastic waste to clean recycled plastics. (Source: MSWPlast experts)

The assessment, excluding the weight of removed moisture and dirt during the recycling process, shows 60 % recycling yield for mechanical recycling and 35 % for pyrolysis based chemical recycling.

Figure 12 illustrates also that utilising plastics from MSW often has one extra sorting step compared to source separated plastic waste, which has some decreasing effect to the yield. Nonetheless, all these recycled plastics would replace waste incineration and thus positively impact overall recycling rates and CO_2 emission reduction.

When comparing the yields between mechanical and chemical recycling, it is important to consider the differences in the quality of the products, resulting in notable differences in suitable applications of the resulting recycled plastics.

7 Integration concept

The ambition for this part of the study was to generate a concept for introducing post-sorting into existing recycling value chains, not impacting the efficiency of the separate collection. This work was two-fold, including a study on the future of residual waste management in relation to as well post-sorting, as recycling and energy recovery; and an analysis of value creation and value chains relating to the recovery of plastic waste via post-sorting. More details on the future residual waste management and the value creation are documented in Appendices D and E.

7.1 Future residual waste management

This work aimed to create future scenarios and analyse potential impacts on the waste that is destined for energy recovery (waste-to-energy, WtE). The focus of the analysis was on how alternative sorting scenarios impact WtE volumes, composition, and emissions, as well as the role of plastics in the WtE process. Further, the impacts on recycling when improving sorting efficiency was studied.

We have built scenarios for future waste management, aiming to calculate the impacts on WtE and the potentials for sorting plastics for recycling:

- **Baseline** was set to 2021 due to good availability of data from 2021. For waste generation, 2019 and 2021 values were combined for Baseline, due to impact of COVID-19 in 2021. The MSW recycling rate is 39%.
- **Scenario1** represents current policy steering using the rationale from the Finnish National Waste Plan. The MSW recycling rate would increase to 49%.
- **Scenario2** represents the required improvements in separate collection efficiency to reach the 2030 recycling rate target of 60 % for MSW.
- **Scenario3** represent current policy landscape supported combined with post-sorting of residual MSW to separate plastics. In this scenario the MSW recycling rate increased to 52 %.

The analysis shows that sorting plastics in an industrial post-sorting process would result in reduction of the waste volumes sent to WtE, while also having significant impact on the composition of the waste. Improving the separate collection efficiency also impacts both waste volumes and composition. Different material fractions have different type of emissions, where renewable materials mainly have biogenic CO_2 output and non-renewables emit fossil CO_2 in incineration. Changes in waste volumes and composition led to changes in the calorific value and emissions (see Figure 13). The results further indicate an increase in the production of secondary plastics, as illustrated in Figure 14.

The results show that although the impacts of post-sorting are relatively small on the over-all recycling rates, the recovery of plastics for recycling is significantly increasing when improving sorting efficiency either through separate collection or industrial post-sorting. More detailed results from the study on future residual waste management can be found in Annex B[12].

Scenario 3 shows that the recycling rate for plastic packaging would increase significantly if implementing post-sorting. The 53 650[13] tonnes of plastic waste annually separated from residual MSW contains 76 % packaging waste (HSY, 2019), which could increase the recycling rate of plastic packaging waste by 25 percentage points if calculating as the share of the reported 166 thousand tonnes of plastic packaging put on the market in 2021. However, if calculating as the share of the calculated total plastic packaging waste generation[14], the increase in the recycling rate for plastic packaging waste would be 18 percentage points. This would require efficient post-sorting of all residual MSW in Finland.

[12] A journal article on the topic is currently in finalization: zu Castell-Rüdenhausen et al., The future of residual municipal solid waste in a circular economy.

[13] Assumptions made: 76 % of the plastic waste in residual MSW is packaging (HSY, 2019) and 44 % of the plastic packaging waste is moisture and food residues (RVF, 2005)

[14] Same assumptions as above related to residual MSW and assuming 80 % of separately collected plastic packaging waste being plastics.

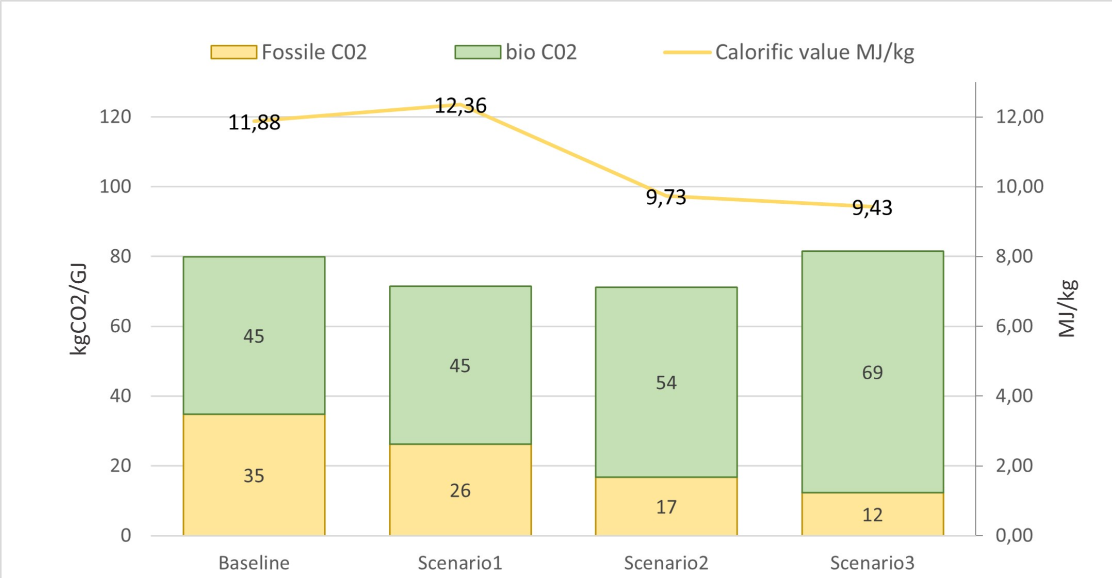


Figure 13. Impacts on incineration show that removing plastics from the incinerated waste decreases fossile CO_2-emissions while also decreasing the calorific value.

Correction [3.1.2025]: The original Figure 13 presented values for CO2/t, the corrected figure displays the values correctly, as kgCO2/GJ.

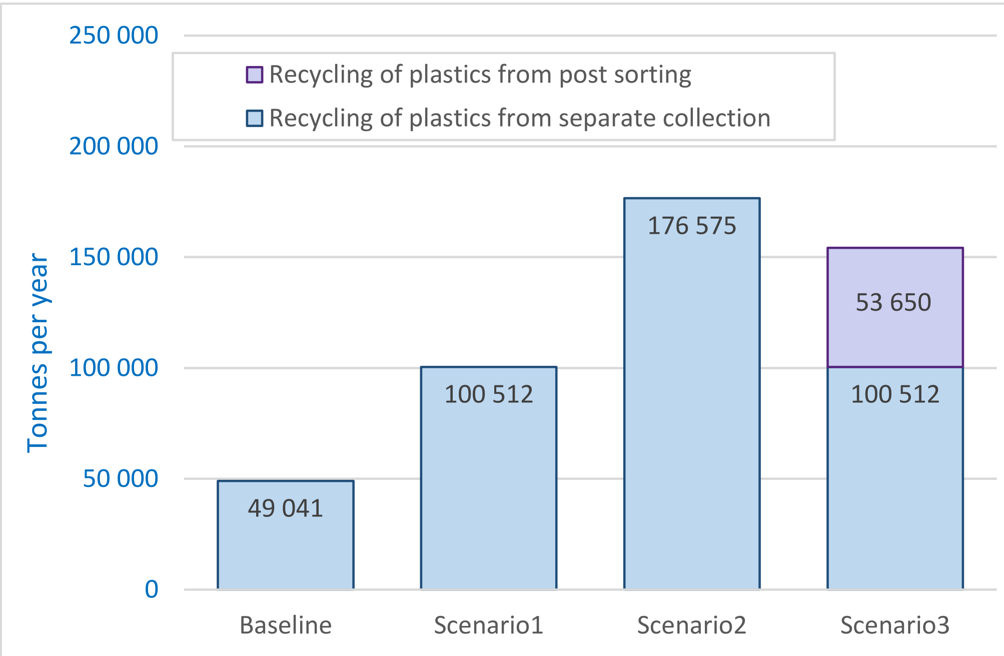


Figure 14. Impacts on production of secondary plastics show that the residual MSW has great potential for secondary plastics raw material sourcing.

7.2 Value creation

This task assessed the value creation in industrial central post-sorting residual MSW for plastic waste recovery, conducted by interviews, recycling site visits and complementary literature studies. The study highlights the importance of a complete value chain to enable the investment and implementation of post-sorting. Environmental regulation is crucial to sustain the business ecosystem. The volatility of plastic material markets and fluctuating energy prices significantly impact the recycling business.

As shown in Figure 15, the value chain from raw material suppliers to end-customers relies on support activities such as infrastructure, human resources, technology development and procurement to enable primary activities such as logistics, sorting and marketing. These coordinated efforts ultimately drive margin creation through operational efficiency and quality assurance.

The case studies underlined the importance of legislation on recycled content in packaging and carbon mitigation (including ETS and other legal instruments for carbon neutrality) for fostering efficient circular ecosystems, thereby enhancing technology development. Policies such as extended producer responsibility, recycled content mandates, plastic waste import and export control, tax incentives, and carbon pricing are crucial for attracting new investments. In the absence of strong regulative drivers, the volatility of virgin plastic raw materials makes the business environment unstable, and recyclate providers face challenges in price competition and the convenience associated with virgin material supply. Additionally, fluctuations in waste composition and quantity have resulted in a mismatch of supply and demand, contributing to price volatility. The current low prices of virgin polymer materials make mechanical recycling less viable, calling for robust strategies to manage price fluctuations.

Moving forward, future research should focus on co-development and co-innovation in relation to individual firms' business model innovation. An interconnected dialogue between packaging developers, designers and sorting facilities could decrease amounts of non-sortable plastic waste. Given the complexity of circular economy models a business ecosystem coordinator may be necessary to facilitate collaboration among diverse stakeholders, ensuring effective management, collaboration, and alignment within this ecosystem.

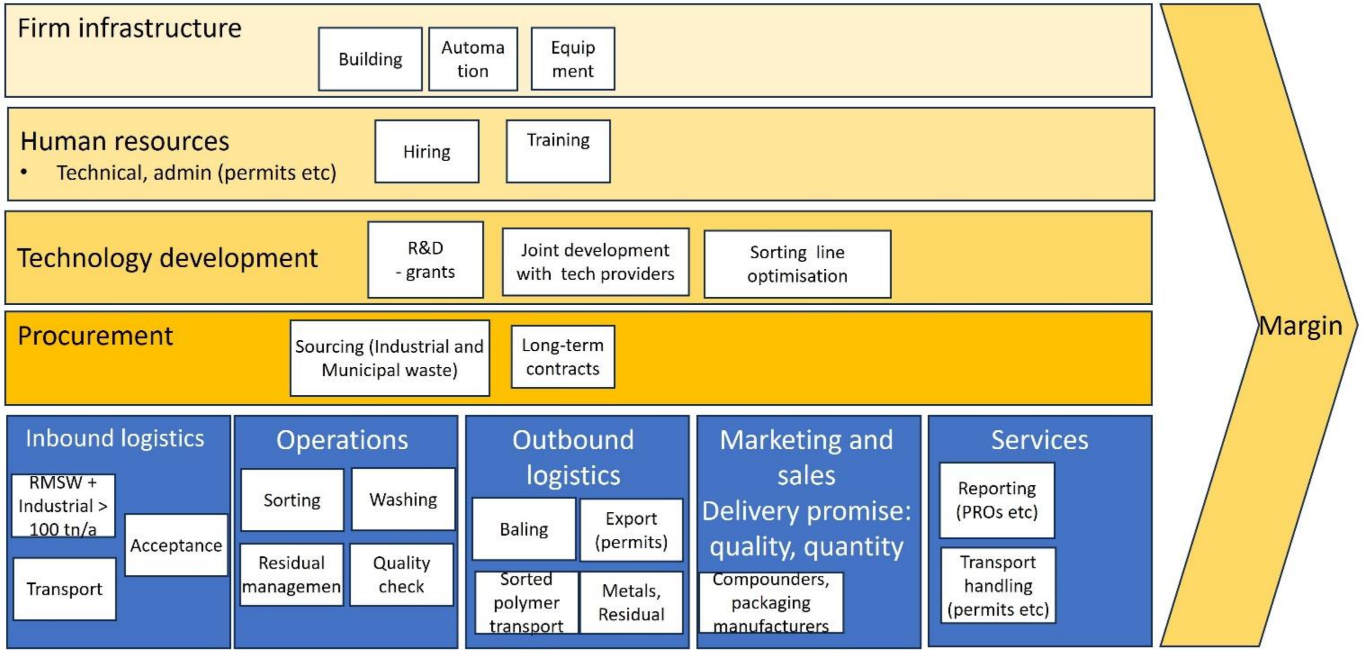


Figure 15. Value adding activities from the raw material supplier (MSW generator) to the end customer (buyer of recyclate). Model according to Porter, 1985[15]

[15] Porter M. 1985. The Competitive Advantage: Creating and Sustaining Superior Performance. NY: Free Press, 1985.

8 Policy instruments for post-separation of plastics from mixed waste

We examined the national and EU instruments that have an impact on post-separation of plastic wastes from residual municipal waste and recovering plastic waste as a material. The study aimed at identifying legal and other potential barriers for centralised sorting of plastic wastes in Finland. Moreover, the study reviewed waste management schemes (MSW, packaging waste and the division of waste management responsibilities) in selected EU countries. The analysis of the countries examined both possible export potential from the perspective of municipal waste management, mixed waste separation and plastics recycling, and interesting national policy measures that can increase recycling of plastics.

8.1 Legal instruments in Finland

The objective of the study of policy instruments in Finland was to identify the drivers and barriers for post-separation of plastics from residual MSW and its recycling. The study examined various policy instruments concerning products, waste, separation at the source, centralised sorting, mechanical and chemical recycling and recycled materials content requirements in new products.

The study shows that the focus of the national waste policy has been primarily on the attaining of the EU recycling targets and aiming to do so through source separation of MSW. No special legal provisions have been laid down concerning post-sorting of plastics from mixed waste streams. Instead, there is more provisions that affects it indirectly and shapes the operating environment of waste management in general. In addition to legal provisions there is also a growing number of voluntary instruments that might have a relatively small effect on the waste management system.

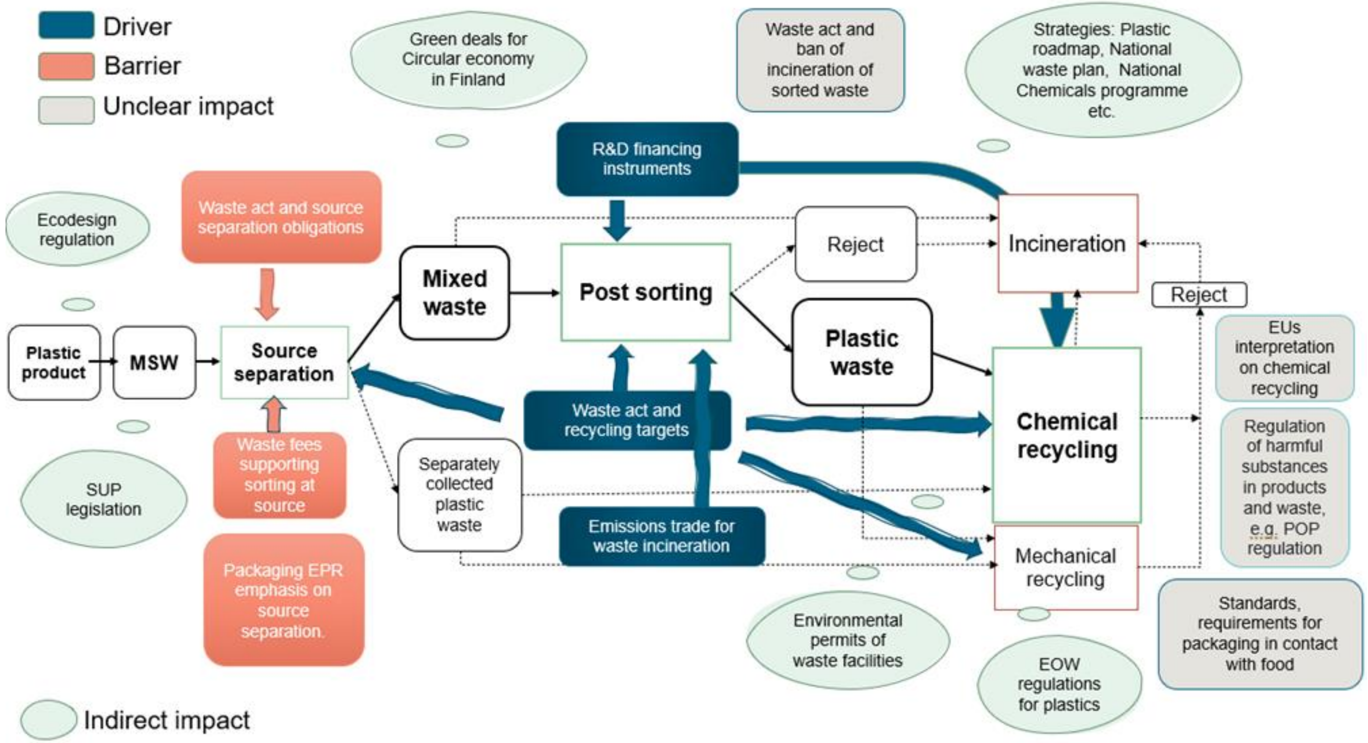


Figure 16. The regulatory environment affecting the post sorting and recycling of plastic in residual waste. The impact can be both promoting and inhibiting, but also indirect. The effects of policy measures are also partly difficult to foresee. MSW refers to municipal solid waste, SUP to the single-use products and EPR to extended produced responsibility.

Even though the waste management of MSW is heavily built on separation at the source, there are no barriers for post-sorting of residual MSW. The policy guidelines allow centralised sorting in parallel with the source separation to increase the municipal waste recycling rate in Finland.

Currently, most of plastic in residual MSW is being incinerated at mass incineration plants. The potential inclusion of mass incineration to the EU Emissions Trading Scheme (ETS), gradually rising recycling targets, recycled material content requirements and other instruments alongside with developing centralised sorting technologies place increased pressure for the post-separation of plastics from residual MSW. In the future, economic and information-based instruments should also aim at promoting the increase of plastics recycling when it is appropriate in terms of the overall environmental impact of the activity. The variable quality and potential impurities can cause problems concerning the use of post-sorted plastic output materials. Chemical recycling of plastics is proposed as one of the solutions to this problem.

8.2 Key findings on policy instruments

The EU's mandatory recycling targets guide the development of municipal waste management in the direction of promoting both source sorting and centralised sorting of mixed waste. Although Finnish waste policy has traditionally been built on source separation, Finnish legislation does not provide for obstacles to the post-separation of plastics from residual municipal waste as long as the mandatory separate collection system remains in parallel. In practice, separation plants can play a role in reducing the incineration of plastics wastes and increasing their recycling rate.

The policy environment for the centralised sorting of mixed waste includes many indirectly related regulations and other policy instruments such as fees, taxes or strategies and voluntary agreements. New significant policies are also being planned: For example, including waste incineration as part of EU ETS could create new incentives for sorting plastic waste from residual MSW.

It is not clear what kind of impacts the introduction of post-sorting technologies will have on municipal waste recycling. This is influenced, among other things, by the composition of the residual municipal waste and e.g. the share of biowastes in it. Centralised sorting facilities can enhance the recycling of plastics that incorrectly end up in residual municipal waste and also prevent them from being incinerated. This reduces carbon emissions from incineration as well as the energy content of the incinerated waste stream. However, post-sorting may reduce citizens' motivation to sort waste at the source. To avoid this, communication about centralised sorting must be prepared carefully, and the importance of separation at the source must not be forgotten. The Netherlands has succeeded in incorporating both source sorting and high-tech centralised sorting of mixed waste into municipal waste management practices, while the reported recycling rate reaches the EU recycling targets. Sweden has also begun to follow this example, although the reported recycling rate has not yet reached the EU targets[16].

In Finland, drafting of a National Circular Economy Act started in the final phase of this study. The draft version of the Act includes plans for regulating the curbing of waste incineration. This can also mean stronger guidance in the direction of sorting mixed waste.

[16] Note that there is a delay in the reporting, and the revision of the Swedish separate collection system is implemented later than available statistical years.

9 Conclusions

Our findings reveal promising recycling prospects for plastics separated from residual MSW. Industrial sorting of plastics from residual MSW is expected to offer an undeniable potential for plastics recycling that would complement the current separate collection system, improving Finland's recycling performance and providing valuable raw materials for the domestic plastic industry. The international benchmarking further supports the conclusion that residual MSW offers a significant source of waste plastic for recycling. In addition, separating plastics from residual MSW instead of incineration, would decrease the fossil CO_2 emissions.

The international benchmarking showed that modern post-sorting plants efficiently separates plastics with very high yields or very high purity. Our identification and recyclability tests further show that plastics can be separated from residual MSW, sorted and washed for recycling. However, the plastics separated from residual waste are dirtier than those collected separately. To enable mechanical recycling, an efficient washing (e.g. hot washing) would be required. A less well-sorted and washed plastic fraction would also be highly potential for chemical recycling, which would then allow more plastics to be recovered from the residual waste for production of equivalent-to-new recycled plastics, but the process displays a lower output yield than mechanical recycling.

It is worth highlighting that all post-consumer plastic waste must go through industrial sorting and washing prior to recycling. This also includes separately collected plastic packaging waste, since it is dirty and consists of many different types of plastic.

Another key highlight is, that although the industrial post-sorting efficiently separates plastics and metals for recycling, most other materials remain in the fraction sent to incineration. The technology is ready for sorting most materials from MSW, but there currently is no market demand for other materials separated from the residual waste. The separation of plastics and metals would not have a significant impact on MSW recycling rates, as their share of the residual waste is modest. The impact on the recycling rate of plastic packaging waste, however, can be significant.

Increasing the plastic packaging recycling rate would have a direct economic benefit for Finland, since it would reduce the payments for 'plastics own resource' or ‘plastic packaging levy’, which currently is approx. 90 million euros for Finland, paid annually to the EU for under-performance in plastic packaging waste recycling.

Separating and recycling plastics from residual MSW not only presents environmental benefits but also creates business opportunities for the plastics industry. Moreover, it reduces the reliance on imported virgin raw materials in plastics production thus promoting both carbon neutrality and material circularity.

Topics for further research include the business models surrounding post-sorting of residual MSW: costs and responsibilities and economic analyses.

Acknowledgements

The MSWPlast project was funded by Business Finland's Co-Research public research grant and co-funded by the industrial partners Borealis, Remeo Group Oy and Vantaan Energia Oy. The project was part of the SPIRIT ecosystem led by Borealis.

The project was steered by a very active steering group. The research partners specifically want to acknowledge the active support provided by the industrial partners throughout the project. The following stakeholders participated in and supported the project execution:

Research partners:
- VTT Technical Research Centre of Finland
- Finnish Environment Institute Syke

Industrial partners:
- Borealis
- Remeo Group Oy
- Vantaan Energia Oy

Steering group:
- Mika Härkönen, VTT Technical Research Centre of Finland
- Eevaleena Häkkinen and Sari Kauppi, Finnish Environment Institute Syke
- Jaakko Tuomainen, Borealis
- Tommi Erla and Mauri Lielahti, Remeo Group Oy
- Perttu Penninkangas and Hanna Pitkänen, Vantaan Energia Oy
- Merja Saarnilehto, Ministry of Environment of Finland
- Mika Surakka, Sumi Oy
- Sanna Peltola, Suomen Pakkaustuottajat Oy
- Miro Aaltonen and Tuomas Lehtinen, Business Finland

Appendix A: Sorting trial

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Johdanto

- Remeo on mukana yrityskumppanina VTT:n ja SYKEn yhteistutkimushankkeessa, jossa tutkitaan sekajätteen muovien jatkohyödyntämismahdollisuuksia. Remeo tuottaa hankkeessa käytettävää tausta-aineistoa toteuttamalla 500 tonnin sekajätteen koeajon laitosmaisella käsittelyllä. Koeajon kokoluokka ja toteutustapa on ainutlaatuinen verrattuna tyypillisiin muutaman kymmenen tai sadan kilon koostumustutkimuksiin.
- MSWPlast-hanke hyödyntää Remeon Vantaan lajittelulaitoksessa suoritettavan pilottitestin tuloksia. Koeajossa lajitellaan 500 tonnia kotitalouksien ja yritysten sekajätettä. Tästä saadaan tuotantomateriaalia analysoitavaksi, minkä lisäksi pilotti tuottaa tärkeää dataa, jonka avulla voidaan saada tietoa sekajätteen lajittelun toteutettavuudesta teollisessa mittakaavassa.

Syyskuu 2023 MSWPlast | sekajätteen koeajo 3 Remeo

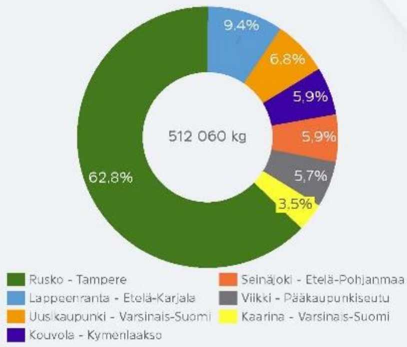
Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Jätteiden alkuperä

Jätteen keräys

- Sekajäte-erä koeajoa varten kerättiin Remeon Tampereen Ruskon kierrätyslaitokselle 12.-20.9.2023 välisenä aikana.
- Yli 75% jätteestä on peräisin eri alueiden kotitalouksista. Vain pääkaupunkiseudulta kerätty jäte on kokonaisuudessaan peräisin kaupan ja teollisuuden asiakkailta. Tampereen seudun jäte on kokonaisuudessaan peräisin kotitalouksilta.
- Tampereen ympäristöstä kerätty jäte purettiin suoraan keräilleistä jäteautoista ja muualta jäte toimitettiin siirtokuormattuna eri vastaanottoasemilta.
- Jokainen kuorma on punnittu Remeon kalibroiduilla vaaoilla ja punnitukset rekisteröity mScales-vaakajärjestelmään.

Jätenäyte-erän maantieteellinen jakauma



Syyskuu 2023 MSWPlast | sekajätteen koeajo 4 Remeo


Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa
Jätteen esikäsittely Ruskossa
Yksinkertaistettu prosessikuvaus
Havainnollistava kuva toiminnasta
Jätteen punnitus ja vastaanotto
512 060 kg
Jätteen syöttö esimurskaimeen
Tana Shark 440DT
Jätteen seulonta kiekkoseulalla
Tana X553T
Seulaylite
Seula-alite
Näytteenotto
Jätteen esikäsittely suoritettiin 13.-21.9.2023
Syyskuu 2023
MSWPlast | sekajätteen koeajo
5
Remeo


Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa
Havainnollistavia kuvia esikäsittelystä
Jätteen toimitus ja purkaminen esikäsittelyyn
Kerätyn jätteen syöttäminen prosessiin
VTT:n näytteenottoa seula-alitteesta (hienoaines ja biofraktio)
Syyskuu 2023
MSWPlast | sekajätteen koeajo
6
Remeo


Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa
Seulonnan lopputuotteet
Seulonnan lopputuotteet: kaksi eri alitetta sekä ylite, joka kuljetetaan Vantaan laitokselle jatkolajitteluun.
Seulaylite
Seula-alitteet
Syyskuu 2023
MSWPlast | sekajätteen koeajo
7
Remeo


Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa
Seulonnan ylitteen laitoslajittelu Vantaalla
Yksinkertaistettu prosessikuvaus
Laitoslajiteltava jätemateriaali
Jätteen esikäsittely suoritettiin 13.-21.9.2023
Jätteen vastanotto
Näytteenotto syötteestä
VTT:n ohjeistuksen mukaan
Jätteen syöttö linjastolle
C&I linja
Jätteen laitoslajittelu
Energiajakeen ohjelma
Tutkittavat muovit
LDPE & 3D muovit
Muut jakeet
Metallit, pahvi, puu..
Näytteenotto
VTT:n ohjeistuksen mukaan
Datan keruu
Datan analysointi
Jätteen laitoslajittelu suoritettiin 18.-22.9.2023
Syyskuu 2023
MSWPlast | sekajätteen koeajo
8
Remeo

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Havainnollistavia kuvia laitoslajittelusta

Lajiteltavan jätteen vastaanottoa

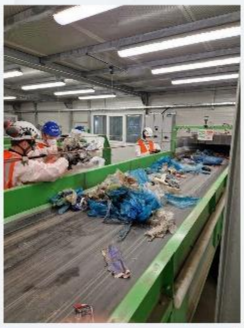
Kuva syötteestä ja ensimmäisestä näytteenotosta

Havainnollistava kuva jätteestä lajittelulaitoksessa

Syyskuu 2023 MSWPlast | sekajätteen koeajo 9 Remeo

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Kuvia näytteenotosta



Näytteenottoa lajitellusta LDPE-muovista

Näytteenottoa lajitellusta muusta muovista

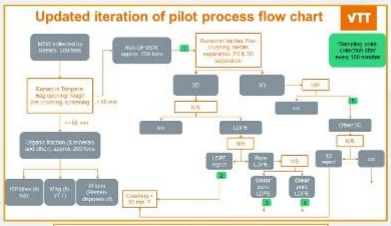
Eroteltua puujätettä

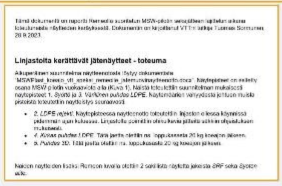
Syyskuu 2023 MSWPlast | sekajätteen koeajo 10 Remeo

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Näytteenotto

- Näytteenotto suoritettiin koeajon aikana VTT:n ohjeistuksen mukaan
- VTT oli seuraamassa ja varmistamassa näytteenoton sujuvuutta ja edustavuutta
- Ruskon seula-alitteesta otettiin näytteitä seulonnan aikana sekä suoraan että kokoomanäytteeseen, josta seulonnan päätteeksi muodostettiin oma näyte
- Seulaylitteestä otettiin näytteet Vantaan lajittelulaitteistolla oheisen suunnitelman mukaisesti useasta eri prosessin vaiheesta



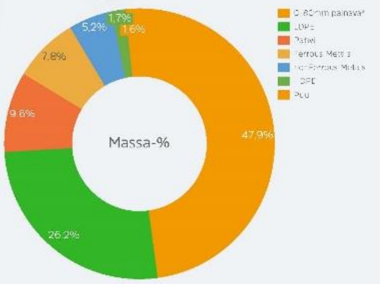


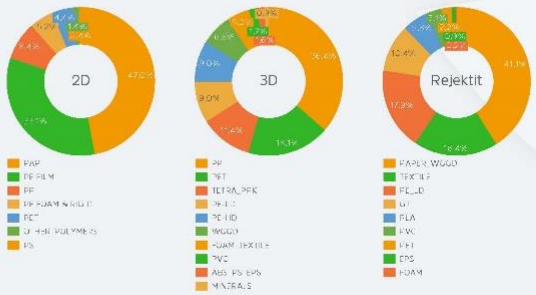
Syyskuu 2023 MSWPlast | sekajätteen koeajo 11

Remeo

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Dataa koejaosta





Massaprosentit:
Eroteltujen jakeiden osuudet massaprosentteina. Erotteluun päätyi tässä testikoeajossa yhteensä 45,6 tonnia 512 tonnin syötteestä.
*mineraalit ja kontaminoituneet kuidut

Pinta-alaperusteinen materiaalijakauma:
Lajittelulinjastolla sensoreiden tunnistamista materiaaleista suuri pinta-alaperusteinen osa on erilaisia muovilaatuja, joita olisi mahdollista laitoslajitella omiksi jakeikseen.

Syyskuu 2023 MSWPlast | sekajätteen koeajo 12

Remeo

Konsortiosopimuksen liitteen 6 mukaista Background-ainestoa

Johtopäätökset

- Koeajon perusteella Remeo näkee sekajätteen laitoslajittelun potentiaalisena konseptina tukien kierrätysastetavoitteisiin pääsemisessä
- Koeajo toi arvokasta dataa sekä kokemuksia
- Remeon nykyinen kaupallisen energiajätteen lajittelulinjasto lajitteli sellaisenaan, ilman muutoksia, yllättävän hyvin seulottua sekajätettä
- Koeajossa saatiin eroteltua erilaisia muoveja sekajätteestä projektin muiden työpakettien tutkittavaksi
- **Remeo näkee, että prosessia säätämällä lajitteluastetta sekä eri jakeiden saantoa on mahdollista kasvattaa huomattavasti**
- Remeon datasta on nähtävissä sekajätteen sisältävän huomattavan määrän erilaisia hyödynnettäviä muovilajeja

Syyskuu 2023 MSWPlast | sekajätteen koeajo 13

Appendix B: International benchmarking

Reports from the visits – kts teamsSince no comprehensive reliable data can be found on the post-sorting of mixed waste, MSWPlast's international cooperation focuses significantly on information exchange, such as the experiences of existing sorting facilities.

Research visits:

- Sweden: Brista post-sorting facility in Stockholm and Svensk Plaståtervinning plastic sorting facility in Motala
- Norway: ROAF post-sorting facility in Oslo
- The Netherlands: AVR post-sorting facility in Rotterdam and Attero post-sorting facility in Wijster
- Finland: Salpakierto post-sorting facility in Lahti

Figure B1. Excursion participants at AVR Rotterdam post-sorting plant.

Sweden

Excursion to Sweden for 12 participants of the MSWPlast project, including visits to Sörab Brista RMSW post-sorting facility in Stockholm[17], Naturvårdsverket[18] for discussions related to the relationship of post-sorting with existing recycling systems in Sweden, as well as Svensk Plaståtervinning's plastic sorting facility in Motala[19]. The excursion led us through the post-sorting value chain in Sweden, starting at the post-sorting of mixed municipal waste in Brista, where plastics were separated from the waste and sent to SPÅ. We continued with the sorting into polymers at SPÅ, learning about efficiencies of the sorting steps. Further, at the visit to Naturvårdsverket, we learned more about the policy framework behind the Swedish decisions to invest in industrial post-sorting.

At Naturvårdsverket we discussed is the political landscape in Sweden, how legislation and steering mechanisms differ from Finland. We learned about the communication of Brista "when you have done all you can, then we can make a small addition" that encourages people to continue and improve sorting at site, that the post-sorting is not an option to site-sorting, but an addition to site-sorting.

Sweden is, as of 2024, introducing separate collection of all packaging waste fractions at all properties throughout the country. A means for this is implementation of multi-locker collection bins. However, as Sweden has implemented emissions trading for waste incineration, waste incineration plants are increasingly investing in post-sorting to remove the plastics and thus reducing fossil CO2-emissions which are covered by emissions trading. These two mechanisms are expected to bring the plastic packaging recycling rates of Sweden to the target level for recycling as stated in Swedish legislation and the Packaging and Packaging Waste Directive.

The waste company SÖRAB has a post-sorting facility directly connected to Stockholm Exergi's incineration plant. The facility sorts out plastic and metal from the waste, as well as organic waste that is collected a green bag. The planned capacity is 140 000 tons annually. In total, approximately 11 tons of plastic and 2,5 tons of metal are sorted out annually. The reason for sorting out the plastic is to reduce CO2-emissions; the incoming waste has a plastic share of approx. 18 %. The post-sorting facility was inaugurated in the spring of 2021 and is owned and operated by SÖRAB.

The SPÅ sorting plant in Motala is the largest plastics sorting and recycling facility in the Nordic countries. It has a full capacity of 200 000 tons, with 60 NIR sensors for separation of 12 different fractions. In SPÅ, separately collected plastic packaging waste is sorted, baled and sent to recyclers. Also the plastics sorted in

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[17] Brista mixed waste sorting facility is similar to what is studied in the project. The main difference is that this facility is originally planned by the incineration plant to remove plastics to reduce the fossil CO_2-content in order to reduce costs associated with emissions trading.

[18] Naturvårdsverket is the EPA of Sweden, equivalent to Syke.

[19] The Motala facility is the largest plastics sorting and recycling facility in the Nordic countries.

the Brista facility are sorted in SPÅ. The quality of the sorted plastics is specifically high, with a content of 95 % of the target material in all fractions.

SPÅ receives the plastics that are separated at Brista from the mixed MSW. In comparison to the separately collected plastic packaging, they told us that the MSW contains more films and less containers. This resulted in some struggle to optimise the sorting line at first, but now all is functioning well. The waste from Brista is first sorted at a separate line, before joined with the packaging lines for final sorting. This is due to the different optimization of the different feeds.

Norway

In Norway municipalities are responsible for reaching the targets for sorting recyclables. As stated by Norwegian law, the sorting can be done either as separate collection, co-mingling or central sorting. Miljödirektoratet[20] has looked into the quality of recyclates from central sorting and agrees the quality is sufficient for washing and recycling. the quality is not as good as separately sorted PPW, but this related only to dirt which can be washed. Many Norwegian municipalities are looking at central sorting as an option to site sorting. In general, it seems Norwegians have good experiences from central sorting. In Norway the legislation accepts post-sorting as a substitute to separate collection. The requirements on door-to-door collection can be exempted by post-sorting.

Plastretur is the EPR for plastic packaging under gröne punkt. In Norway it is the municipalities that do the collection of the plastic packaging. Most often as co-mingled collection or in separate bins or bags. In collaboration with Tomra, Plastretur is building a fine-sorting plant for sorted mixed plastics that have been sorted at a post-sorting plant. Tomra is building similar facilities in e.g. Germany. It is planned to have a max capacity of 90 kt/yr.

ROAF is a municipally owned post-sorting plant with a capacity of 75 kt/yr. It is the first residual waste sorting facility in Norway, starting in 2014. The target was originally to sort out biowaste, but during the planning processed it was extended to include also metals and plastics.

In total the waste management system includes bring point system for metals and glass, door-to-door separate for fibres (paper cardboard) and co-mingled collection of residual waste with biowaste (green bag). The co-mingled fraction is taken too ROAF's post-sorting and is sorted into metals, 4 different plastic fractions (95-97% polymer purity) and rejects for incineration.

[20] Miljödirektoratet is the EPA of Norway, equivalent to Syke.

The Netherlands

Excursion to the Netherlands for 10 participants of the MSWPlast project, including visits to Rotterdam AVR residual MSW post-sorting facility in Rotterdam and Attero Wijster residual waste post-sorting and packaging waste post-sorting facility in Wijster.

AVR Rozenburg (Rotterdam)[21]: The waste company AVR has a post-sorting facility with an adjacent incineration plant. The facility sorts out plastic, drinking cartons and some metal from the waste. The capacity is 450 000 tons annually, the waste originating from Rotterdam and other municipalities . In Rotterdam city there is no separate collection of recyclables, the waste from other municipalities may have been subject to separate collection with parts of the recyclables extracted. Thus the feedstock varies, but all feedstock is residual MSW. The output from the sorting is mixed 3D plastics, mixed 2D plastics, beverage cartons and large ferrous metals, in total 20-30% of the feedstock is extracted for recycling, the residues are incinerated at site. The plastics are sent to plastics sorting and recycling, the others directly to recycling. Approx. 15% of the feedstock is plastics, of which 75-95% can be extracted for sorting and recycling, the capture is determined by the quality requirements of the next recycling step.

Attero Wijster[22]: The waste company Attero operates a waste treatment center, including a facility for post-sorting residual MSW, a facility for sorting of separately collected packaging waste, incineration plant, biogas plant, landfill, and recycling of plastic films to pellets. Attero is a private company that contracts sorting for municipalities and the PRO. We visited the MSW and packaging sorting lines.

The MSW sorting has a capacity of 300 000 tons annually. The small (0-50mm) fraction is sent to anaerobic digestion (digestate is dried and incinerated). The separation process extracts metals (ferrous, non-ferrous), plastics (2D, PET, PP), and beverage cartons, the residues are incinerated at site. The 2D plastics are further sorted in the packaging sorting plant.

The packaging plant sorts co-mingled collected PMD (plastics, metals drinking cartons). The output from the packaging plant is LDPE, PET bottles, PET trays, HDPE, PP, mix plastics, beverage cartons, ferrous metals, and non-ferrous metals, the residues are incinerated at site. The LDPE is recycled into granulates by Attero itself in Wijster[23]. The plastics are shredded and then cold and hot washed, using cleaning agents[24].

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[21] AVR mixed waste sorting plant represents the plant studied in the project, the only municipally owned and operated mixed waste sorting plant in the Netherlands.

[22] The Attero Wijster mixed waste and separately collected packaging waste sorting plant is operated by a private waste management operator.

[23] https://www.attero.nl/en/about-waste-processing/from-packaging-waste-to-raw-materials/polymeren-recycling-plant-life-aganfoils_1/

[24] https://www.attero.nl/en/about-waste-processing/from-packaging-waste-to-raw-materials/

A previous research visit to Attero Wijster shows some changes in the configuration has happened since 9 months ago. This shows the operation is constantly being developed and the planning of such facilities must take into consideration changes in the operation.

Finland

Salpakierto runs the only post-sorting plant in Finland. However, the composition of their residual MSW can differ from other regions in Finland due to a history of separate collection of ‘energy waste’ in the region. The residual waste (and previously also the energy waste) is sorted in Salpakierto’s LATE post-sorting facility. The separated plastics is sent for pre-treatment and recycling with separately collected plastic packaging. Salpakierto also sorts the separately collected bulky waste that has been collected at civic amenity sites, this waste is used in the production of composites.

Appendix C: Mechanical recycling tests

Ilkka Rytöluoto

In WP2 of MSWPlast project, the main objective was to assess the recyclability and to establish a technical concept for mechanical recycling of 2D polyethylene (PE) fractions sorted from municipal solid waste (MSW).

The main tasks encompassed: (1) optimized laboratory-scale washing of sorted PE fractions, (2) compositional analysis of the feedstock, (3) upgrading and in-line characterization of sorted and washed LDPE fractions using VTT's advanced pilot-scale mechanical recycling line, and (4) characterization of the upgraded plastic compounds and demonstration of film processability by mono-layer cast film extrusion and biaxial stretching.

Laboratory-scale washing

The washing trials for the sorted 2D LDPE plastics were initially conducted at VTT in Bioruukki, focusing on the non-shredded LDPE clear and LDPE colored fractions from the Remeo sorting trial. The laboratory scale washing was realized in 11 kg batches in an IBC container with hot water and no detergent. However, it was concluded that the washing efficiency was inadequate and significant amount of dirt was remaining on the plastics after washing. Moreover, challenges with the mechanical stirring of the non-shredded plastics, and the presence of impurities such as dirt, metals and non-PE plastics in the feedstock further complicated the washing.

In the next stage, optimized washing was performed at National Test Centre Circular Plastics (NTCP) in the Netherlands as a part of researcher exchange. The material was shredded into 50 mm flakes before washing, and both colored and clear LDPE streams were mixed to yield enough material for extrusion. Three washing programs were studied in the laboratory scale: a cold wash with tap water at 10°C, a hot wash at 85°C, and a hot wash at 85°C with detergent. In terms of mass, the amount of surface contamination removed in the different programs was roughly equal. However, visually the sample washed in the hot wash with detergent, looked the cleanest, and this procedure was used for washing of a bigger batch of LDPE at NTCP.

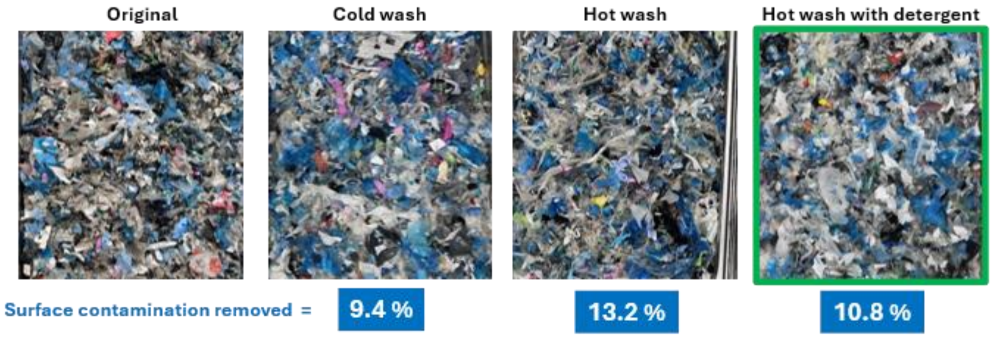

Figure C1. Optimized washing at NTCP. The pictures show the original shredded feedstock (after washing at VTT) and the feedstock after washing at NTCP by different methods.

Compositional analysis of sorted PE fractions

Before upgrading and mechanical recycling demonstration, characterization of the sorted 2D LDPE plastic film fraction was performed by using differential scanning calorimetry (DSC), Fourier-transform infrared spectroscopy (FT-IR) and thermogravimetric analysis (TGA) methods to elucidate the composition and heterogeneity of the r-PE plastic fraction. The analyses were done both on randomly selected individual plastic pieces and melt-homogenized samples.

DSC and FTIR analyses confirmed the presence of mainly L-/LDPE in the sorted 2D LDPE fraction, however, some minor polymer contaminants including PP, PA and PET were also detected in the individual plastic flake samples. TGA analyses revealed ~8% mass loss between 200-450 °C which can be attributed to organic mass, cellulosics, VOCs, waxes and moisture in the starting feedstock, for instance. Main plastic decomposition occurs between 450-500 °C which is associated mainly with the decomposition of LDPE (and other minor plastic components). The PET content was approximated to be ~5% from the TGA analyses, while the residual mass attributed to inorganic residues (metals, sand, fillers) was approximately 8-10%.

In addition to compositional analysis of the 2D LDPE fraction, also the 3D HDPE fraction from the Remeo sorting trial was analyzed by hand-held near-infrared (NIR) spectrometer. Out of the total 26.2 kg of rigid plastics analyzed by NIR, the amount of HDPE and LDPE detected were 93.0% and 5.5% respectively, while the rest were PP (1.2%) and PET (0.3%).

Upgrading of sorted and washed PE fraction

Re-processing and upgrading of the shredded and washed 2D LDPE fraction were performed at VTT by using an in-line instrumented advanced mechanical recycling line. The mechanical recycling and upgrading process in WP2 is depicted in Figure, showing the different processing steps from the upgrading trials. Based on the feedstock compositional analyses, the main approach for the material upgrading was to blend the sorted and washed 2D LDPE with virgin L-/LDPE and additives to reach suitable properties for the film demonstration. A maleic anhydride grafted compatibilizer and a proprietary antioxidant blend optimized for post-consumer L-/LDPE waste were selected, and various formulations for the material upgrading with 40-50% recycled content were established.

Continuous melt filtering of r-LDPE waste feedstock was performed using a 250 µm screen, allowing significant amounts of metals (e.g. Al foil) and other impurities (such as cellulosics, non-melted polymers and rubbers, dirt) to be removed during the extrusion processing. According to the XRF elemental analysis, ~5-6 % of the filter residues were comprised of aluminium. Other significant elements detected included e.g. Ti (possibly from pigments), Co and Pb, all in ppm range concentrations.

Figure C2. Pilot-scale advanced mechanical recycling of flexible PE plastics from MSW.

In-line rheology characterization was performed and a basis for the online tailoring of shear and elongational viscosity profiles was established, allowing for the optimization of rheology for film conversion, see Figure C3. Furthermore, in-line UV/VIS spectroscopy allowed observation of the melt-state color properties and material heterogeneity during the compounding.

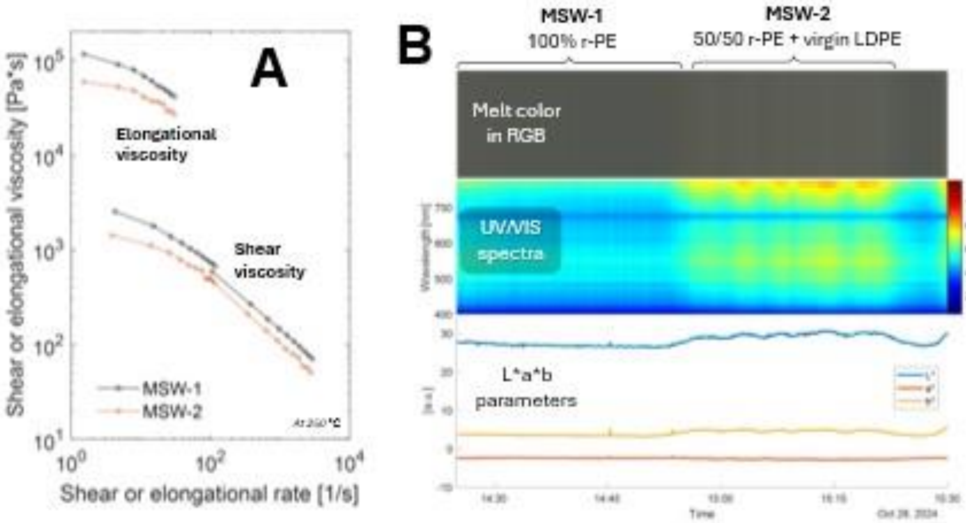

Figure C3. Example of in-line characterization data obtained during advanced mechanical recycling. A: In-line viscosity characterization. B: In-line UV/VIS data.

Film processability assessment

Film demonstrations, including mono-layer cast film extrusion and laboratory-scale biaxial stretching, were performed using the upgraded r-PE blends. The upgraded r-PE showed good processability in thin biaxially stretched films with basic mechanical characteristics comparable to those of a virgin LDPE, though with greater variability (Figure C4). Reducing the film thickness may lead to easier breakage due to impurities in r-PE. Therefore, further improvements in upgraded r-PE quality are still desirable, as impurities, mostly cellulosics, dirt and gels, are present in the films (see the optical microscopy images in Figure C4). This can potentially be achieved through a combination of improved sorting, washing, and industrial scale melt filtration with a self-cleaning filter design.

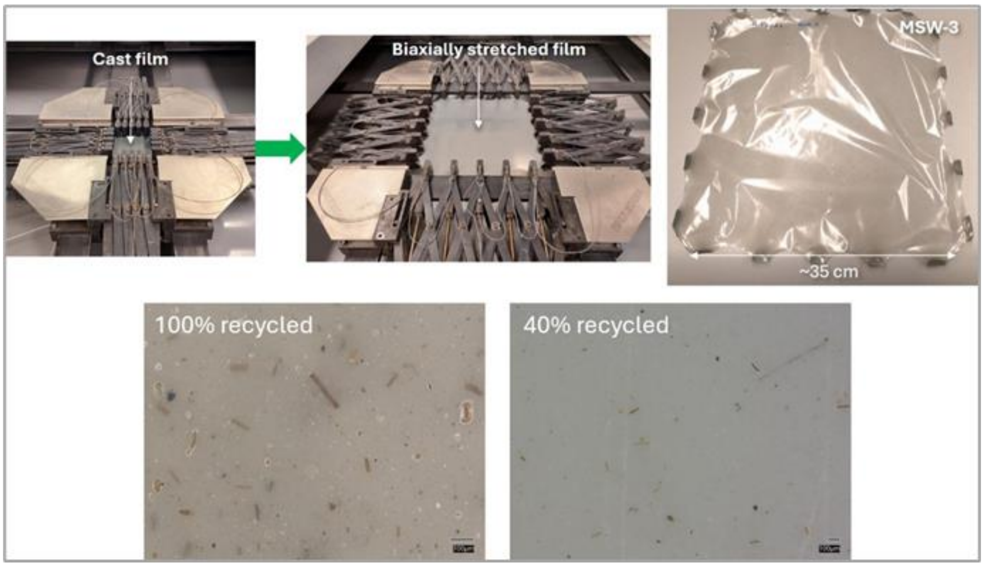

Figure C4.Top: Biaxial stretching of the mono-layer cast films produced from upgraded LDPE waste. The photograph on the right exemplifies a biaxially stretched film with 40% recycled content (3.5 x 3.5 stretch ratio). Bottom: Optical microscopy of biaxially stretched films.

In conclusion, the material demonstration showed the potential of mechanical recycling of LDPE plastic fractions sorted from MSW, with potential applications envisioned in both mono- and co-extruded film products. Further improvements in the feedstock quality are however desirable, including e.g. further removal of labels, adhesives, and inks in the washing step, and improved separation of metals and rubbers in the pre-treatment.

Appendix D: The future of residual municipal solid waste

Malin zu Castell-Rüdenhausen & Winnie Ruismäki

D1. Objectives

This study aimed to create future scenarios and analyse potential impacts on the generated residual municipal solid waste (MSW), i.e. the waste that is destined for energy recovery (waste-to-energy, WtE). The focus of the analysis was on how alternative sorting scenarios impact WtE volumes, composition, and emissions, as well as the role of plastics in the WtE process. Furthermore, the impact of improved sorting efficiency on recycling was studied.

We have built scenarios for future waste management, aiming to calculate the impacts on WtE and the potentials for extracting plastics for recycling. Firstly, the analysis shows that extracting plastics in an industrial post-sorting process would result in the reduction of waste volumes sent to WtE, while also having significant impact on the waste composition. Secondly, improving the efficiency of separate collection impacts both the volume and composition of waste. Different material fractions emit different types of emissions, with renewable materials primarily producing biogenic CO_2, while non-renewables emit fossil CO_2 in incineration. These changes in waste volumes and composition led to variations in both the energy content (MJ/kg) and emissions (kg CO_2/kg) of the WtE, which in turn has significant impact on the energy recovery potentials and emissions. Finally, the results indicate significant change in the fossil emissions per unit of energy produced (kgCO_2/GJ) when altering the composition of WtE.

D1.1 Scope

This study focuses on MSW, including waste generated at households, including also similar wastes from sources such as commerce, offices and public institutions. Packaging waste include waste fractions generated both at household and non-household activities. The non-household packaging waste is not included in MSW, whereas the packaging waste generated in households is included in MSW, thus also contributing to reaching the MSW recycling targets. Non-household packaging waste is generated in e.g. businesses and services. As the packaging waste is not fully covered by MSW, this study will not concern the recycling targets for packaging.

D2. Background

Finland generates more than 3 million tonnes of municipal waste annually, and the waste generation has increased over the past five years (see Figure D1). In 2021, the country generated 630 kg/cap of municipal waste which is significantly above the (estimated) EU27 average of 527 kg/cap.

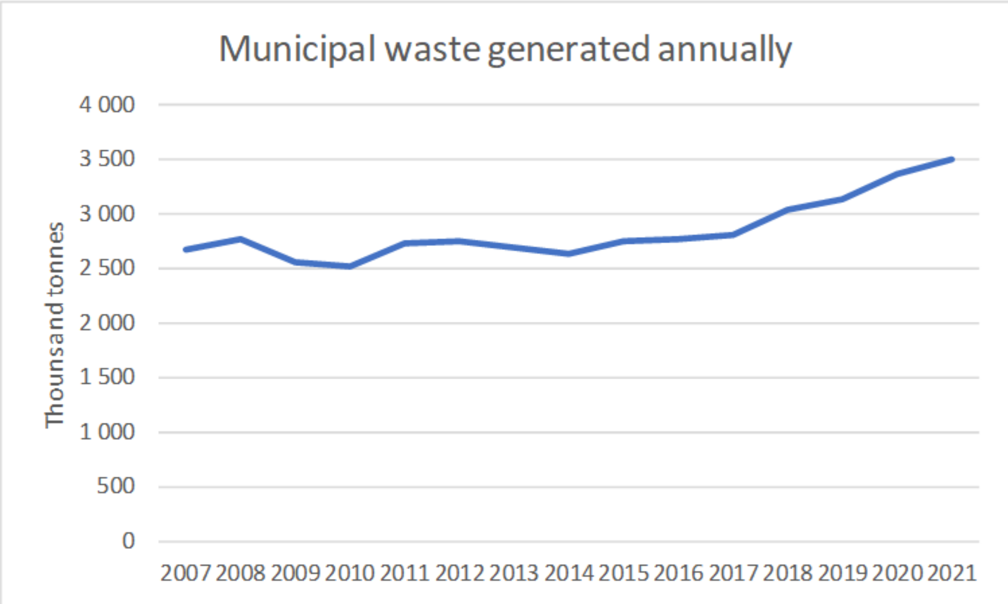

Figure D1. Annual municipal waste generation in Finland in thousand tonnes, 2007–2021 Source: (Eurostat, 2025)

Finland has a recycling rate of 39 % in 2021 and struggles to reach the recycling target of 55 % in 2025. The recycling rate has slowly increased from 33 % in 2010. Finland has made considerable progress in reducing landfilling of waste, although this has resulted in a significant increase in incineration. The incineration rate was 61 % in 2021 with a total volume of 2110 thousand tonnes. In 2021, 53 % of all MSW was collected as residual MSW. To reach the MSW recycling targets with the recycling system of today, which is highly relying on separate collection for recycling, the share of residual waste collection must reduce in favour of separate collection.

The recycling rate for packaging waste has steadily increased in the past ten years. In 2020, the recycling rate for packaging waste was 72,5 %. All packaging fractions show increasing trends in recycling rate. Finland has already reached the 2025 recycling target for packaging waste, as well as the specific targets for all material fractions, except for plastic packaging waste. The recycling rate for plastic packaging is steadily increasing – from 26 % in 2010 to 43 % in 2021. Yet, Finland is far from reaching the targets of recycling 50 % of plastic packaging in 2025 and 55 % in 2030.

The key fractions that needs to improve the recycling performance in Finland are MSW and plastic packaging. Packaging from households is included in MSW, however, packaging from businesses are not included in MSW. Increasing the share of recycled business packaging further assists in reaching the packaging recycling targets but not the MSW recycling targets.

To improve recycling of MSW (including household packaging waste), Finland has revised the waste legislation and tightened the requirements on the coverage of the separate collection system. Stepwise implemented in 2023-2024, Finland will have a door-to-door separate collection system for packaging waste at household properties with at least five apartments, that are located in urban areas with more than 200 inhabitants, as well as bring points in rural areas. In addition, a door-to-door separate collection system for bio-waste at household properties located in population centres with more than 10 000 inhabitants is introduced in 2024. In addition, Finland has a wide coverage of separate collection for non-packaging paper waste, and is also introducing separate collection of textiles.

To further promote the diversion of (mainly recyclable plastic) waste from incineration, Finland is planning to implement emissions trading[25] for waste incineration in 2028–2030. Today, the emissions trading system (ETS) is implemented in the energy sector, including co-incineration of refuse derived fuels such as SRF[26]. This has sparked a debate regarding the potentials of investments in post-sorting facilities at waste incineration plants. Sweden has already implemented ETS, which has resulted in increasing investments in post-sorting facilities adjacent to mass incineration plants, striving to reduce the plastic content of residual MSW and subsequently reduce the costs of waste incineration.

[25] The EU Emissions Trading System (EU ETS) is a system to reduce emissions via an intra-EU carbon market

[26] SRF (Solid Recovered Fuel) refuse derived fuels that have been classified according to the standard EN 15359, which prescribes the specification of -certain physical and chemical properties of the fuel.

D3. Methodology

D3.1 Scenario building for separate collection

Scenarios for modelling the development of waste generation and impacts on recycling rates, plastics recovery volumes, WtE potentials and CO2-emissions are set for the year 2030, with a linear development from Baseline in 2021. Currently some fractions already have a high separate collection efficiency, while others have significant room for improvement, thus, when increasing separate collection to improve total MSW recycling, different materials are targeted, impacting the composition of the residual MSW.

- **Baseline** was set to 2021 due to good availability of data from 2021. The baseline composition of residual MSW was acquired by combining several literature sources. The general assumption that 70 % of residual waste is from households and 30 % from non-households was used. The household composition was generated by interpolation of two datasets by KIVO (2020 and 2023) (KIVO, 2024, 2020). The non-household composition used results from composition studies done in the Circwaste project (Materiaalit kiertoon, 2024), with the assumption that the non-household waste generation is divided between grocery stores (50 %), hotels (12,50 %), restaurants (12,50 %), and municipal services (25 %)27. The combination of all data sets gave the baseline composition (see Figure D2). Waste generation values (per capita) for 2019 was used due to impact of COVID-19 in 2021, combined with population in 2021 to get the total waste generation for Baseline. The recycling rate for MSW was 39 %.

[27] This is an assumption = expert opinion

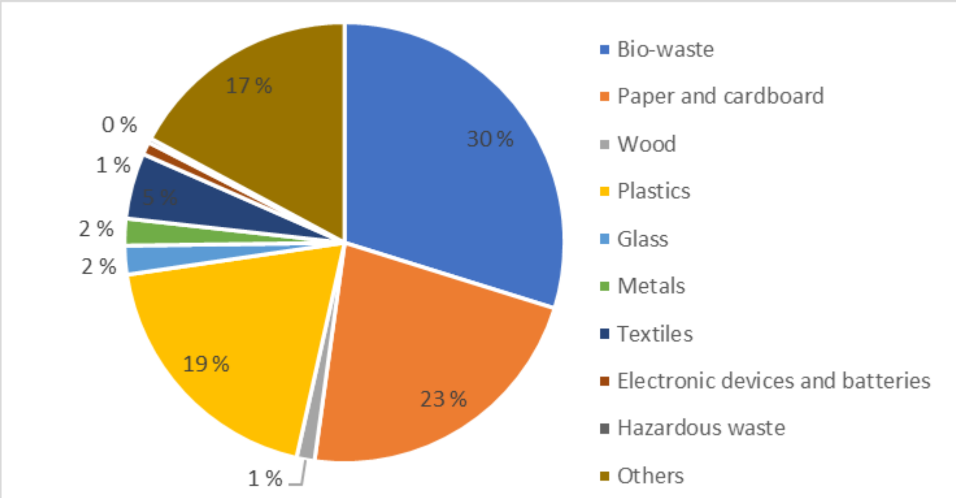

Figure D2. The baseline composition of residual municipal waste

Although MSW generation shows an increasing trend, the waste legislation and National Waste Management Programme also presents several policies and measures for waste prevention, which are expected to counterbalance the increasing trend on waste generation. Thus, this study makes the assumption that waste generation would remain at Baseline level for Scenarios 1-3.

Based on the current separate collection efficiency (Tilastokeskus, 2024), bio-waste and plastic packaging were identified as having the poorest performance and thus the most potential for increasing separate collection efficiencies and recycling rates. This is also in line with the background study by the government of Finland related to the impacts of the legislative revisions (Government of Finland, 2021). Thus, plastics and biowaste are focus materials for the improved separate collection in Scenarios 1-3.

- **Scenario 1** represents current policy steering using the rationale from the Finnish National Waste Plan (Ympäristöministeriö, 2022) and the Finnish waste law revision. The impact analysis presented by the Government of Finland (2021) related to the waste law revision gives an estimated 5–10 percentage point increase in recycling rate due to improvements in the separate collection system. Scenario1 aims at the optimistic improvement, where better separate collection efficiency would lead to a 10 percentage point increase in recycling rate, from 39 % in 2021 to 49 % in 2030.
- **Scenario 2** represents the required improvements in separate collection efficiency to reach the 2030 recycling rate targets of 60 % for MSW as stated in the revised Waste Framework Directive (2008/98/EC). The capture rate of the separate collection system was increased until the pre-defined recycling rate was reached. The capture rates of bio-waste and plastic packaging were increased more than that the other separately collected fractions (paper and cardboard, glass, metals, and textiles).
- **Scenario 3** represent current policy landscape (Scenario1) being supported by post-sorting of residual MSW to increase plastics recycling. This scenario utilizes separate collection at Scenario1 level. At a post-sorting facility, 75 % of the plastics in the residual MSW would be extracted for recycling, of which 50 % is recycled into secondary raw materials.

D4. Results

Shifting MSW volumes, increasing separate collection, and implementation of post-sorting would result in changes in the volumes and composition of the residual MSW. This section provides an overview of the key results.

With a steady MSW generation, increasing separate collection would result in reduction of the residual waste volumes that are sent to incineration. Scenarios 1-3 divert waste from the residual fraction, while the implementation of post-sorting in Scenario3 also would have significant impact on the composition of the waste sent to incineration (see Figure D3).

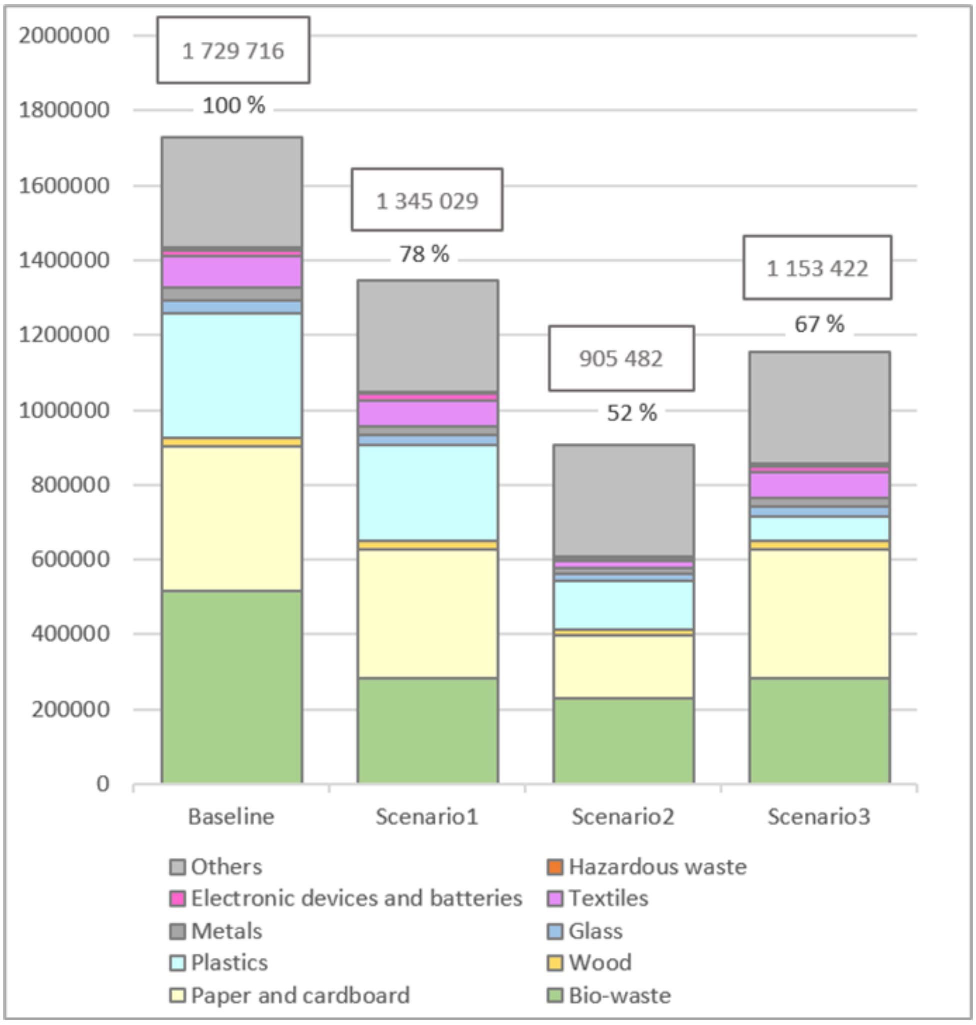

Figure D3. Volumes and composition of waste sent to incineration in Baseline and Scenarios 1-3

Plastics have a significant energy content, and the removal of plastics has an impact on the energy content of the residual waste sent to incineration. Declining waste volumes combined with reduction in calorific value has a significant impact on the total potentials for generating energy from residual waste. Figure D4 presents the total energy content for scenarios 1-3 in comparison to Baseline (100%). Different material fractions also have different types of emissions, where renewable materials mainly have biogenic CO2 output and non—renewable materials emit fossil CO2 in incineration. The final emissions per unit of energy produced (kgCO2/GJ) changes when altering the composition, as illustrated in Figure D5.

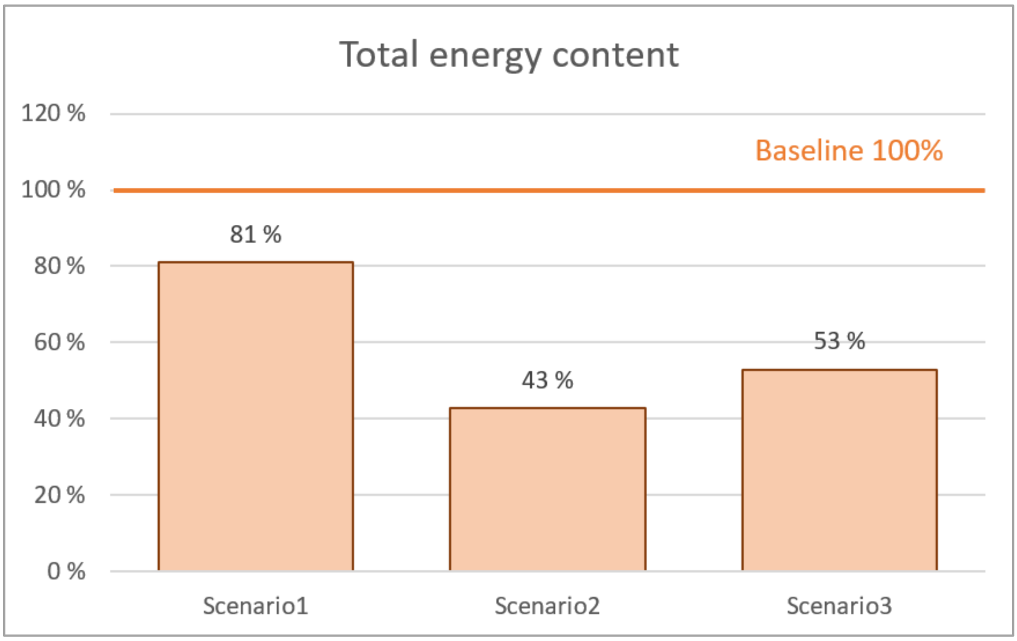

Figure D4. Total energy content in waste sent to incineration - relative to baseline (100%)

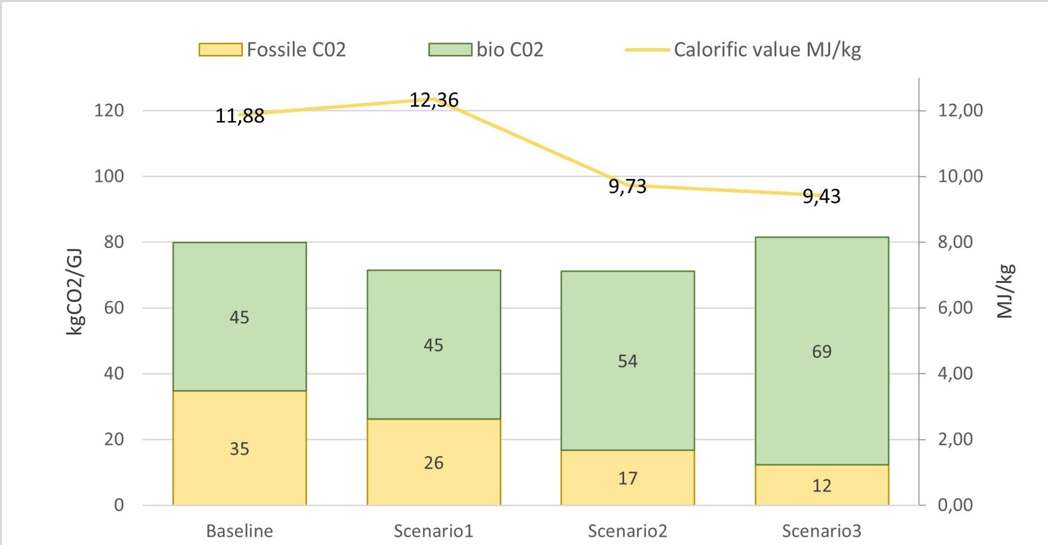

Figure D5. Emissions CO_2/GJ and calorific value MJ/kg for the waste sent to incineration in all scenarios

Correction [3.1.2025]: The original Figure D5 presented values for CO2/t, the corrected figure displays the values correctly, as kgCO2/GJ.

The production of secondary plastics show a significant improvement in the modelled scenarios. In Scenario1 the volume of recovered plastics has more than doubled from Baseline. The major difference between scenarios 1 and 3 is the recovery of plastics in the post-sorting facility. However, while increasing the plastics recovery rate by 53 %, it increases the MSW recycling rate by only 3 percentage points, leading to a MSW recycling rate of 52 %. As expected, Scenario2, which is built to reach the 60% recycling target[28], presents significant increase in the volume of recovered plastics since plastics is a focus material for the improved separate collection. The recovered volumes in Figure D6 are calculated under the assumption that the recycling would capture as much materials as in Scenarios 1-3 as in the Baseline Scenario[29].

[28] The separate collection system must become significantly more efficient for reaching the 60 % recycling rate, the separate collection must capture 70-90 % of most fractions, a more than threefold increase for plastic packaging waste compared to Baseline.

[29] The impacts of increased separate collection and post-sorting on the final recycling rates are difficult to assess due to uncertainty of material quality when increasing the capture rates.

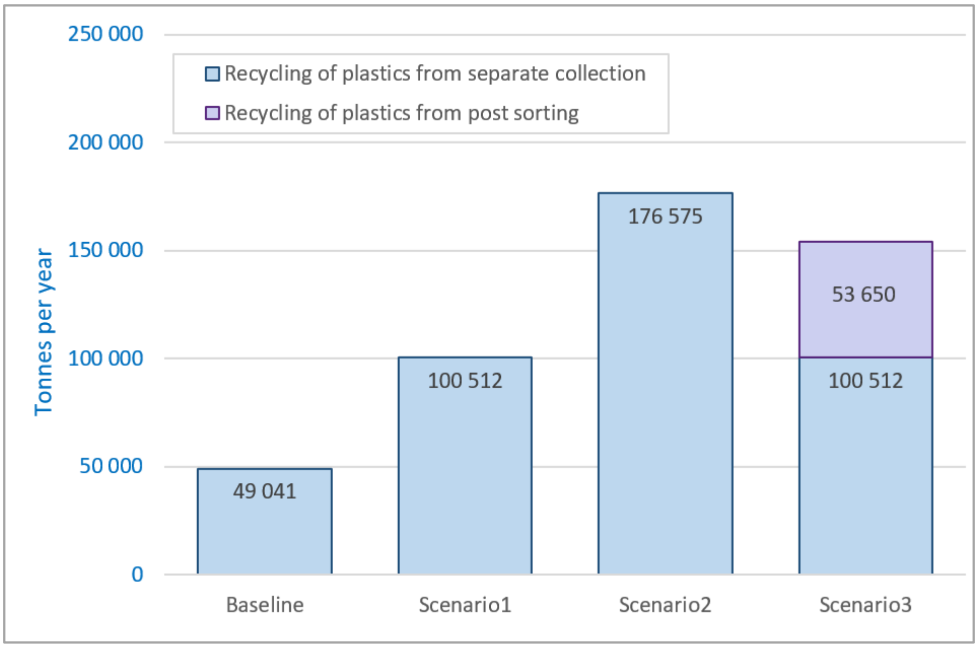

Figure D6. The production of secondary plastics for all scenarios

The final recycling rate for plastic packaging cannot be calculated based on MSW recycling alone; MSW contains also non-packaging plastics, while plastic packaging includes also industrial and commercial packaging that is not included in MSW.

Scenario 3 shows that the recycling rate for plastic packaging would increase significantly if implementing post-sorting. The 53650[30] tonnes of plastic waste annually extracted from residual MSW contains significant volumes of packaging, which could increase the recycling rate of plastic packaging waste up to 22 percentage points if calculating as the share of the reported 166 thousand tonnes of plastic packaging put on the market in 2021. However, if calculating as the share of the calculated total plastic packaging waste generation[31], the increase in the recycling rate for plastic packaging waste would be 11 percentage points. This would require efficient post-sorting of all residual MSW in Finland.

[30] Assumptions made: 76 % of the plastic waste in residual MSW is packaging (HSY, 2019) and 44 % of the plastic packaging waste is moisture and food residues (RVF, 2005)

[31] Same assumptions as above related to residual MSW and assuming 80 % of separately collected plastic packaging waste being plastics.

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Appendix E: Viable ecosystems integrating the separation of plastics from RMSW into the current plastic value chain

RESEARCH REPORT VTT-00039-25

Mona Arnold

E1. Introduction

This report aims to give a description of viable ecosystems integrating the centralised industrial separation of plastics from residual municipal solid waste (RMSW) into the current Finnish plastic waste value chain. The value network analysis will consider the relationships with existing or new recycling systems, such as the Producer Responsibility of plastic packaging, and through tangible case studies include an estimate of a cost structure for MSW plastics subject to producer responsibility. The work is based on grey and scientific literature and interviews of national and international experts and value chain stakeholders.

E1.1 Background

Despite established directives and regulations relating to the end of life of plastic goods and established source separation systems, a significant proportion of recyclable plastic still ends up in the residual municipal waste. The statistics of 2021 (PirELY 2022) showed that only 41% of plastic packaging material placed on the Finnish markets were separately collected for recycling. 15-20 % of the mixed residual waste is plastics, a large proportion of which is packaging waste (PPW) which falls under the extended producer responsibility (EPR) regulation. Complementary actions and solutions are necessary in order to achieve the targets set by the European Commission 50% of PPW recycled by 2025 and 55% by 2030 (European Parliament 2024). Moreover, according to 2024 national budget, Finland pays the EU 88 M€ annually in plastic waste fees (Laatikainen 2024).

E1.2 Value networks

While there is no agreed upon definition of value network, it can be generally described as a network of roles linked by interactions in which economic entities engage in both tangible and intangible exchanges to achieve economic or social good (Figure E1). This definition is comparable to the one given by Allee (2008).

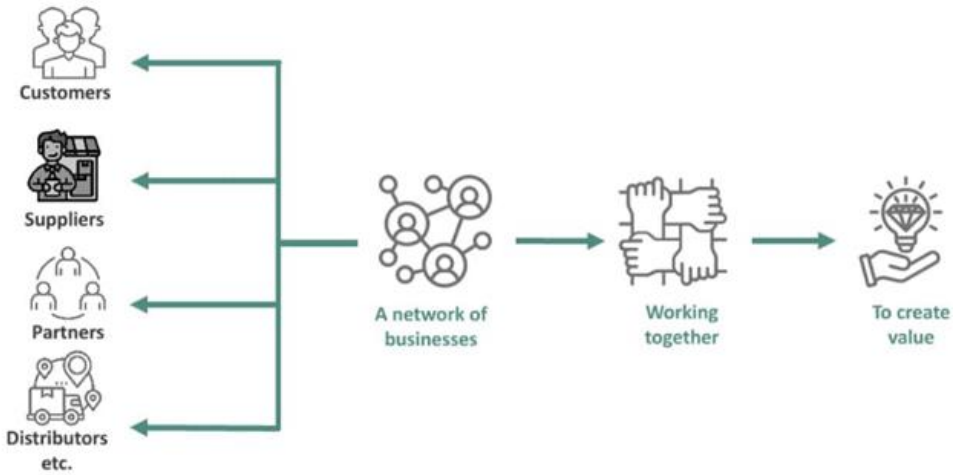

Figure E1. Value network (modified from Khalid 2023[32]).

In this context a plastic value chain has a double goal; while its social goal is to achieve significant circularity for the plastic material, it also needs to create economic value for its partners. Driven by both regulation and economic incentives, the common goal for plastic value networks is achieving closed loops for the material.

While source separation of plastic packaging waste is established in most European countries the efficiency of separate collection remains low. A major part of plastics packaging waste still ends up in the residual MSW and is consequently incinerated. An alternative or complementary approach which has been launched in a handful of countries is centralised industrial separation of plastics waste and other recyclable fractions from the collected RMSW.

E2. Goal and limitations

This report aims to analyse the added value and enabling factors of a plastic waste business ecosystem which includes the centralised automated sorting of plastics from residual MSW. Thus it does not give a complete overview of all technological, policy and socio-economic factors contributing to the creation of plastic waste business ecosystems. Moreover, only isolated cost figures are disclosed as allocated resources did not allow to provide complete coverage of the financial aspects of investment in equipment in the studied cases/countries. The geographical focus is European countries.

[32] https://www.wallstreetmojo.com/value-network/

E3. Methods

The methodology employed in this study involved a comprehensive approach combining interviews, scientific articles, and grey literature. Semi-structured interviews were conducted with key stakeholders to gain qualitative insights and diverse perspectives on the research topic. Scientific articles from peer-reviewed journals provided a foundation of validated, evidence-based knowledge, ensuring the incorporation of current academic findings. Additionally, grey literature, such as reports, and policy documents was utilized to capture relevant, non-traditional sources of information not readily available in scholarly databases. This multi-source approach enabled a robust analysis of the subject matter.

The interviewees represented international experts and ecosystem partners in four selected countries. The latter took mostly place in connection to site visits. In addition, MSW project partners were interviewed about their view on future plastics waste business ecosystems in Finland and their own role in its creation.

A list of site visits contributed to this report and interviewees is provided in the end of Appendix E.

E4. Results

E4.1 Value chains and business ecosystems in forerunner countries

E4.1.1 Norway

Norway implements strongly decentralised decision-making taken to the municipal level. Municipalities are independently responsible for their own environmental strategy and regional solutions apply. On a national level, Norway has set similar national environmental targets as those of the EU, i.e. aims at reaching 50 % recovery rate by 50 % recycling rate for plastic packaging by 2025, stated in the packaging and packaging waste directive (94/62/EC) as amended in 2018. Like many other EU countries, the target is far from reached; while the average plastics consumption is 26 kg/inh. and year, the Norwegian average recovery rate is 7-9 kg (31%) and even lower in Oslo, 3.5 kg). Post separation of plastics from RMSW has been installed in two regions, as an alternative to source separation at households, by which targeted recovery rates has not been reached.

Kamfjord et al (2021a) estimated that to reach the Norwegian target, 50% material recovery, a further 140,000 tonnes are needed to be recovered, requiring the development of material recycling capacity and new markets for material recycled plastic. To reach the target, additional capacity to sort out plastic waste from 1.6 million tonnes of residual waste from households and businesses is needed. Kamfjord et al recommended 10 rough sorting facilities in addition to capacity for household-like waste from business. There will also be a need for one national facility for fine sorting and a national facility for upgrading and production of new plastic raw material which to a greater extent can deliver the quality in demand to plastic product manufacturers in the Norwegian plastics industry and abroad. Such a plant can produce LDPE, HDPE and PP which make up a large proportion of the polymer types found in the waste. Total investments for the development of infrastructure for sorting and material recycling of household and commercial waste was estimated at 6.8 billion NOK (576 M€). With the additional supply, Norwegian plastic goods industry has the potential to increase the use of recycled plastic by an estimated 50,000 tonnes.

Figure E2 shows the flow chart for ROAF, Romarike Avfallsforedling, Romarrike region post sorting facility, which separates waste collected from 7 % of Norway's inhabitants. In 2024, ROAF plant was the only functioning post sorting facility in Norway, after the closedown of IVAR post-sorting facility, caused by a fire accident. The plant sorts mixed household and industrial waste into eight fractions of which four monoplastics fractions are baled and exported. According to plant management, the initiative to the investment was not directly regulatory driven, but a forerunner regional manager convincing member municipality of the needed investment (Figure E3**Figure**).

Acknowledging the need for higher recovery the Norwegian PRO Plastretur has recently found a joint venture with the technology provider Tomra and invested in a plastic packaging sorting plant. The 90 000 kton/a capacity plant will sort municipal sourced-separated and mechanically recovered mixed plastic waste into seven types of plastic which will be processed into high-quality fractions that are ready to be used to produce new packaging and other high-quality products. In the new venture, Plastretur will continue to take responsibility for sourcing plastic packaging waste from Norwegian municipalities, trade and industry, and deliver this to the plant as input. TOMRA will be responsible for grading the fractions based on type and selling the plastic output. Residual material will be sent to incineration. The 50 M€ TPRF plant (Tomra Plastics Recycling Facility) is planned to be in operation in the middle of 2025.

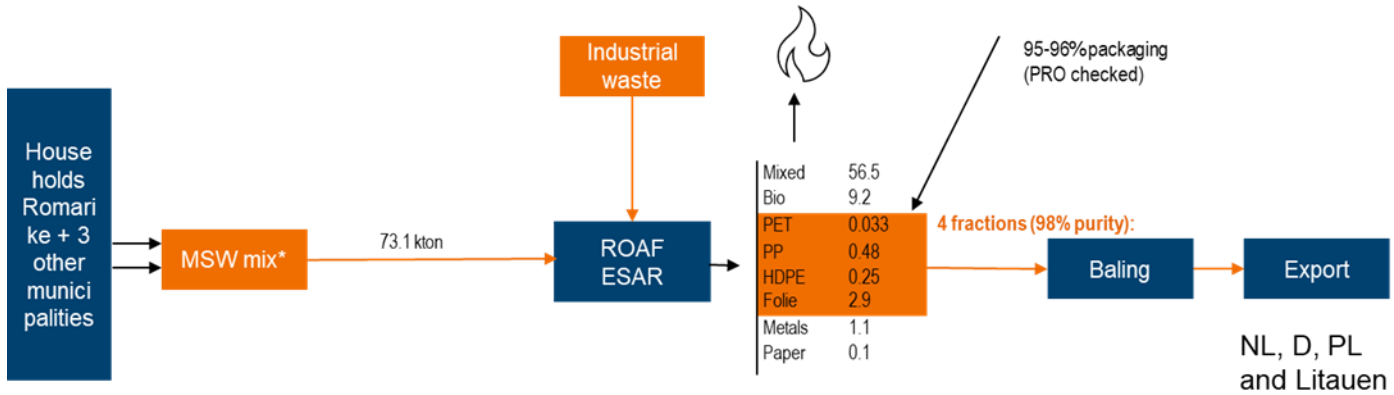

Figure E2. ROAF post separation plant. MSW mix contains bio in green bags, but ROAF has plans for full source separation to increase separation motivation (as of 2024)

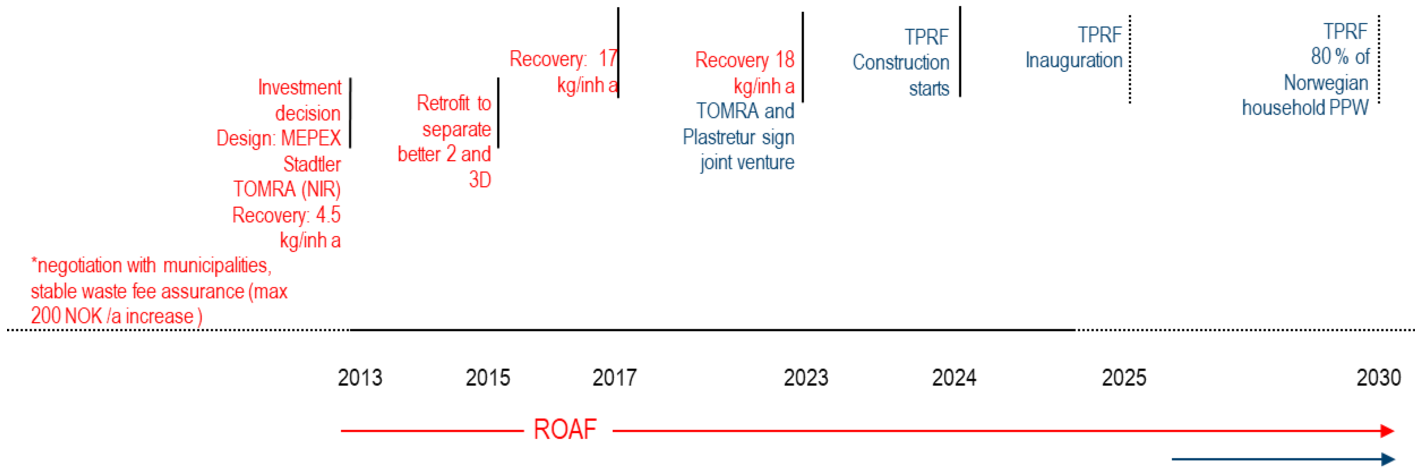

Figure E3. Development of post separation and recovery of plastics waste in Norway.

E4.1.2 Netherlands

The Netherlands implemented as one of the first European countries source separation of packaging waste applying a co-mingled systems where PMD (plastic, metal, and beverage carton packaging) are collected in one fraction. The country also hosts several waste separation facilities; N+P Rotterdam, Attero Wijster, Prezero Zwolle and KSI Heerenveen, the major part privatised since 2012. The producer responsibility organisation Verpact charges one of the highest EPR-fees from the producers 1.10 €/kg as of Q2 2024 (Thoden van Velzen 2024; KiDV 2024).

Figure E4 depicts the value chain of the Attero separation facility. Originally built by municipalities in 2005, the now private company separates 90 kton/a of PMD and residual mixed waste into 10 fractions. Packaging monofractions are further delivered to their owner, the PRO organisation, whereas mixed plastics (non-packaging) and foils are washed and sold to recyclers in the Netherlands or abroad.

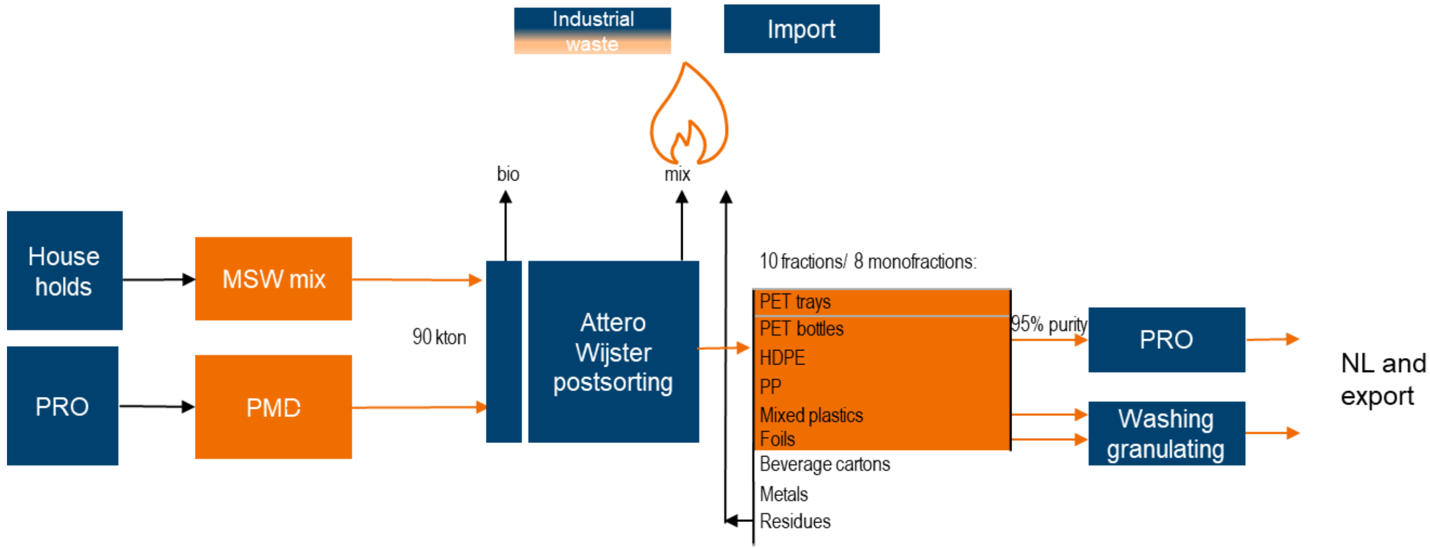

Figure E4. Attero waste separation value chain

E4.1.3 Sweden

The first plastic waste value chain which included post-sorting of mixed municipal waste commenced in 2021 and is currently owned and operated by the waste company SÖRAB. The facility is directly connected to Stockholm Exergi's incineration plant who made the investment. The facility sorts out plastic and metal from the waste, as well as organic waste which has been collected in green bags. The planned capacity is 140 000 tons annually. In total, approximately 11 tons of plastic and 2.5 tons of metal are sorted out annually (Figure E5). Sorted plastics are separated from the waste and sent to SPÅ Waste Zero plastics sorting plant.

The investment in the plastic sorting plant followed a sharp increase in the carbon tax, which Sweden, as the first country in the EU had put on waste incineration already 2013 (Figure E6**Figure**). By sorting out the fossil plastic the waste incineration can significantly avoid or minimise its carbon tax, as the incoming waste has a plastic share of approx. 18 %.

Figure E6 also indicates the prerequisite for Sörab's 450 MSEK investment. The outlet for post separated plastics was in place by the construction of a plastic sorting plant built by the PRO Svensk PlastÅtervinning (SPÅ), inaugurated 2019. Moreover, the investment received 134 MSEK support from the government's strategic program Klimatklivet.

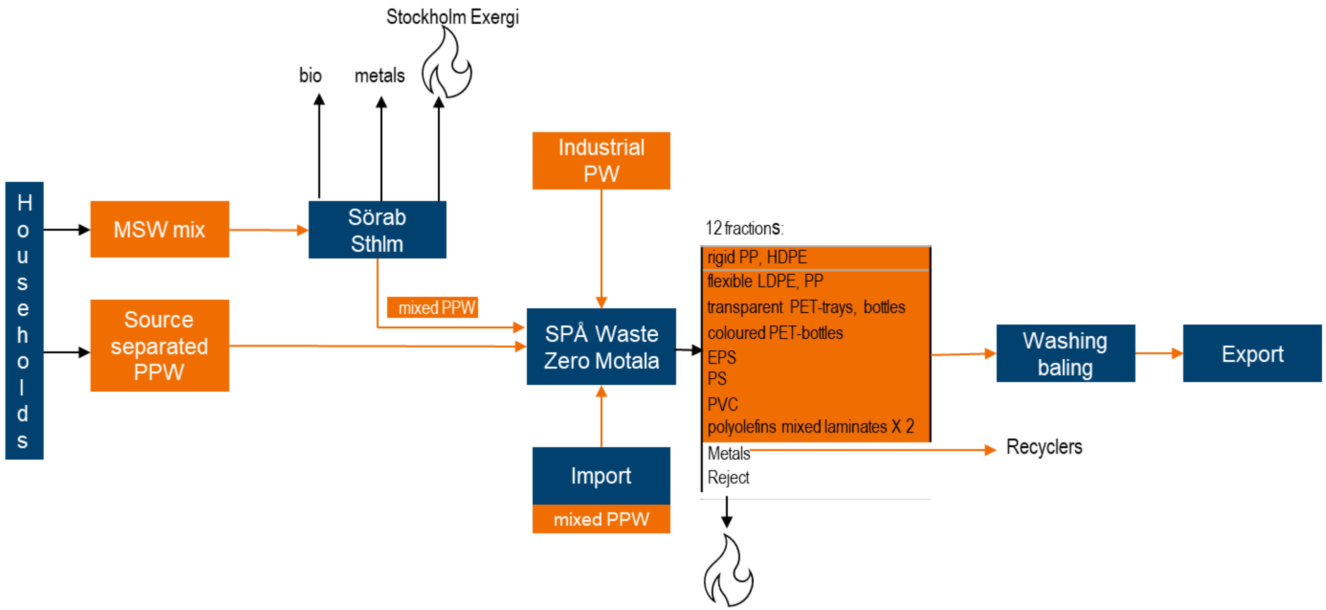

Figure E5. Value chain of municipal plastic waste from Stockholm area.

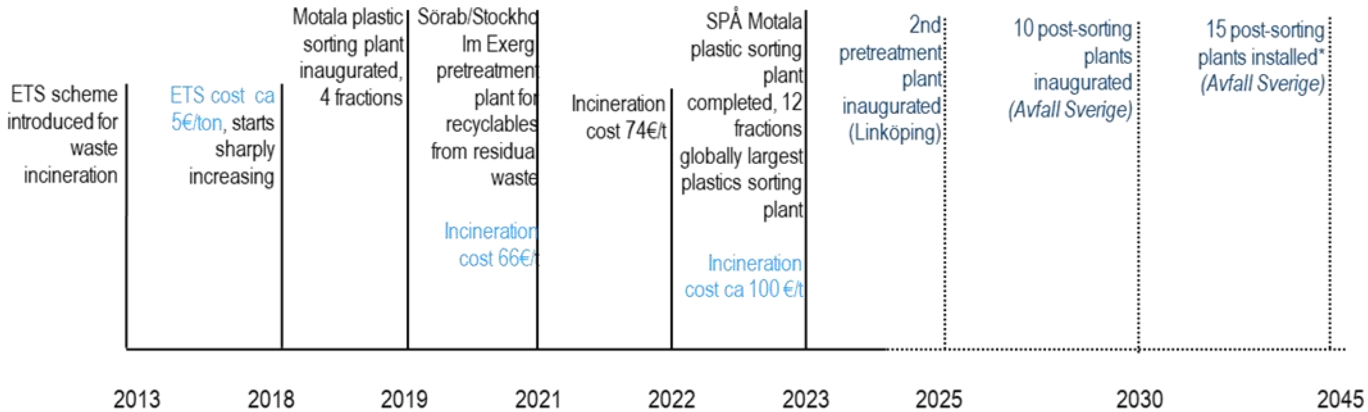

Figure E6. Capacity building to increase plastic waste recovery (Avfall Sverige = 2050 Consulting 2021)

According to the interviewee, SPÅ paid Brista for recovered plastics (through EPR fees) until 2023. However, this finance seized since 1/2024. Instead, the economy is built upon the fact that gate fee to incineration plant for fossil free waste is 400 SEK/ton, while a fossil content rises the fee to 800-1000 SEK/a.

Sweden is, as of 2024, introducing separate collection of all packaging waste fractions at all properties throughout the country. However, as Sweden has also implemented emissions trading for waste incineration, waste incineration plants are increasingly investing in post-sorting to remove the plastics and thus reducing fossil CO2-emissions which are covered by emissions trading. These two mechanisms are expected to bring the plastic packaging recycling rates of Sweden to the target level for recycling as stated in Swedish legislation and the Packaging and Packaging Waste Directive (Stenmark, 2024).

SPÅ Ab plastic sorting plant, Site Zero

The SPÅ sorting plant Site Zero in Motala is the largest plastics sorting and recycling facility in the Nordic countries. It has a full capacity of 200 000 tons, with 60 NIR sensors for separation of 12 different fractions. The sorted plastics are baled and then exported to recyclers, mainly in Central Europe. The sorted plastics has a content of 95 % of the target polymer in all fractions.

The post-separated plastics from Sörab makes up ca 6 % of SPÅ's current input, the other ones being mostly domestic and foreign source separated plastics. According to the operators, the main difference between these flows is the post-separated's higher proportions of films and less 3D plastics. The post separated mixed plastic waste is thus first sorted in a separate line, before joined with the main sorting lines for final sorting. This is due to the different optimization of the different feeds.

E5. Value creation in a Finnish business ecosystem

Factors affecting the creation of a future business ecosystems involving centralised separation of plastic material from residual municipal waste were identified by interviewing central actors and project participants

Figure E7 depicts a general plastic waste value chain where the interviewees are marked in red. The interviews related to current and future position in the plastic value chain as well as barriers and drivers affecting future possible investments and/or new operations. Weight was put on possible future capacity of post separation of residual MSW.

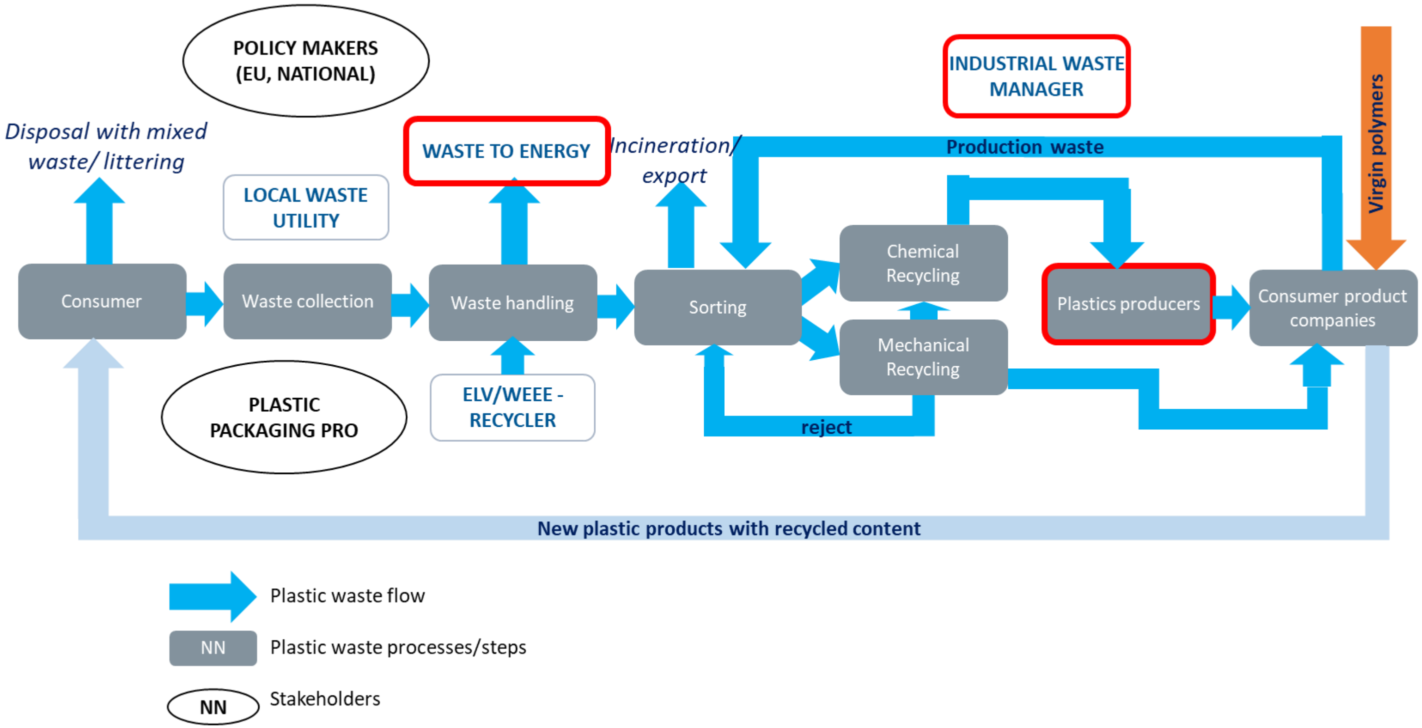

Figure E7. Plastic waste value chain. Modified from Arnold 2022.

As follows some main discussion points relevant to the business ecosystems.

Generally, circular economy models add complexity to supply chains. While the supply of virgin polymers is normally not associated with challenges in quality and quantity, suppliers of recyclates are able to provide lower quantities at a time and normally with some variation in quality, depending on the origin (country, recycler). Generally, more restricted supply implies that a wider network of various suppliers is needed to assure a resilient supply. The buyer of recyclates sets tight criteria on the polymer quality. Offtaking contracts also include also a certain minimum delivery volume which adds some pressure upwards the value chain.

Processing waste into recyclates involves several steps, which altogether adds to the price of recycled material, compared to its virgin equivalent. Thereby, the offtaker needs to face clear incentives to adopt the price premium of recyclates, either internal deriving from the company's sustainability strategy or external, which derive from climate policies and /or EU circular economy directives. circular economy. In times of low prices of virgin material, markets become especially challenging and investments in waste processing are easily halted.

A mixed waste sorting plant is a huge investment with all required sensing and automation equipment. Thus only plants with significant, > 100 tonne/a, sorting capacity can pay off the investment. In Finland only few waste utilities are collecting required tonnage of residual MSW, which sets limits to the localisation of such a plant. The municipal waste management market is typically characterised by long-term contracts, which adds security to operations, when/if such contracts can be established between the municipal waste collector and a post-sorting service.

While the transportation of mixed and sorted plastic waste takes place across borders, international movement of voluminous non-value residual waste is mainly related to energy recovery and not for material recovery. However, for covering lost waste volumes due to possible increase in separate collection and removal of materials from residual MSW at central sorting plants, imports of residual MSW could be a potential solution that would enable the newly built high-tech waste-to energy plants to produce district heating and electricity.

As a whole, future carbon tax for waste incineration overrode other plastic waste relating policies as a driver for investment in centralised waste sorting. Secondly, the national implementation of plastic waste legislation was seen important, but at this point, its impact cannot be foreseen. Interestingly, the role of extended producer responsibility of packaging put on the market, was hardly noted, though factor underlying the policy environment.

Figure E8 depicts as a summary the value creation of RMSW sorting. Figure E9 gives a SWOT analysis based on conducted interviews.

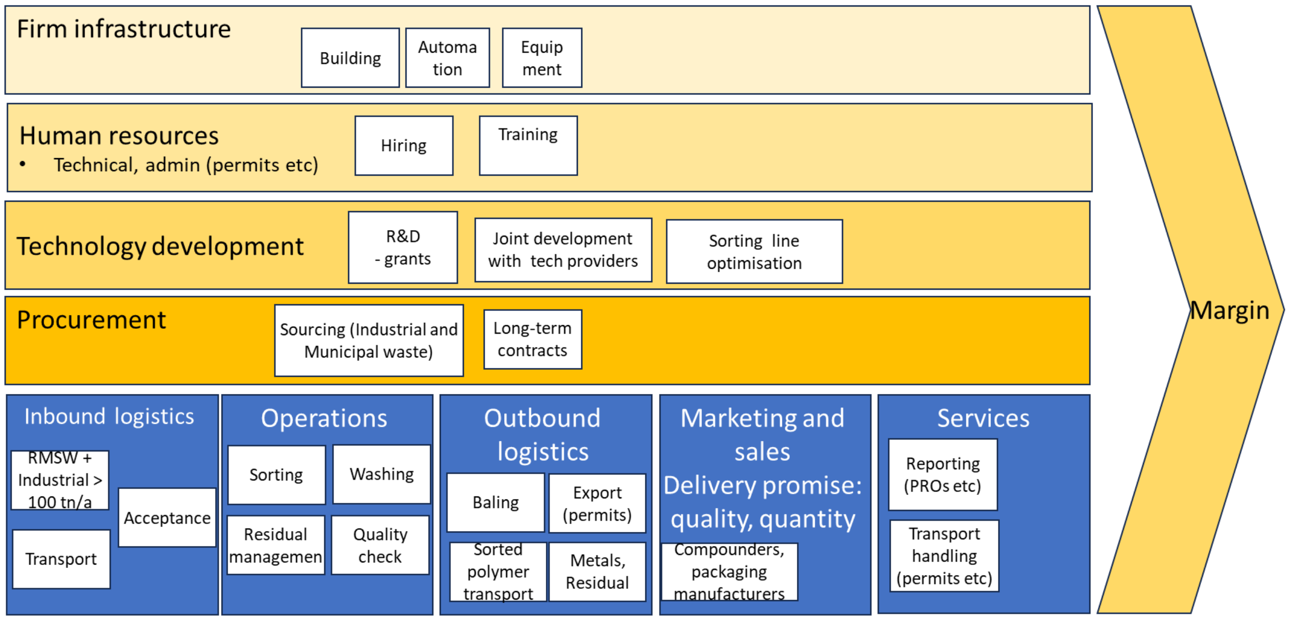

Figure E8. Value adding activities from the raw material supplier (MSW generation) to the end customer (buyer of recyclate). Model according to Porter (1985).

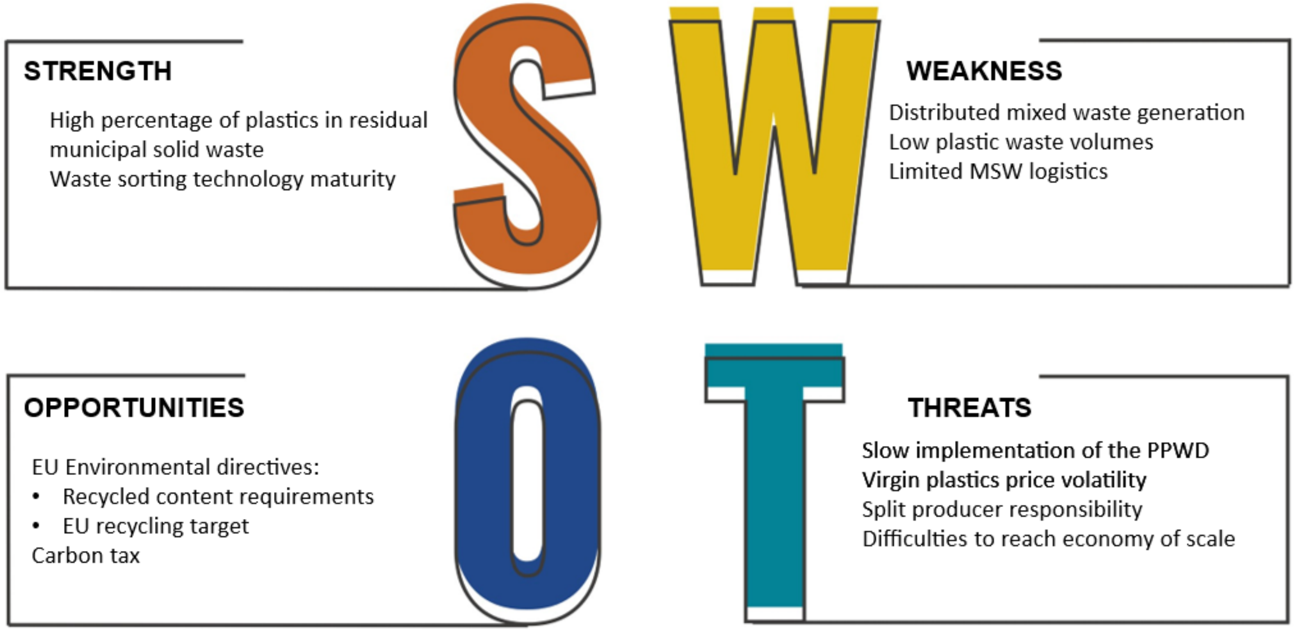

Figure E9. SWOT analysis

E6. Discussion

E6.1 Policy impact on technology development and innovation

Environmental regulation has been a main driver enhancing circular strategies for plastics. Likewise, policy impact was acknowledged in several interviews, however not unambiguously. Also the results from a substantial body of research on the relationship between environmental regulation and economic growth, remain contentious. Environmental regulation is generally regarded as promoting the uptake of innovations, but depending on the time frame and intensity, also opposite effects can take over. Firms can either become more creative or abandon a risk-prone strategy.

Detailed analyses on Policies relating to plastics waste and post sorting of plastics from RMSW have been elaborated by the Finnish Environmental Institute (WP4). Policies' impact on technology and business innovation were again analysed by Arnold (2024) who raised some following focal policy tools:

- *Extended Producer Responsibility (EPR)* encourages producers to design products that are easier to recycle
- *Recycled Content Mandates* creates a steady demand for recycled plastics, encouraging companies to improve quality and cost-efficiency of recycling technologies.
- *Plastic Waste Import/Export Control* forces countries to develop better local recycling systems and promotes investment in technology to process plastics that are traditionally hard to recycle.
- *Tax Incentives for CE Initiatives* incentivize Companies to develop new business models.
- *Eco-Labelling, Green Certifications* increases awareness and changed consumer references drive companies to innovate in recycling tech and processes to meet demand. This same driving effect can be reached by *Public Awareness/Education Campaigns*
- *Carbon Pricing or Plastic Tax* can shift the economic balance in favour of recycled plastics, incentivizing the recycling industry to develop more efficient, low-cost recycling processes. It also spurs innovation in alternative materials or sustainable product design to reduce dependency on virgin plastics.
- *Plastic Ban Policies* need to be paired with innovation support policies/ grants to develop alternatives.
- *Research and Development Grants Policy* provides funding for research into new plastic recycling technologies.

Findings from the interviews indicate, that of the policy tools listed above, carbon pricing is seen especially important for driving new investments in central sorting of residual MSW.

E6.2 Economic aspects

Waste is generated by both the general public and industries, resulting in continuous fluctuations in its composition and quantity. These variations are influenced by consumer behaviour and industrial production trends.

Although sorting technologies enable waste managers to extract valuable fractions and control contaminants to some extent, they do not regulate the composition of incoming waste. As a result, the types of materials suitable for various applications fluctuate constantly. There is also a strong correlation between the quality of feedstock waste and the quality of reprocessed output, affecting both mechanical and chemical recycling processes.

This dynamic often creates a supply-demand mismatch. Combined with the need for quick material turnover, it contributes to significant price volatility. For example, between Q3/2022 and Q2/2024, prices for 90% mixed polyolefin bales in northwest Europe ranged from €0 to €600/tonne. The price spread across different grade recyclate is significant.

In 2024, for instance, the price spread for recycled polypropylene (R-PP) in Europe reached up to €1,500/tonne. This difference was seen between the highest-priced grade and the lowest-priced grade—black injection-moulded pellets, which are typically used for non-packaging applications (Packaging Europe, 2024).

The inherent volatility of plastic polymer prices necessitates robust strategies for businesses to manage exposure to such fluctuations. Low polymer prices have a particularly severe impact on the recycling industry. Mechanical recycling, with its relatively high variable costs, becomes less viable under these conditions (Boswell, 2023). During the last years, especially Asian polymer producers have flooded the European markets with very low-priced for virgin polymers (e.g. Svensk Plaståtervinning 2024). Especially off-grade or wide-specification materials, often result in the substitution of recycled products. Producers may prioritize virgin materials due to their higher performance and the potential for increased productivity in cost calculations. Increased storage capacity of sorted plastic waste can be used as a buffer in times of low waste prices, and the option to store sorted plastics to wait for price increase is indeed practiced at the described sites in Norway and Sweden where the sorting facility also owns the waste. The Dutch Attero, again, processes the packaging waste for the PRO, which owns the waste and manages the clientele pool for the sorted packaging materials.

Volatile feedstock costs also result in challenges for investment. New actors seeking private investment are often required to project future costs, with waste feedstock typically their largest variable cost. The unpredictability of waste values makes the projection exceptionally difficult.

In the future upscaling of chemical recycling of plastics waste may provide a meaningful additional outlet especially for plastics waste separated from RMSW. Cleanliness and homogeneity criteria are foreseen to be less strict for chemical recycling compared to those set for mechanical recycling.

E7. Conclusions and future research

The report assesses value creation in industrial central post-sorting RMSW for plastic recovery. The conclusions are in the first hand based on conducted interviews and recycling site visits.

The entire value chain, including the end user of recyclate, must be in place to enable investment and implementation of post-sorting RMSW. Regulation plays an essential role to sustain the business ecosystem. The volatility of the plastic material market as well as fluctuating energy prices can have significant impact on the recycling business, indicated e.g. by the progress of Viridor (UK) plastic recycling facility, which shot down after only two years of operation (Bosley 2024).The European case examples and interviews of Finnish plastic waste business actors underline that in Europe, the legislation relating to recycled content of packaging and as well as to carbon mitigation are essential to create efficient circular ecosystems thereby also enhancing technology development. In the absence of driving regulation, the volatility of virgin plastic raw material makes the business environment very insecure and plastic recyclates can hardly, in the near future, compete with the price and easiness associated with virgin material supply, as noted by one of the Finnish interviewees.

Although the demand and price of plastic recyclate are foreseen to rise in future, e.g. as a result of the requirement of recycled content, the current markets for recyclate continues to be demanding, As noted by one interviewee, before the implementations of regulation, foreseen by 2030 in EU, raw material prices dominate the picture and the current ow prices of virgin polymer producers.

E7.1 Future research

The value chains described in this report are traditional linear models with clear roles of the supplier manufacturer/processer and the end customer. Future research could put stronger emphasis on co-development and co-innovation in relation to individual firms' business model innovation. Having a conscious ecosystem orchestration strategy can offer additional gain of projecting to customers a progressive nature and a willingness to co-develop and co-innovate in order to maintain relevance in the future (Sjödin et al., 2021). One potential mode of co-development and co-innovation – also mentioned by the Norwegian waste sorting facility manager – is the dialogue between packaging developers and designers and the sorting facility. Avoiding certain colours and certain material combinations in packaging may easily decrease the amount of residual, non-sortable plastic waste.

The increased complexity associated with circular economy models may also render a business ecosystem coordinator necessary or beneficial. Generally, a business ecosystem coordinator is needed when an organization operates within a network of interconnected stakeholders, partners, or industries, and there is a need for effective management, collaboration, and alignment within this ecosystem. Also, a business ecosystem coordinator can be crucial whenever collaboration among diverse, interdependent stakeholders is essential to achieve strategic objectives, especially in dynamic or innovative industries. This aspect was not raised in the interviews and deserve further exploration.

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List of site visits and interviewees

<u>Site visits</u>		
Site	**Place**	**Country**
Sörab, Brista Verket	Brista, larger Stockholm	Sweden
Naturvårdsverket	Stockholm	Sweden
SPÅ Site Zero	Motala	Sweden
ROAF	Skedsmokorset	Norway
Miljødirektoratet	Oslo	Norway
Plastretur and TOMRA	Oslo	Norway
Attero	Wijster	The Netherlands
<u>Interviewees</u>		
Name	**Affiliation**	**Country**
Ulphard Thoden van Velzen	Wageningen University	The Netherlands
Jaakko Tuomainen	Borealis	Finland
Perttu Penninkangas	Vantaan Energia	Finland
Olli Miettinen, Tommi Erla	Remeo	Finland

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Thoden van Velzen U. 2024. Ulphard Thoden van Velzen, Wageningen University. Interview 23.1.2024.

Series title and number

VTT Technology 439

Title	**Recycling Plastics from Residual Municipal Solid Waste** Final Report of the MSWPlast Project
Author(s)	Malin zu Castell-Rüdenhausen, Mika Härkönen, Tuomas Sormunen, Pauli Räsänen, Arto Wallin, Ilkka Rytöluoto, Joonas Mikkonen, Emma Väre, Mona Arnold, Winnie Ruismäki, Tuomo Mäkelä, Hanna Salmenperä, Topi Turunen & Annika Markuksela
Abstract	A vast majority of post-consumer plastics end up in the residual MSW destined for incineration, causing emissions and contributing to climate change, while also consuming fossil material resources. In addition, Finland struggles to meet the recycling targets set in legislation for plastic packaging waste. The MSWPlast project studied if industrial post-sorting of plastics from residual MSW could offer a solution for plastics recycling, that would complement the current separate collection system. A large share of the plastics in residual MSW is plastic packaging waste, but it contains also other plastic items. In Finland it is estimated that the residual MSW contains more than 15 % plastics. However, little is known about the specific polymers present in the residual MSW. Different polymers are, in fact, different materials that need to be separated for recycling. A key step of the project was the industrial sorting of 512 tons of residual MSW that enabled studying the composition of MSW plastics and the recyclability of the separated plastics. From the separated plastic waste, VTT successfully produced recycled plastic pellets and oriented films. The sorting trial also provided invaluable data for the development of models to evaluate the yield and efficiency of sorting facilities. The MSWPlast project further investigated how new systems for sorting and recycling could fit into our current recycling system. The MSWPlast project demonstrated that plastics can be effectively separated from residual MSW and recycled into new products, offering a viable alternative to incineration. With the right investments in technology and with a supporting policy framework, industrial post-sorting offers a solution for recovering plastics from residual MSW. This would improve the recycling performance and provide valuable raw materials for the domestic plastic industry.
ISBN, ISSN, URN	ISBN 978-951-38-8803-9 ISSN-L 2242-1211 ISSN 2242-122X (Online) DOI: 10.32040/2242-122X.2025.T439
Date	August 2025
Language	English, Finnish abstract
Pages	37 p. + app. 49 p.
Name of the project	MSWPlast
Commissioned by	Business Finland, Borealis, Remeo Group Oy, Vantaan Energia Oy
Keywords	Waste sorting, central sorting, plastics recycling, plastics circularity, municipal solid waste
Publisher	VTT Technical Research Centre of Finland Ltd P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111, https://www.vttresearch.com

Julkaisun sarja ja numero

VTT Technology 439

Nimeke	**Sekajätteen muovit talteen** MSWPlast-projektin loppuraportti
Tekijä(t)	Malin zu Castell-Rüdenhausen, Mika Härkönen, Tuomas Sormunen, Pauli Räsänen, Arto Wallin, Ilkka Rytöluoto, Joonas Mikkonen, Emma Väre, Mona Arnold, Winnie Ruismäki, Tuomo Mäkelä, Hanna Salmenperä, Topi Turunen & Annika Markuksela
Tiivistelmä	Suurin osa kuluttajamuoveista päätyy sekajätteeseen, joka päätyy poltettavaksi. Tämä aiheuttaa päästöjä, edistää ilmastonmuutosta ja kuluttaa fossiilisia raaka-aineita. Lisäksi Suomella on vaikeuksia saavuttaa lainsäädännössä asetetut muovipakkausjätteen kierrätystavoitteet. MSWPlast-projekti tutki, voisiko sekajätteen teollinen jälkilajittelu tarjota ratkaisun muovien kierrätykseen, joka täydentäisi nykyistä erilliskeräysjärjestelmää. Suurin osa sekajätteen muoveista on muovipakkausjätettä, mutta sekajäte sisältää myös muita muoviesineitä. Suomessa arvioidaan, että sekajätteessä on yli 15 % muoveja. Emme kuitenkaan tiedä, kuinka paljon eri muovilaatuja löytyy sekajätteestä. Eri polymeerit ovat eri materiaaleja, jotka on eroteltava kierrätystä varten. Projektin keskeisimpiä vaiheita oli 512 tonnin sekajätteen teollinen lajittelukoe. Tämä mahdollisti sekä sekajätteen muovien koostumuksen että eroteltujen muovien kierrätettävyyden tutkimisen. Erotellusta muovijätteestä VTT tuotti onnistuneesti uusiomuovipellettejä ja orientoituja kalvoja. Lajittelukoe tuotti myös arvokasta dataa mallien kehittämiseksi lajittelulaitosten tuoton ja tehokkuuden arvioimiseksi. MSWPlast-projekti tutki lisäksi, miten uudet lajittelu- ja kierrätysjärjestelmät voisivat sopia nykyiseen kierrätysjärjestelmään. MSWPlast-projekti osoitti, että muovia voidaan tehokkaasti erotella sekajätteestä ja kierrättää uusiksi tuotteiksi, tarjoten käyttökelpoisen vaihtoehdon polttamiselle. Investoimalla oikeanlaisiin teknologioihin ja luomalla tukevaa politiikkakehystä, teollinen jälkilajittelu tarjoaisi ratkaisun muovien talteenottoon sekajätteestä. Tämä tehostaisi kierrätystä ja tarjoaisi arvokkaita raaka-aineita kotimaiselle muoviteollisuudelle.
ISBN, ISSN, URN	ISBN 978-951-38-8803-9 ISSN-L 2242-1211 ISSN 2242-122X (Verkkojulkaisu) DOI: 10.32040/2242-122X.2025.T439
Julkaisuaika	Elokuu 2025
Kieli	Englanti, suomenkielinen tiivistelmä
Sivumäärä	37 s. + liitt. 49 s.
Projektin nimi	MSWPlast
Rahoittajat	Business Finland, Borealis, Remeo Group Oy, Vantaan Energia Oy
Avainsanat	Jätteiden lajittelu, teollinen lajittelu, muovien kierrätys, muovien kiertotalous, yhdyskuntajäte
Julkaisija	Teknologian tutkimuskeskus VTT Oy PL 1000, 02044 VTT, puh. 020 722 111, https://www.vtt.fi/

Recycling Plastics from Residual Municipal Solid Waste

Final Report of the MSWPlast Project

The MSWPlast project aimed to deepen the understanding of recycling plastics from residual municipal solid waste (MSW). By developing a technical concept for pre-treatment and recycling and a systemic model for integrating industrial post-sorting into existing recycling value chains, the project has revealed promising pathways to increase the recycling of plastics from residual MSW.

Today, significant volumes of plastic waste are not sorted for recycling but remain in the residual MSW sent to incineration. Industrial post-sorting of residual MSW to remove the plastics for recycling would promote sustainability and climate neutrality by reducing waste incineration and by providing feedstock for secondary plastic production.

The Business Finland funded co-research project, MSWPlast, started in January 2023 and continued until April 2025. The project was coordinated by VTT Technical Research Centre of Finland, with research partner Finnish Environment Institute Syke, and industrial partners Borealis, Remeo Group Oy and Vantaan Energia Oy. The project was part of the SPIRIT ecosystem led by Borealis.

ISBN 978-951-38-8803-9
ISSN-L 2242-1211
ISSN 2242-122X (Online)
DOI: 10.32040/2242-122X.2025.T439

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