D 1.4. Framing technical/technological solutions for the collection and sorting of plastic and innovative plastic waste materials in the Baltic Sea Region

Contents

EXECUTIVE SUMMARY

The chain of plastic waste recycling at different stages involves multiple players, e.g., municipalities, state or regional authorities, waste operators, businesses, etc. Each of these players has a role in the complex process of plastic waste recycling, and collaboration among them is essential to promote a more sustainable approach to plastic cycles in society. The European Strategy for Plastics in a Circular Economy highlights that existing municipal systems do not support sufficient volumes and quality of plastic waste collection and sorting. **Thus, there is a need for enhancement of the systems for separately collected plastic waste and plastic waste sorting capacities.** Local authorities in cooperation with waste management operators have a key role in high-quality plastic waste collection and separation. Better and more harmonized separate collection and sorting of plastic waste according to their chemical composition is a crucial step in the recycling process, turning mixed plastics waste into a high-value resource.

For plastic sorting, the proposed technical solution is based on "trinamiX" a portable near-infrared (NIR) spectroscopy device. The hand-held trinamiX device offers the advantage of portability and real-time plastic material identification. This solution is well aligned with the aims of the BALTIPLAST project and provides innovative technical/technological perspective for plastic waste sorting at municipal level. Also, it has wider applicability in various target groups because portable devices are already available on the market.

Moreover, developing and implementing innovative plastic materials, despite their environmental benefits, presents challenges at the municipal level. The rapid introduction of bioplastics into the market has been a notable trend driven by increasing environmental concerns, sustainable development goals, and a growing emphasis on reducing the environmental impact of conventional plastics. Bioplastics, derived from renewable resources such as plants, bacteria, or algae, offer a promising alternative to conventional plastics, which are primarily derived from fossil fuels. **Transition from conventional plastics (fossil-based) to bioplastic alternatives requires commitments from local governments to successfully integrate them into municipal waste management systems.** Currently, the existing waste sorting facilities are not equipped to handle the specific characteristics of bioplastics; thus, specialized facilities and processes are required. Ongoing research and development efforts have led to innovations in bioplastics identification, offering cost-effective and versatile hand-held devices. The advancements of trinamiX solution have made possible distinguishing between compostable and non-compostable plastics. **Thus, introduction of innovative techniques for identification of bioplastics is crucial for municipalities to ensure enhancements in the waste management chain.**

1. INTRODUCTION

Most of the existing municipal systems do not support sufficient volumes and quality for collection and sorting of plastic waste, thus, enhancement of the systems for separately collected plastic waste and sorting capacities are in the focus of the BALTIPLAST project. To tackle technical solutions for the collection and sorting of plastic waste, the project consortium has identified municipal administrations, along with other municipal entities, such as waste collection operators, as key actors in this process.

The key actors and project partners have jointly framed a technical/technological solution for the collection and sorting of plastic waste and handling of innovative plastic materials with the aim to achieve higher rates of plastic recycling.

The following implementation steps were projected for this activity:

1. Mapping of quantitative and qualitative characteristics of plastic waste at different municipal entities.
2. Categorization of plastic waste according to polymeric properties.
3. Framing technical/technological solutions under point 1 and 2.
4. Development of step-by-step implementation process/procedure (for the pilots) for the solutions under points 1 and 2.
5. Communication of the drafted technical/technological solution and procedure to targeted municipalities and businesses.

Also, the BALTIPLAST project aims to deliver solutions for handling of innovative plastic material solutions. To tackle this issue partners from the project together with the experts from BIO-PLASTICS EUROPE (Horizon 2020) project organized several workshops for municipal authorities and local experts named 'Historic Cities Against Plastic Waste' in Tallinn, Estonia and Vilnius, Lithuania. The participants had the opportunity to get acquainted with the current policy and legislation related to management of bioplastics. Also, participants provided insights into the opportunities and barriers of bioplastics management at municipalities/organizations.

2. CURRENT SITUATION OF PLASTIC WASTE MANAGEMENT IN THE BALTIC REGION COUNTRIES

2.1. Legal framework

In December 2015, the (European) Commission adopted a Circular Economy Action Plan with the aim to set the European Union on the course of the transition towards a more sustainable model for economic development. The action plan remarks that less than 25 percent of collected plastic waste is currently recycled and about 50 percent goes to landfill and underlines recycling as an essential part of a circular economy. The action plan proposes that "smarter separate collection and certification schemes for collectors and sorters are critical to divert recyclable plastics away from landfills and incineration into recycling" (Commission, 2020).

In 2018, the European Union adopted a European strategy for plastics in a circular economy as a part of the corresponding action plan. Sustainability is the underlying motivation behind the plastics strategy with the goal of addressing how plastics are designed, used and recycled in the EU. One of the aims of this strategy is that by 2030, all plastic packaging placed on the EU market is either reusable or can be recycled in a cost-effective manner (Commission, 2019).

The Waste Framework Directive 2008/98/EC (amended by Directive (EU) 2018/851) includes a target to be achieved by 2025 which is recycle and prepare for reuse 55 % of the municipal waste generated. The Packaging and Packaging Waste Directive (94/62/EC, amended by Directive (EU) 2018/852) includes targets for the recycling of packaging waste, both in total and by material, to be achieved by 2025. The Landfill Directive (1999/31/EC as amended by Directive (EU) 2018/850) requires to limit the landfilling of municipal waste to 10 % of the generated municipal waste by 2035.

Lithuania

Lithuania's main legal acts related to packaging waste comprise:

- Law on Waste Management (Lietuvos Respublikos Seimas, 1998);
- National Waste Management Plan 2014 - 2020 (Lietuvos Respublikos Vyriausybė, 2002);
- Law on Packaging and Packaging Waste (Lietuvos Respublikos Seimas, 2013).

The National Waste Management Plan (NWMP) states the implementation of the waste hierarchy, extended producer responsibility for packaging, WEEE, ELV, oils, batteries. The NWMP also defines the waste collection systems, such as waste treatment facilities and capacities.

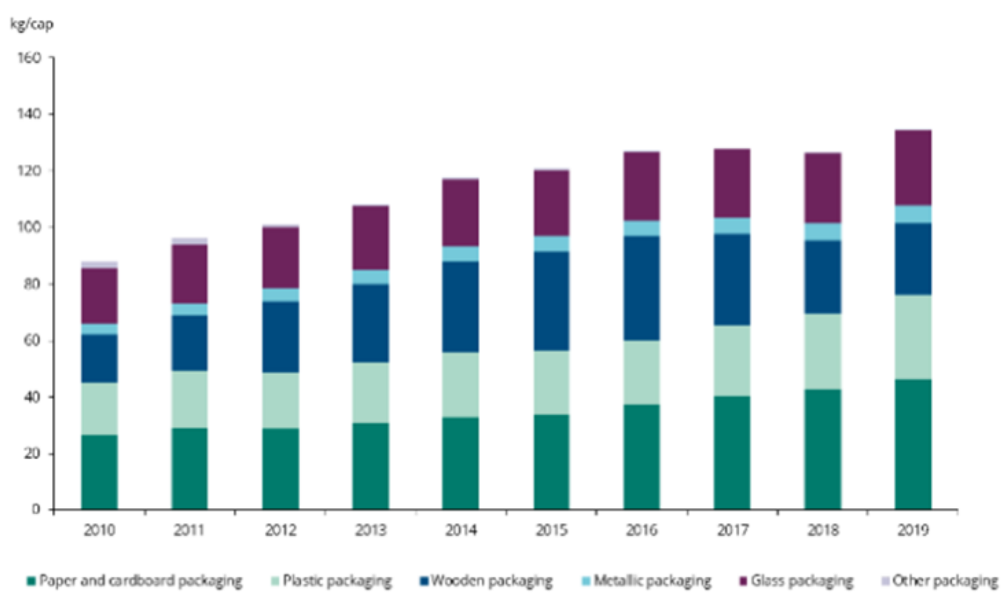

Fig.1 Packaging waste generation in Lithuania between 2010 and 2019, in kg per capita

Municipalities are responsible for the implementation of the tasks set out in the NWMP. By 2020 at least 50 % (in terms of waste volume) of paper and board, metals, plastics and glass waste in the municipal waste stream is prepared for re - use and recycling.

In Lithuania, 375 000 tonnes (134 kg/cap) of packaging waste were generated in 2019, which is below the EU average of 177 kg/cap. However, packaging waste generation has been increasing over the past decade

(Fig.1). Wooden packaging waste has significantly decreased in 2017-2018 compared to 2015-2016, while other packaging fractions are fluctuating between years, with a trend of increasing waste generation for these packaging materials (EEA, 2022a).

Latvia

Latvia's regulatory framework aims to transpose the EU waste acquis. The key legislation related to packaging waste consists of (MEPRD and LEGMC, 2021):

- "Law On Pollution" (2001), which regulates polluting activities, such as waste recovery, disposal and storage facilities, according to their potential environmental risk (OECD, 2019; Latvijas Republikas Saeima, 2001);
- The Packaging Law (Latvijas Republikas Saeima, 2002).
- The Waste Management Law (2010), last amended in 2020, supports the implementation of the National Waste Management Plan (NWMP), sets targets for Municipal Solid Waste (MSW) recycling, and outline the responsibilities of the Ministry of Environmental Protection and Regional development, the municipalities and waste management companies (Latvijas Republikas Saeima, 2010) for reaching the recycling targets.

Regarding packaging waste, the NWMP (National Waste Management Plan) includes a Waste Prevention Programme, providing measures for the prevention of packaging waste. These measures have been supplemented with initiatives to promote the circular economy, i.e. the introduction of a deposit system for beverage packaging in the national territory from 1 February 2022 (EEA, 2022b).

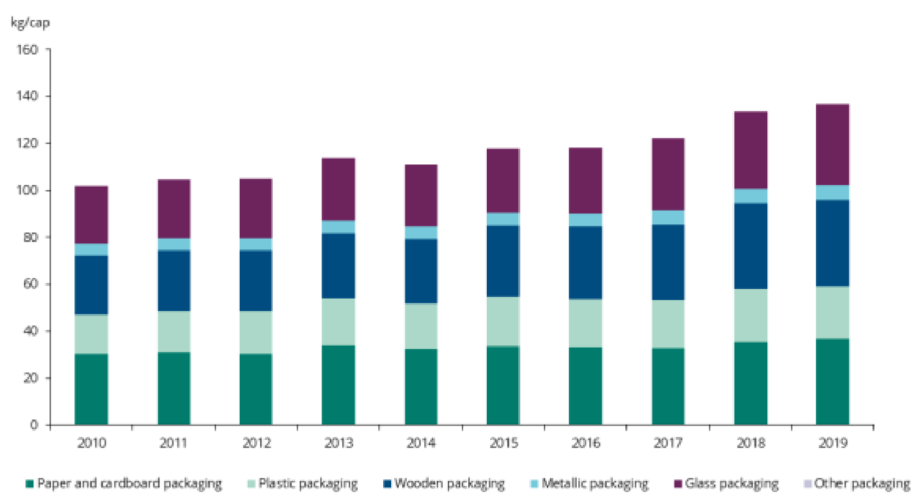

Fig.2 Packaging waste generation in Latvia between 2010 and 2019, in kg per capita

In Latvia, approximately 262 000 tonnes (137 kg/cap) of packaging waste were generated in 2019, which is below the EU average of 177 kg/cap. The overall packaging waste generation increased since 2010 for all packaging materials (Fig.2).

Estonia

Overall, the Estonian waste legislation follows the EU waste legislation. The main acts and regulations regarding packaging waste are listed below:

- Packaging Excise Duty Act (Riigikogu, 1997);
- Waste Act (Riigikogu, 2004b);
- Packaging Act (Riigikogu, 2004a);
- The Regulation of the Minister of the Environment Procedure for sorting municipal waste and basis for classification of sorted waste (Olmejäätmete sortimise kord ning sorditud jäätmete liigitamise alused) (Minister of the Environment, 2007);

  The Regulation of the Government of the Republic Pakendiregistri põhimäärus (Statute of the Packaging register) (Vabariigi Valitsus, 2018);
- The Regulation of the Minister of the Environment Pakendi korduskasutuse ja pakendijäätmete taaskasutamise ja ringlussevõtu arvutamise metoodika (Methodology for calculating the reuse of packaging and the recovery and recycling of packaging waste) (Minister for the Environment, 2021a);
- The Regulation of the Minister of the Environment Olmejäätmete korduskasutuseks ettevalmistatud, ringlusse võetud ja ladestatud koguste arvutamise metoodika (Methodology for calculating quantities of municipal waste prepared for re-use, recycled and disposed of) (Minister for the Environment, 2021b).

In addition, new targets were set for the recycling of packaging waste. Recycling of packaging waste has to reach 65 % by 2025 and 70 % by 2030. In addition, it sets separate recycling targets for different packaging materials (Parliament of Estonia, 2021).

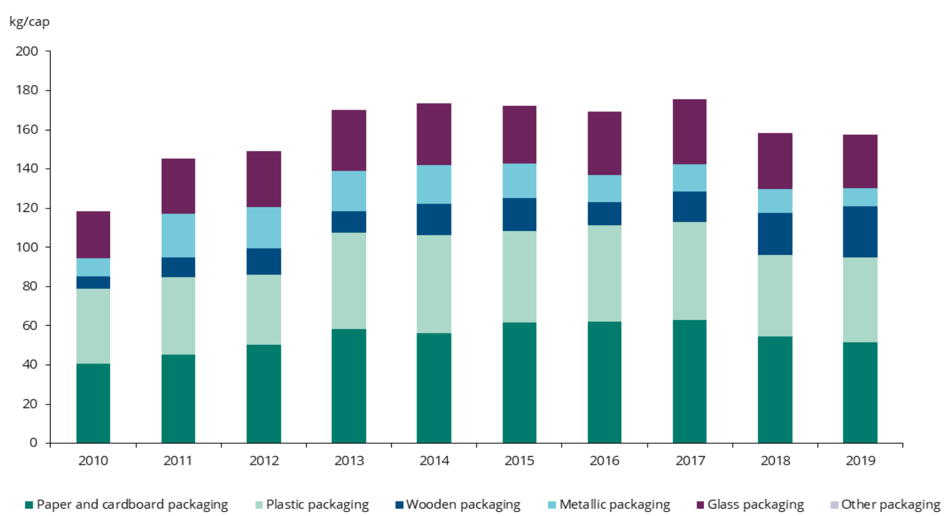

Fig.3 Packaging waste generation in Estonia between 2010 and 2019, in kg per capita

A NWMP was needed to set a strategic approach for waste management in line with the transition to a circular economy (CE). (Ministry of the Environment of Estonia, 2021). The plan is based on the waste hierarchy especially focusing on waste prevention and recycling or recovery.

In Estonia, 0.21 million tonnes (158 kg/cap) of packaging waste were generated in 2019, which is below the (estimated) EU average of 177 kg/cap. Packaging waste generation increased rapidly between 2010 and 2013, from 119 kg/cap to 170 kg/cap (Fig.3). From 2013 onwards, the waste generation remained rather stable for five years, but in 2018, the waste generation decreased around 10 % from the previous year. Between 2010 and 2019 the recycling rate for packaging waste has varied from 53.5 % in 2017, to 66.2 % in 2019 (EEA, 2022c).

Finland

Generally, the Finnish waste legislation follows the EU waste legislation, but it is stricter and more comprehensive. Government Decree on Waste Incineration (ÅFS 2015:16), the Government Decree on Packaging and Packaging waste (ÅFS 2018:92), and the Government Decree on the Return System for Beverage Containers (ÅFS 2018:9) apply in Åland with certain adjustments.

- Government Decree on the Return System for Beverage Containers 526/2013 (to be revised) (Government of Finland, 2013b);
- Government Decree on Waste Incineration 151/2013 (amended in 2015) (Government of Finland, 2015)
- Waste Tax Act 1126/2010 (amended in 2020) (Government of Finland, 2020a)
- Act on Excise Duty on Certain Beverage Containers 1037/2004 (amended in 2020) (Government of Finland, 2020b)
- Environmental Protection Act 527/2014 (amended in 2021 (715/2021)) (Government of Finland, 2021a)
- Government Decree on Landfills 331/2013 (amended in 2021 (1030/2021)),) (Government of Finland, 2021c)
- Government Decree on Waste 978/2021 (Government of Finland, 2021f)
- Government Decree on Packaging and Packaging waste 1029/2021 (Government of Finland, 2021g)
- Government Decree on Environmental Protection 713/2014 (amended in 2021 (979/2021)) (Government of Finland, 2021h)
- Waste Act 646/2011 (amended in 2021 (714/2021)) (Government of Finland, 2021i)

From recycling to a circular economy - The National Waste Plan to 2027 (NWP) adopted by the Finnish Government in 2022 (Ministry of the Environment, 2022b) includes a ten-point vision for waste management and waste prevention in 2030, as well as detailed targets up to 2027 and measures to be taken to achieve these targets, for example, the recycling of packaging waste needs to increase to be at least in line with the target levels of the EU Packaging and Packaging Waste Directive.

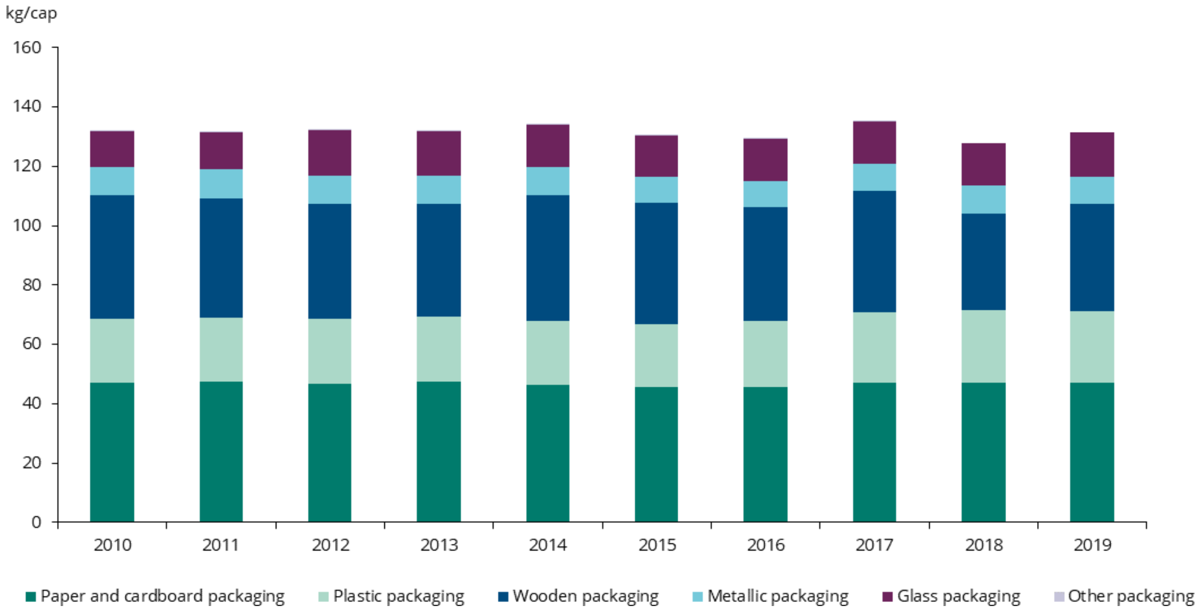

Fig.4 Packaging waste generation in Finland between 2010 and 2019, in kg per capita

In 2019, Finland generated 0.7 million tonnes (131 kg/cap) of packaging waste, which is below the (estimated) EU average of 177 kg/cap. Packaging waste generation per capita has remained quite stable since 2010, fluctuating slightly between the different years (Fig.4). Packaging waste generation data is based on data of packaging put on the market reported by producer responsibility organizations (EEA, 2022d).

Sweden

In Sweden, the following legal acts are of relevance for the area of waste:

- According to the Environmental Code (Riksdagsförvaltningen, 1998), each municipality should, in addition to the local waste management plan, also have local regulations concerning the handling of municipal waste (Miljöbalken 15 kap 41 §).
- Law on waste tax (Sveriges riksdag, 1999)
- Landfill Ordinance (Sveriges riksdag, 2001)
- The Swedish Environmental Protection Agency's regulations and general advice on the management of combustible waste and organic waste (Naturvårdsverket, 2004).
- Regulation and recycling targets concerning packaging materials. Ordinance (2018: 1462) on producer responsibility for packaging (Riksdagsförvaltningen, 2018).
- Law on the tax on waste incinerated (Sveriges riksdag, 2019).
- Regulations and requirements concerning municipal waste management plans and waste prevention plans: Swedish Environmental Protection (NFS 2020:6) (Naturvårdsverket, 2020).
- The Waste Ordinance (Sveriges riksdag, 2020) includes regulations concerning waste, waste management and waste prevention measures. The Waste Ordinance also includes requirements concerning the classification of waste.
- The Environmental Code (Riksdagsförvaltningen, 1998) – the country’s package of environmental laws – includes general consideration of resources and waste. The purpose of the

Environmental Code is to promote sustainable development which will ensure a healthy and sound environment for present and future generations. To achieve this, the Code is to be applied so that reuse and recycling, as well as other management of materials, are encouraged and natural cycles are established and maintained (Swedish EPA, 2021b).

The Environmental Code (Riksdagsförvaltningen, 1998) – the country's package of environmental laws – includes general consideration of resources and waste. The purpose of the Environmental Code is to promote sustainable development which will ensure a healthy and sound environment for present and future generations. To achieve this, the Code is to be applied so that reuse and recycling, as well as other management of materials, are encouraged and natural cycles are established and maintained (Swedish EPA, 2021b).

Sweden has a National Waste Management Plan (NWMP) and Waste Prevention Program for the period of 2018-2023, which was revised in 2020 (Naturvårdsverket, 2021). The targets for recycling of packaging waste are in several cases higher than the recycling targets at the EU level.

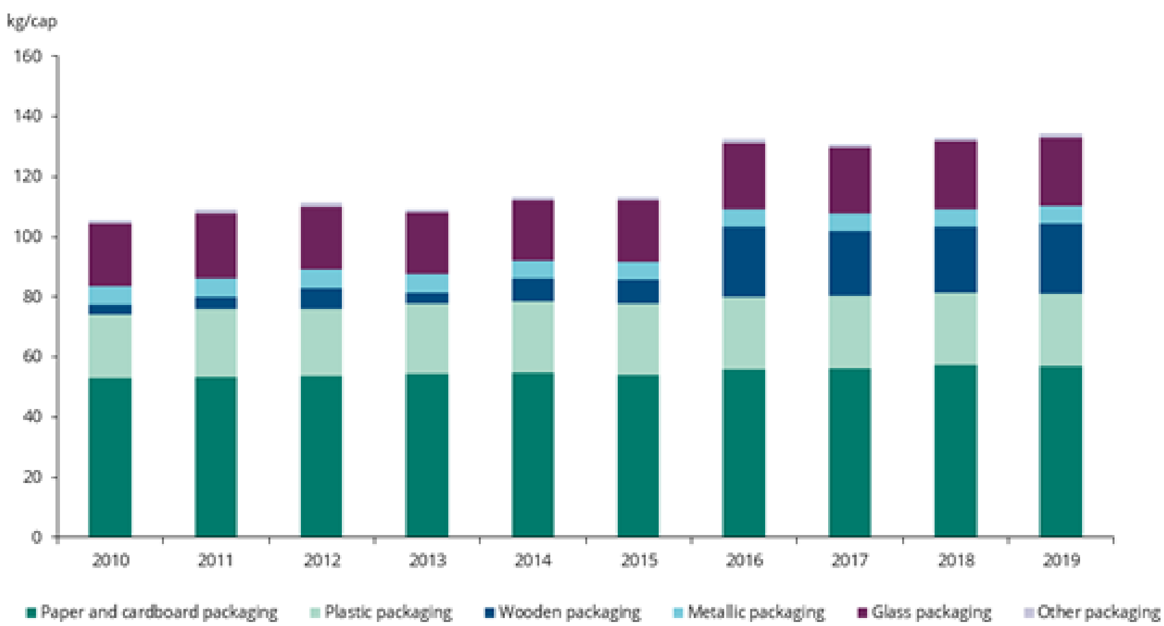

Fig.5 Packaging waste generation in Sweden between 2010 and 2019, in kg per capita

In Sweden, almost 1.4 million tonnes (134 kg/cap) of packaging waste were generated in 2019, which is well below the EU average of 177 kg/cap. In comparison with 2010, packaging waste generation has increased by 27.1 % in 2019, which can be mainly attributed to the increase in wooden packaging generation (EEA, 2022e).

Germany

Waste related legislation in Germany comprises a number of laws and ordinances. The regulations can be divided into general regulations, with the Circular Economy Act (KrWG) being the core element, waste-stream specific regulations (e. g. the Packaging Act – VerpackG) and regulations for waste treatment and for cross-border waste shipment.

The KrWG stipulated separate bio-waste collection as mandatory from January 2015 onwards. The separate collection requirement also applies to paper, metal, plastic and glass waste. The German Packaging Act was amended in the light of the amended Packaging and Packaging Waste Directive (Directive EU/2018/852, amending Directive 94/62/EC on packaging and packaging waste). On 3 July 2021, the amended version of the Packaging Act (Verpackungsgesetz) entered into force, making the Packaging Ordinance, which was in force until 31 December 2018, invalid.

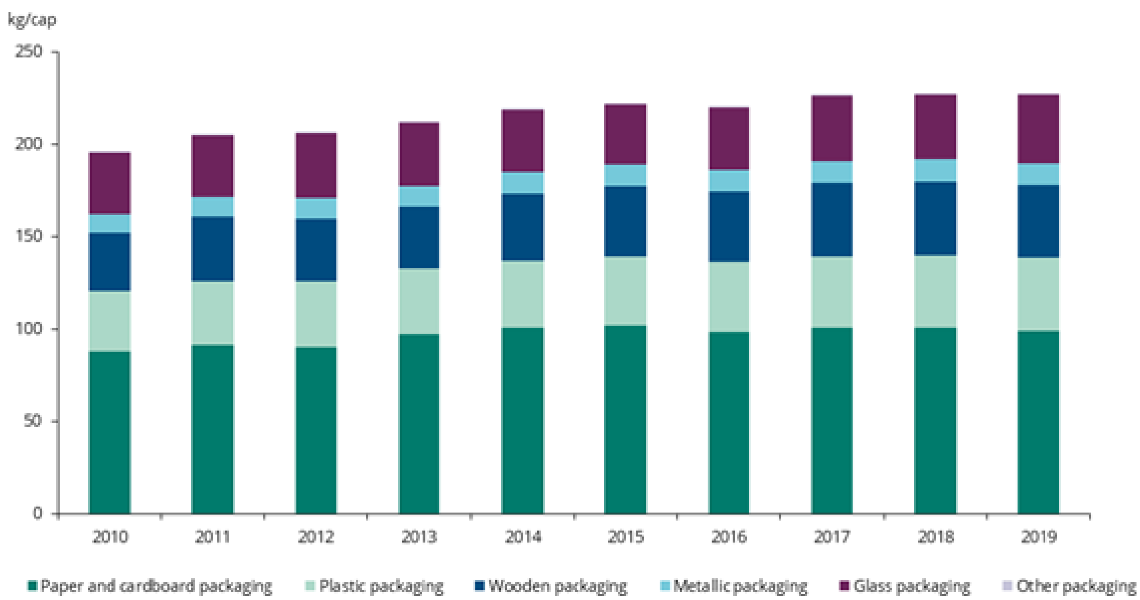

Fig.6 Packaging waste generation in Germany between 2010 and 2019, in kg per capita

In Germany, 18.9 million tonnes (228 kg/cap) of packaging waste were generated in 2019, which is well above the EU average of 177 kg/cap. The overall packaging waste generation increased since 2010 but remained rather stable over the past five years (Fig.6). Looking at each of the waste packaging streams, the waste generation rate remained stable over the past five years (less than 5 % relative deviation). Waste generation for plastic and glass increased by 5 % and 13 % since 2015 (EEA, 2022f).

2.2. Collection of plastic waste

Lithuania

In Lithuanian cities, various types of plastic waste collection systems are implemented: door-to-door (separate and co-mingled wastes), bring points (with a density of > 5 per km2 and density of < 5 per km2) and civic amenity recycling sites. Municipalities, households and companies are responsible for separate collection of recyclable waste. The collection system does not distinguish between packaging waste and non-packaging waste. In cities, for plastic waste high-density bring points are the dominant collection system, with some co-mingled collection and supported by collection at civic amenity sites.

Table.1 Calculated collection rates of plastic waste in Lithuania (2019)

Amount of plastic in Municipal Solid Waste (tonnes)	131 197
Amount of residual plastic (tonnes)	95 518
Amount of separately collected plastic (tonnes)	35 679
Collection rate of plastic (%)	27

Separate collection systems are a key enabler for high recycling rates and for collecting recyclables at adequate quality. The collection rate is a good performance indicator of the effectiveness of the separate collection system. The collection rate is calculated by dividing the separately collected weight of a certain material for recycling by the weight of the material in total municipal waste (EEA, 2022a).

Latvia

The minimum service standards for the collection of waste are set in Regulations No.788 (Latvia Cabinet of Ministers, 2016) defining types and requirements of waste collection and sorting sites, types and volumes of containers, markings on the containers, frequency of collection, and types of waste to be collected: paper, metal, plastics and glass, as well as biodegradable waste. Producer Responsibility Organizations (PROs) play a key role in the development of the separate waste collection systems. Regulations No. 788 provide that the manager of PROs must ensure that at all civic amenity sites managed by waste management companies contracted by municipalities collect household plastic packaging waste and single-use cutlery, as provided in Regulation No. 480 (Latvia Cabinet of Ministers, 2016, 2021a, 2017c). Separate collection is also mandatory for business premises.

Table.2 Calculated collection rates of plastic waste in Latvia (2019)*

Amount of plastic in Municipal Solid Waste (tonnes)	82749
Amount of residual plastic (tonnes)	72390
Amount of separately collected plastic (tonnes)	10359
Collection rate of plastic (%)	13

In Latvia, the current waste collection system does not distinguish between packaging waste and non-packaging waste. For plastic waste, bring point collection is the dominant system in cities. Civic amenity site are other significant systems. On January 1, 2022 Latvia introduced beverage container deposit system, which considerably increased collection of post-consumer PET beverage containers (EEA, 2022b).

Estonia

In Estonia, separate collection of packaging waste from households, trade sector and industry is mandatory (Ministry of the Environment of Estonia, 2021). The lack of focus on collection, and slow and limited implementation of the legal obligation to collect waste from apartment buildings, limits the efficiency of the separate collection and overall performance of the system. Municipalities across the country organized many civic amenity sites, for recyclables, which has resulted in steadily increased separate collection. Difference between collection of packaging materials and non-packaging materials exist. Plastic packaging wastes are collected mostly from bring points collection system, but in bigger cities also door-to door co-mingled collection systems for plastic packaging wastes are used to some extent. Non-packaging plastic waste is only collected in civic amenity sites (EEA, 2022c).

Table.3 Calculated collection rates of plastic waste in Estonia (2019)*

Amount of plastic in Municipal Solid Waste (tonnes)	75625
Amount of residual plastic (tonnes)	52127
Amount of separately collected plastic (tonnes)	23498
Collection rate of plastic (%)	31

Finland

In Finnish municipalities, door-to-door collection of packaging waste from households and municipal services is organized according to the requirements laid down in the national waste legislation or by stricter requirements stated in the municipal waste management regulations. PROs (Producer Responsibility Organizations) are responsible for organizing bring point collection of household packaging waste across Finland. Currently, there are more than 670 collection points for plastic packaging waste nationwide organized by PROs. In addition, municipalities may organize supplementary bring point collection and deliver packaging waste collected to PROs. The obligation to sort recyclable waste at source is described in the waste legislation, both for households and business, services and administration. For plastic packaging door-to-door separate collection is the dominant system in cities. Bring point and civic amenity site are also significant systems (EEA, 2022d).

Table.4 Calculated collection rates of plastic waste in Finland (2019)*

Amount of plastic in Municipal Solid Waste (tonnes)	362525
Amount of residual plastic (tonnes)	288028
Amount of separately collected plastic (tonnes)	74497
Collection rate of plastic (%)	21

Sweden

In Sweden the municipalities have the freedom to implement the separate collection system of their choice, which is why the service varies between municipalities. Sweden implements an EPR (Extended producer responsibility) for packaging waste with more than 5 000 bring points for sorted packaging waste. Some municipalities also offer door-to-door collection of packaging waste. The collection system for packaging waste does not accept non-packaging waste of the same material, such waste is instead collected at civic amenity sites. Companies are obliged to sort their packaging waste for separate collection.

In general, companies are not allowed to use bring points system and civic amenity sites for sorting packaging waste. However, in certain civic amenity sites companies can sort their packaging waste free of charge or at a cost based on the volume of packaging waste. Alternatively, companies can also procure the packaging waste management to private contractors themselves.

Table.5 Collection rates of plastic waste in Sweden (2019)*

Amount of plastic in Municipal Solid Waste (tonnes)	465796
Amount of residual plastic (tonnes)	330096
Amount of separately collected plastic (tonnes)	135700
Collection rate of plastic (%)	29

In Swedish cities, plastic packaging waste bring point collection is the dominant system but door-to-door and civic amenity site are also significant systems (EEA, 2022e).

Germany

Plastic packaging waste is usually collected via door-to-door methods, either co-mingled in one bin (yellow bin) or in plastic bags (yellow bag). Usually, door-to-door or bring points collection is limited to packaging materials. However, in certain municipalities, this system is extended to include plastic non-packaging waste. Non-packaging items of the same material are usually collected separately at civic amenity sites or by private companies (scrap trade). In Germany for plastic packaging waste door-to-door separate collection is the dominant system in urban areas. Bring point and civic amenity site are also significant systems (EEA, 2022f).

Table.6 Collection rates of plastic waste in Germany (2019)*

Amount of plastic in Municipal Solid Waste (tonnes)	3 367 842
Amount of residual plastic (tonnes)	906 242
Amount of separately collected plastic (tonnes)	2 461 600
Collection rate of plastic (%)	73

2.3. Case Studies: Morphological Analysis of Plastics in Mixed and Separately Collected Waste Streams in Kaunas (LT), Tallinn (ES) and Daugavpils (LV)

Morphological analysis of plastic waste in the main municipal waste streams "collection-recycling-disposal" (including separately collected plastic waste, mixed and other municipal waste and waste treatment products) was performed at:

- Kaunas MBT facility (Lithuania) – 07/06/2023
- Tallinn Recycling Center (Estonia) – 15/09/2023
- Daugavpils Recycling Center (Latvia) – 29/09/2023.

Morphological analysis was performed according to the 'Standard Test Method for Determination of the Composition of unprocessed Municipal Solid Waste'. During morphological analysis the following plastic sub-fractions have been identified:

- high density polyethylene (jars) – HDPE;

- low density poliethylene (films) – LDPE;
- polypropylene (jars, rigid packaging) – PP;
- polypropylene (films) – PP;
- polypropylene film with Al layer;
- polyethylene terephtalate (bottles, rigid packaging) – PET;
- polystyrene (foam) – PS
- polystyrene (jars, rigid packaging) – PS
- polyvinyl chloride – PVC;
- polyamide – PA;
- other plastic – OTHER;
- combined packages (tetrapack)
- combined packages (blisters).

Kaunas mechanical – biological treatment (MBT) facility



Fig.7 Kaunas MBT facility

The processing line of Kaunas MBT is presented in Fig.7. Two types of waste were processed via the MBT line:

(a) 136,5 kg of plastic waste collected separately from residents

(b) 253,4 kg mixed municipal waste.

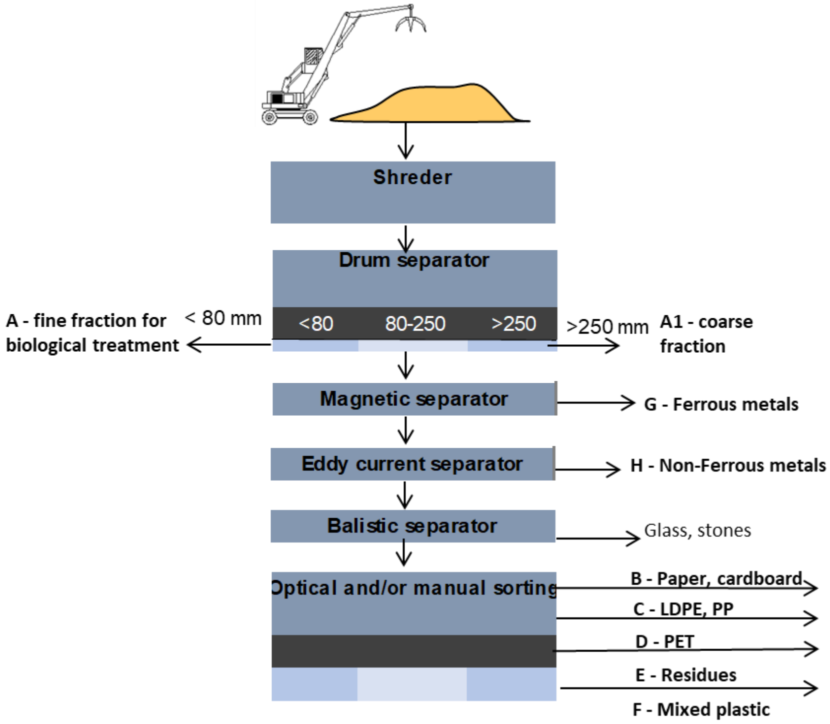

Fig.8 Schematic view of Kaunas MBT line

First, the < 80 mm fraction is sieved through 80 mm meshes in the first part of the rotating sieve. This fraction is marked as **A** and named **„Fine fraction ",** which usually goes to biological treatment. Next, the 80-250 mm fraction is sifted through 250 mm meshes and directed to the 1st mechanical separation line. In another mechanical separation line, the fraction > 250 mm, marked as **A1** and called **„Coarse fraction"**, is processed. Further 80-250 mm fraction is passed through magnetic separator, Eddy current separator, ballistic separator, optical sorter and manual sorting line. Each output flow is marked correspondingly **B, C, D, E, F, G, H.**

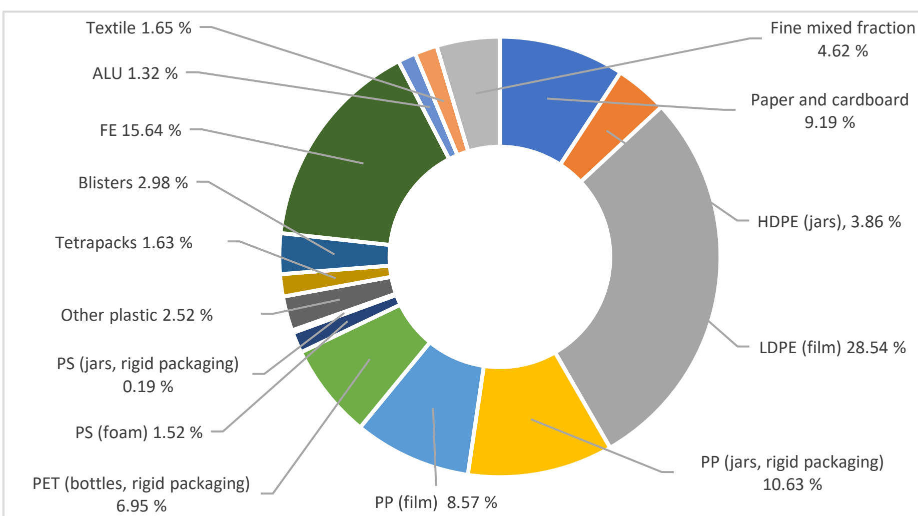

Fig.9 Morphological composition (%) of separately collected plastic waste in the city of Kaunas, 2023

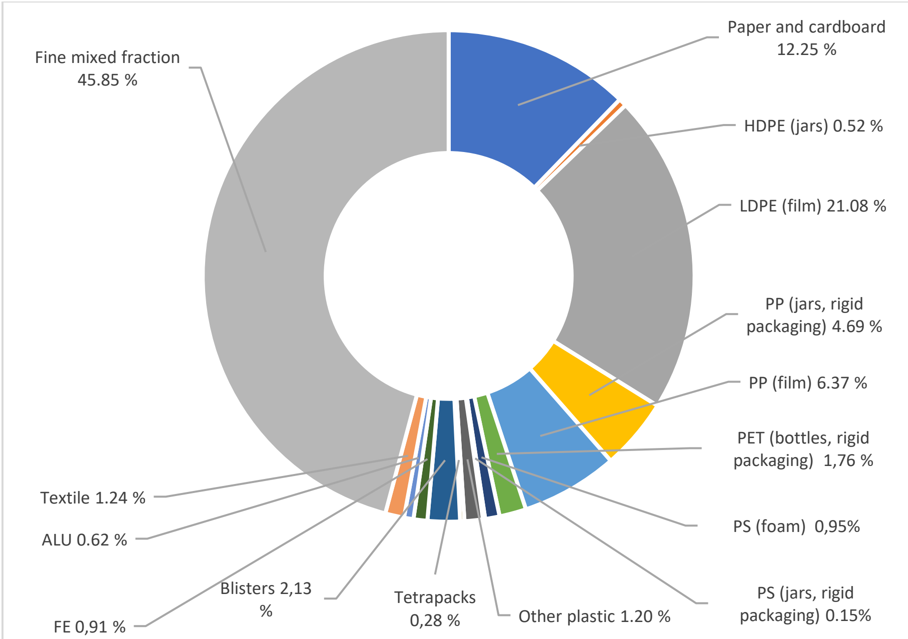

Fig.10 Morphological composition (%) of mixed municipal solid waste in the city of Kaunas, 2023

After determining the amounts of the mentioned plastic types in each post-treatment output and knowing the amount of each output, the average fractions of plastic subfractions in percent are calculated. Fig. 9 presents morphological composition of separately collected plastic waste, while Fig. 10 identifies plastics in the mixed municipal waste. Most common polymers in separately collected plastic waste were PP ~ 20% and LDPE ~ 29%, the rates of the same polymers in the mixed municipal solid waste were PP ~ 11% and LDPE ~21% respectively.

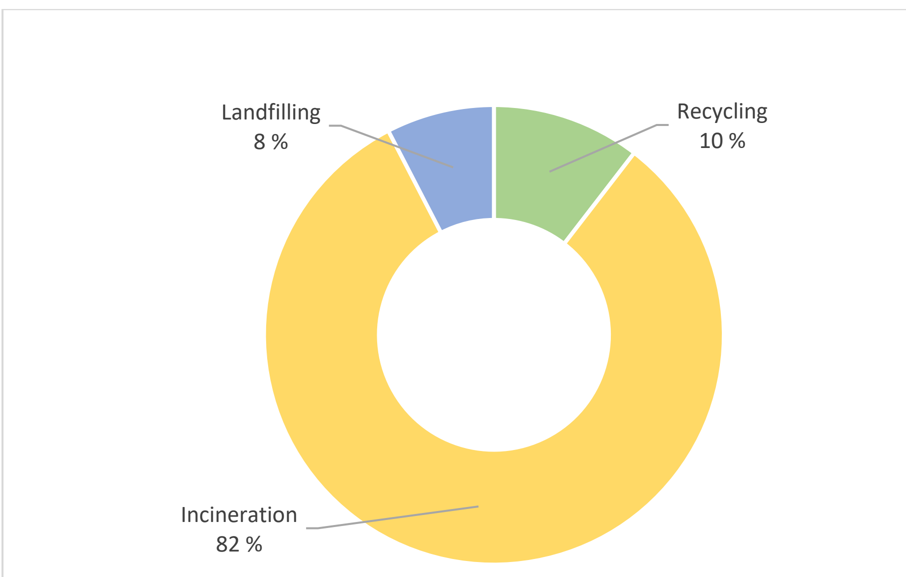

Fig.11 Rates (%) of municipal plastic waste handling in the city of Kaunas, 2021

In terms of waste management methods, incineration is the most common way of disposing of plastic waste (~82 %), while landfilling (~8%) and recycling (~10%) are the least common.

Tallinn recycling center

Fig.12 Tallinn Recycling Center

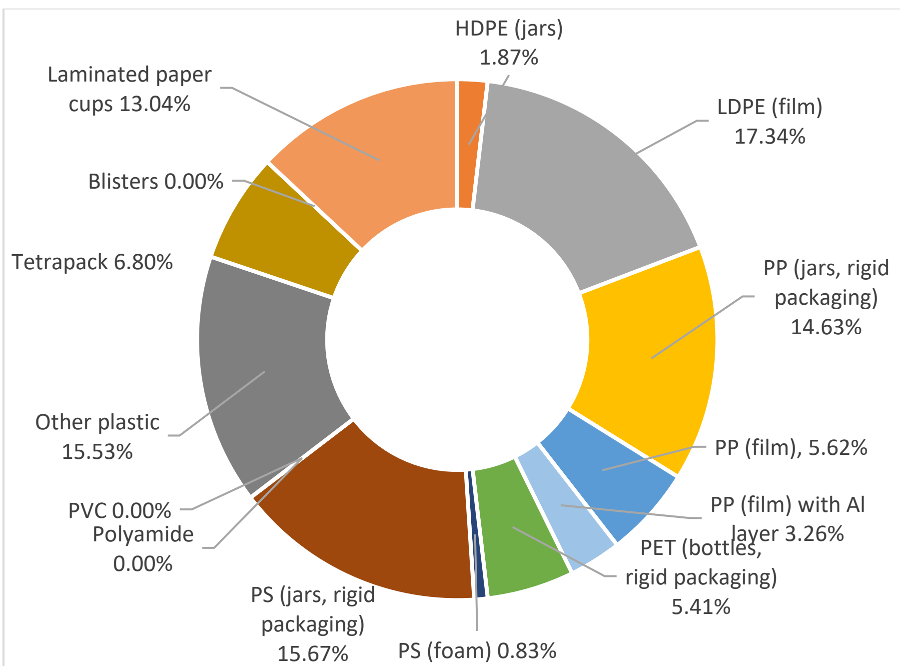

Fig.13 Morphological composition (%) of mixed municipal solid waste in the city of Tallinn, 2023

Analysis of the composition of plastic fractions by polymer type shows that most common plastics are: PP (~ 20 %), LDPE (~ 17 %), PS (~ 17 %).

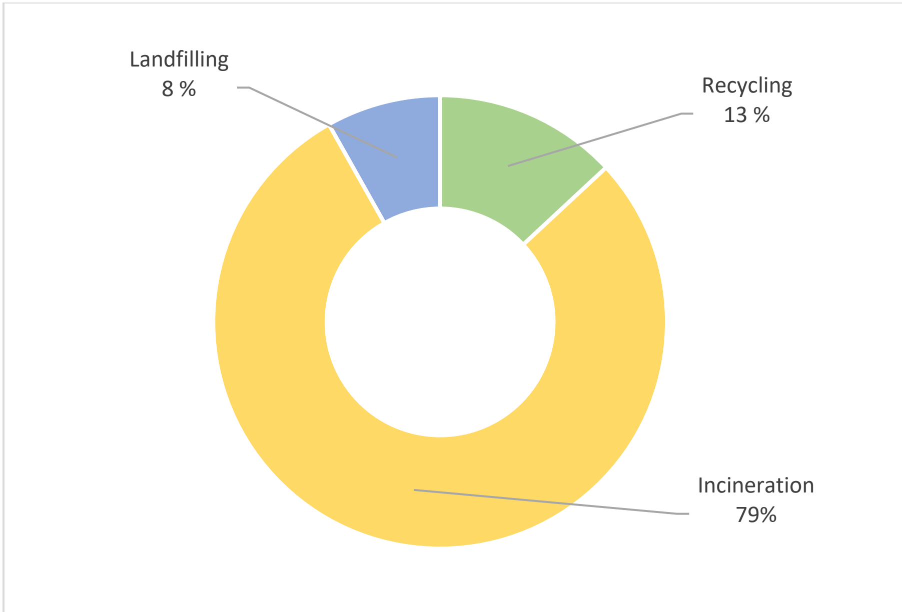

Fig.14 Rates (%) of municipal plastic waste handling in the city of Tallinn, 2022

Incineration (~79 %) is the dominant way of plastic waste treatment, while landfilling (~8%) and recycling (~13%) are less common.

Daugavpils recycling center

Fig.15 Daugavpils recycling center

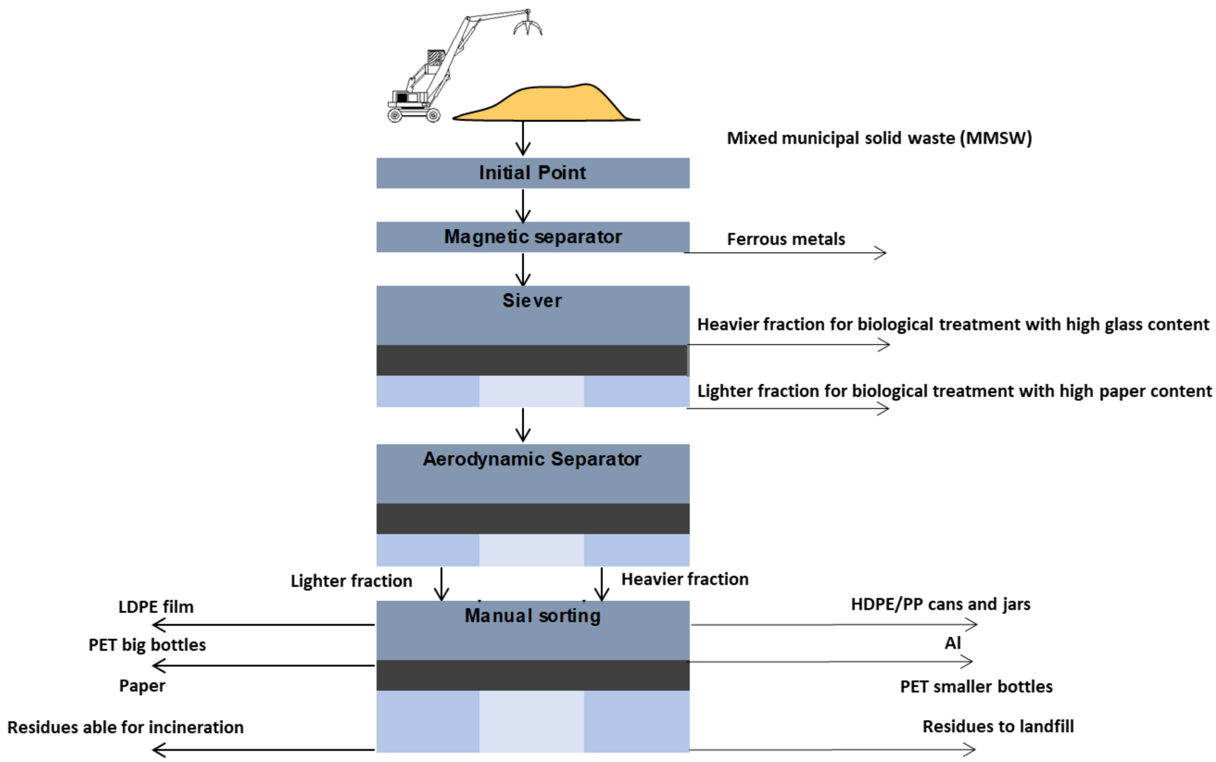

Fig.16 Schematic view of Daugavpils MBT line

During treatment, at first the ferrous metals are extracted by magnetic separator from mixed municipal waste. After, heavier and lighter fine fractions for biological treatment are separated by rotating sieve. Further the remaining coarse fraction is separated aerodynamically to lighter and heavier fractions which are separated manually to some recyclable fractions and residues able for incineration and landfilling.

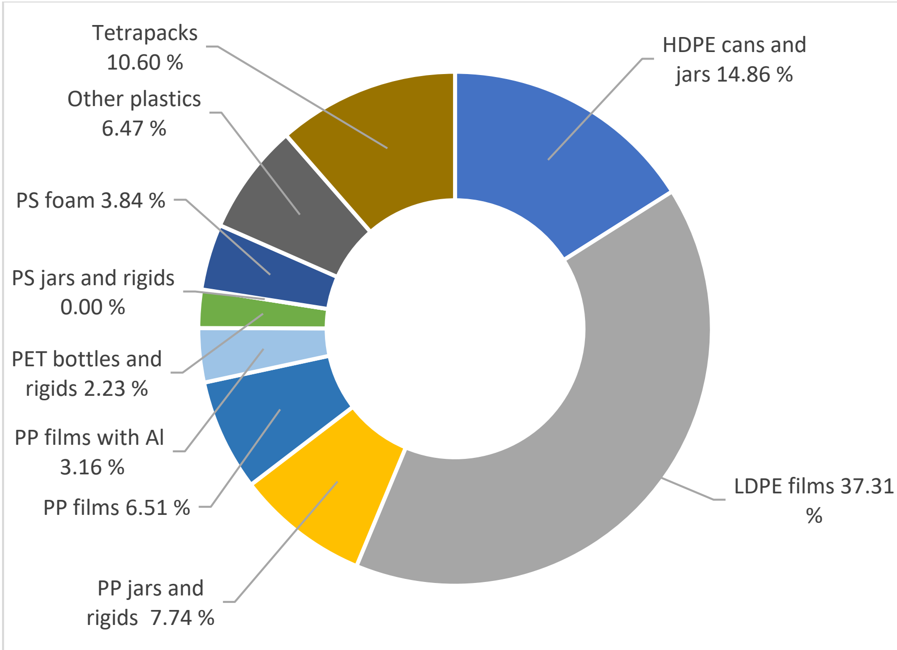

Fig.17 Morphological composition (%) of mixed municipal solid waste plastic fraction in the city of Daugavpils, 2023

After determining the amounts of the mentioned plastic species in each post-treatment output and knowing the amount of each output, the average rates (%) of different types of plastics were calculated. It was determined that total amount of plastics in the mixed municipal waste was 20,34%. Most common polymers in separately collected plastic waste were LDPE (~37 %), HDPE (~15 %), and tetrapacks (~11 %).

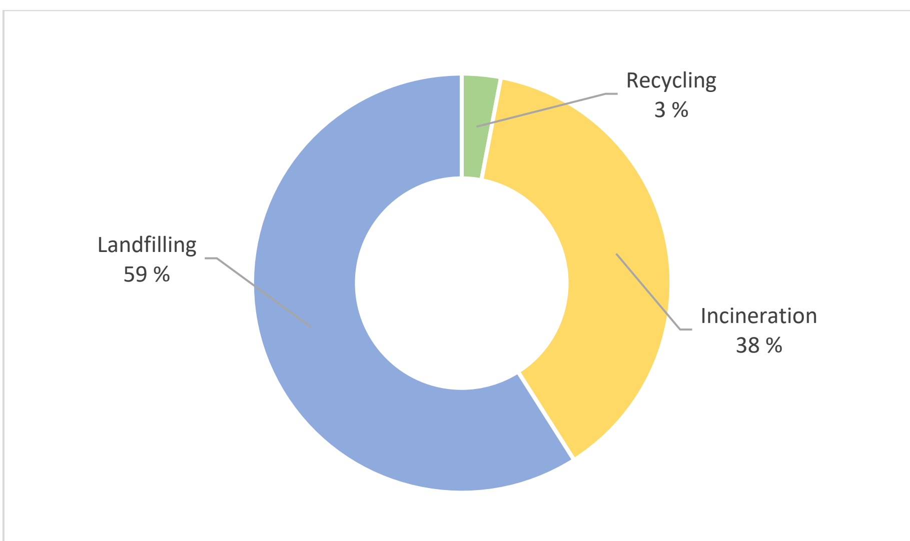

Fig.18 Rates (%) of municipal plastic waste handling in the city of Daugavpils, 2023

In terms of waste management methods, landfilling (~59 %) and incineration (~38 %) are the most common ways of disposing plastic waste, while recycling (~3 %) is the least common.

3. PLASTIC WASTE SORTING

Efficient and correct sorting of plastic waste can turn mixed plastic waste into high-value resources, which otherwise would be only suitable for combustion. It directly contributes to better availability of waste input for recycling as well as better recycling quality. Sorting can be done on both product/object level (macro-sorting) and on shredded plastic flakes (micro-sorting). While macro-sorting is often done manually or with the help of object recognition, micro-sorting needs automated classification (https://onlinelibrary.wiley.com/doi/10.1002/macp.202100488).

3.1. Near-infrared (NIR) spectroscopy solution

NIR spectroscopy is the technique that is commonly used to distinguish different plastic materials. NIR spectroscopy has been available for some years for high-speed sorting lines to distinguish different polymer streams. Sweden and Germany are the world's leading countries in terms of plastic packaging recycling, there, nearly no plastic packaging ends up in landfills, incineration or nature.

Successful examples of appropriate plastic sorting:

Site zero https://www.svenskplastatervinning.se/en/site-zero/ By not recycling plastics we are wasting our resources. Therefore, we have decided that all plastic packaging in this country should be recycled so that it can become new plastic products. We have built the largest and most efficient plant for plastic recycling in Europe, thereby taking a big step towards our vision. Thanks to our fully automated technology, we sort different plastic types with maximum precision, which helps to reduce waste and ensure that as much as possible can become new plastic products. And best of all, we have the capacity to collect and handle all plastic packaging from all households in Sweden. The Site Zero plant is fully automated and can sort plastic packaging from all Swedish households, with a capacity of up to 200,000 tonnes of plastic packaging per year. Fully automated process, 60 NIR sensors, approx. 5 km conveyor belt. The plant is very flexible and can sort up to 12 different fractions that consist of, for example, colored or transparent PP, HDPE, LDPE, PET.

PreZero https://prezero-international.com/en/press/2022/prezero-starts-up-europe-s-newest-sorting-plant-for-lightweight-packaging In Eiting, Bavaria, PreZero is a company focusing on creating a sorting plant capable of sorting packages into 18 different fractions of plastics. The plant will be able to sort up to 120,000 tonnes of lightweight packaging from the yellow bag and will be processed for recycling outside the gates of Munich every

year. In addition to the 38 NIR sorters, the facility also has ballistic separators, robot-assisted secondary sorting and 272 conveyor belts on five levels, supported by over 1,000 tonnes of steel.

The latest technology is being used in the sorting process. Black scans identify black plastics that are difficult to sort in conventional plants. Furthermore, the latest generation of sorting robots supports employees in quality control and re-sorting. Based on artificial intelligence, the fully automatic sorting plant will surpass all of sorting quotas prescribed by law under the Packaging Act adopted in 2019.

The collected packaging material is sorted into a total of 18 different fractions. This includes the types of plastic, polypropylene, polyethylene terephthalate (PET), polyethylene and polystyrene. Unlike in other plants, the respective fractions can also be sorted by color. Using the latest detection technology and innovative separating units, manual sorting can be largely dispensed with automated lines.

A series of technical/technological improvements keep pushing the boundaries for plastic sorting. The company trinamiX has developed hand-held devices where a sample can be directly scanned on site to determine the polymer type and correct assignment to recycling streams before entering mixed streams, or for spot checks and process control. Even structurally similar polymers, such as PA6 and PA66 or HDPE and LDPE can be distinguished with this technique. For automated sorting, such advanced spectral analysis capabilities are a promising approach.

Cloud-based computing and centralized databases provide practically unlimited computing power for classification algorithms and enormous spectral databases. Here, the basics of hand-held NIRS and the essentials of the corresponding data analysis with a focus on plastics sorting are discussed.

Fig.19 Hand-held trinamiX spectroscopy solution

With the help of trinamiX NIR Spectroscopy Solutions, all common plastics can now be easily identified within seconds. The spectrum ranges from classic polyolefins such as PE, PP and PVC (polyethylene, polypropylene and polyvinyl chloride), to PET (polyethylene terephthalate), which is best known as a material for beverage bottles. In addition, technical plastics such as ABS (acrylonitrile butadiene styrene) or PA (polyamide), whose distinction is particularly important for the recycling companies, can also be correctly identified in the field (especially in blends with other plastics). The trinamiX solution is a good decision aid. In recycling, for example, it is aimed at companies that do not need a large, stationary sorting plant, but a flexible and mobile solution.

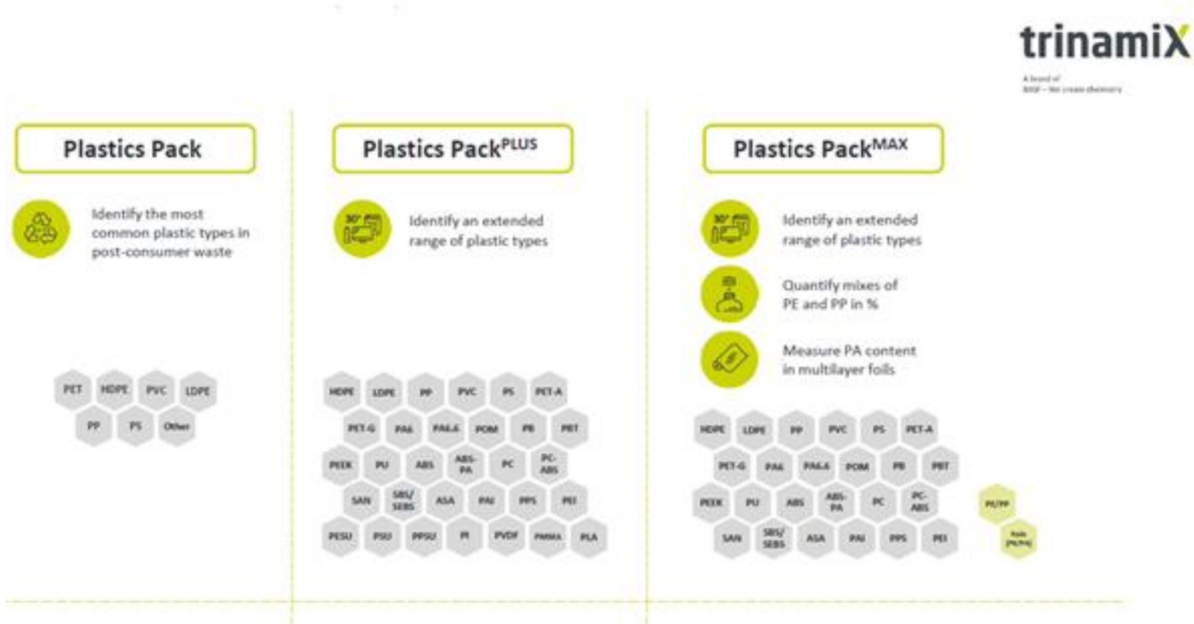

Fig. 20 trinamiX packs

Equipped with trinamix' mobile NIR spectroscopy solution, they are empowered to perform detailed on-the-spot analyses of diverse solids, e.g., to identify different kinds of plastics during recycling. Table 7 presents a list of companies from the BSR which are already using trinamiX solution for their business activities.

Table.7 List of companies from the BSR applying trinamiX solution.

Volvo	https://www.volvo.com/en/
Tomra	https://www.tomra.com/en/
Sun Technology AB / PEA Invest AB	https://www.peas.com/
Recuro AS	https://www.recuro.no/
ELM Recycling GmbH & Co. KG	https://www.elm-recycling.de/en/
Krall Kunststoff-Recycling GmbH	https://kunststoff-recycling.de/

Kunststoff Recycling Grünstadt GmbH	https://www.krg.center/startseite
Klöckner Pentaplast Group	https://www.kpfilms.com/en/

Source: personal communication with representatives from trinamiX

3.2. Piloting activities

The proposed technical solution involves the use of portable trinamiX NIR spectroscopy device for plastic sorting. This hand-held device provides real-time identification of plastic materials, aligning well with project goals and offering innovation at the municipal level. The trinamiX solution's portability and applicability across various target groups make it a valuable asset in advancing plastic waste sorting. With the use of this tool, separation of plastics with similar melting temperatures and characteristics would be possible, which will then allow higher recycling rates and upscaling of plastic waste.

3.2.1. Description of pilot sites

Kaunas (Lithuania)

Kaunas is the second-largest city in Lithuania after the capital, Vilnius. Kaunas occupies an area of 157 km^2 and has a population of 304,459 (2023). It is an important center of Lithuanian economy, academic, and cultural life.

Kaunas Regional Waste Management Centre (RWMC) is responsible for organization and administration of household mixed municipal solid waste treatment (collection, transportation, recycling and disposal) in Kaunas region. The center unites four municipalities of Kaunas district and Kaunas city. For this purpose, mechanical biological treatment (MBT) and mechanical treatment (MT) plants in Kaunas city and Kėdainiai district were established.

Kaunas city municipal waste is managed by JSC “Kauno švara”. Yearly, about 730,000 m^3 of domestic and industrial waste is removed from Kaunas city by the JSC “Kauno švara”. Municipal waste is collected in i) container-based system; ii) civic amenity sites; iii) door-to-door collection; iv) supplementary schemes (EPR for packaging waste).

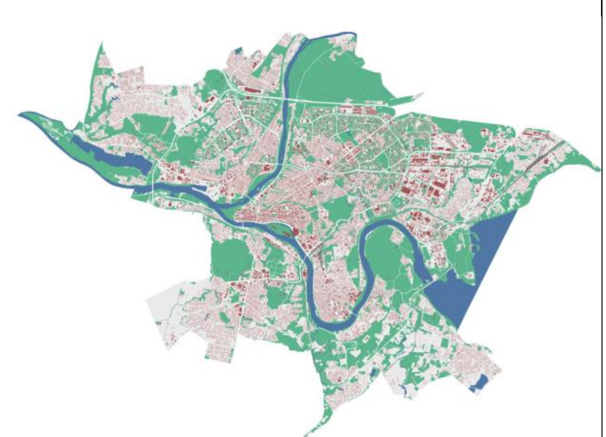

Fig.21. Separated waste collection in Kaunas city

In 2016 all individual households were equipped with sorting containers. Currently, more than 63,000 bins of separately collected waste are emptied in the city every month. The individual (single-family) households in Kaunas separate waste into the three categories (separate bins): paper-plastic-metal, glass, and mixed waste to landfill. The experimental analysis of paper-plastic-metal waste morphology revealed the following composition of collected waste: plastic and multi-layered packaging – 39.15%, paper and cardboard – 37.79%, metal – 7.99%, and residuals – 18.07%. Containers for plastic are used to collect packaging made of plastic, metal and composite material.

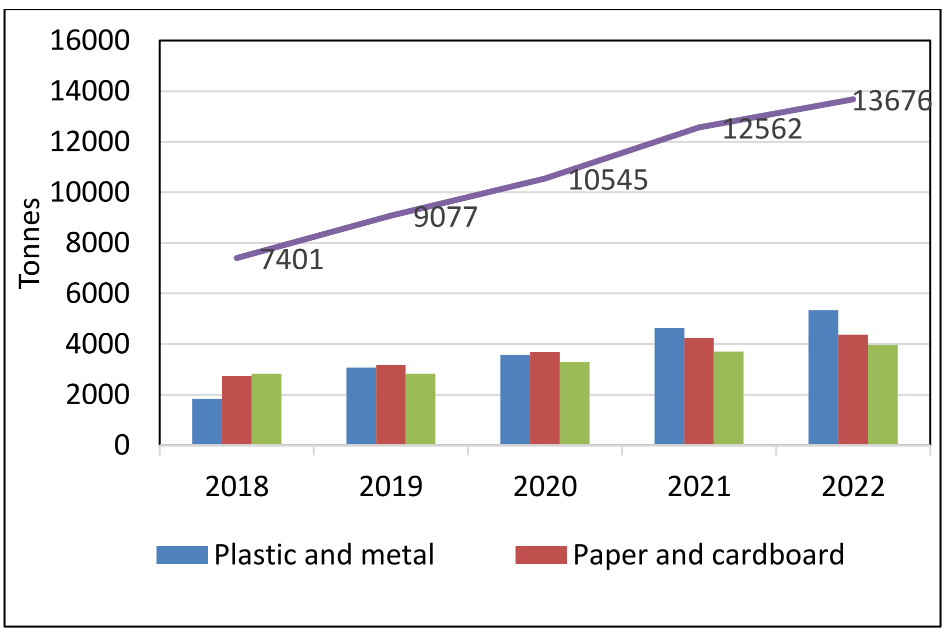

Fig.22 Amounts of packaging and secondary raw materials collected in the city of Kaunas

Currently, the residents of Kaunas are given opportunities to successfully sort not only municipal waste, but also other household waste. The awareness of the population is also shown by the significantly increasing amounts of waste sorted after primary sorting every year (See Fig.22). Currently, more than 63,000 separately collected waste bins are emptied in the city every month.

Daugavpils (Latvia)

Daugavpils is the second-largest city in the country after the capital, Riga. Daugavpils occupies an area of 72,37 km^2 and has a population of 78,850 (2023). Daugavpils is an important center of Latvian economy, academic, and cultural life.

The collection of municipal solid waste (collection, transportation, recycling and disposal) in Daugavpils is organized by the municipality in close cooperation with waste operator JSC ‘AADSO’. The collection points (containers/bins) for separate collection of waste are distributed all over the administrative territory of the city. Special attention is given to separate waste collection from multi-family and individual households. After the collection process, the separated waste undergoes sorting at the "Cinīši" landfill facility. There are no landfills or waste deposit areas in the territory of the city of Daugavpils.

According to the agreement “On the Management of Municipal Waste in the Administrative Territory of the City of Daugavpils” between Daugavpils City Council and "Waste Management South Latgale Intergovernmental Organization (AADSO), starting from October 1, 2017, AADSO carries out municipal waste management in the city of Daugavpils.

Fig.23 Sorted waste collection site in Liginiški residential area, Daugavpils

Sorted waste collection site in Liginiški residential area provides the opportunity to deliver pre-sorted waste which can be recycled free of charge. The sorting of waste and the delivery of packaging to this type of collection sites allows to reduce the amount of total waste to be handled by the waste manager, thus reducing the overall waste management costs.

Tallinn (Estonia)

Tallinn is the capital and largest city of Estonia. Tallinn occupies an area of 159.2 km^2 and has a population of 438,569 (2023). Tallinn is important financial and business center in Estonia, famous for its technology-based business environment and location for investments.

Waste management in Tallinn is developed on the basis of the national waste plan and the city waste management plan for the period 2022-2026 adopted in 2022. The state and city waste plan deals with the state and organization of waste management and how to achieve more efficient use of resources. When preparing the city's waste plan, the provisions of the national development plan are taken into account and it is part of the development plan of the local government.

As a European Green Capital, Tallinn recommends that all event coordinators think about finding sustainable and environmentally friendly options when planning events. From 1 June 2023, all public events in Tallinn will be allowed to serve food and drinks only in reusable containers and to use only reusable cutlery.

Fig.24 Tallinn's waste transport areas and sites of separate collection of waste

Door-to-door waste collection involves the collection and transportation of household waste from a designated area to specified waste disposal sites by a company selected through a procurement organised by a local government unit.

According to the Waste Act, the local government has an obligation to organise household waste transportation within its administrative territory. It is collected and transported by a waste transport company to which the city has awarded the exclusive right to serve the waste transport area. When granting the exclusive right, the lowest service price offered to residents by competing waste transport companies will be the decisive tender.

In Tallinn, packaging collection is based on more than 400 collection points over the city. Every citizen can give away their packages for free. Public packaging containers in Tallinn are managed by:

- Eesti Taaskasutusorganisatsioon MTÜ (ETO),
- Eesti Pakendiringlus OÜ (EPR)
- Tootjavastutusorganisatsioon OÜ (TVO).

Packaging waste includes both packaging with a deposit label (so-called deposit packaging) and without a deposit label. Separate collection of packaging from other waste, ensures that packaging materials end up being recycled and the use of natural resources is reduced.

3.2.2. Protocol for plastic sorting from post-consumer packaging waste samples

The protocol for implementing plastic waste sorting during the piloting phase of BALTIPLAST in 2024 has been described below in detail. This sorting protocol describes a method for analyzing plastics in post-consumer packaging (also called lightweight packaging – LWP) waste samples and will consist of the following sequential steps:

1) **Selection of plastic waste sampling locations**
The collection spots of post-consumer packaging waste samples include public waste collection containers and waste collection bins/containers near households or home communities. Collected samples can contain post-consumer plastics, composite packages waste, as well as consumer goods (household items, dishes, toys, etc.).

2) **Formation of a representative waste sample**
The minimum amount of collected post-consumer waste should be 300 kg. This sample is formed from waste collected in different and equally distant places of the municipality; preferably, by taking 10 kg waste samples from 30 distant points. The collection time – three weeks in a row. The samples of packaging waste should be stored in polyethylene bags. To avoid external impacts the bags with the samples should be stored in a cool place.

3) **Sorting of post-consumer packaging waste**
Sorting of post-consumer packaging wastes into plastic and non-plastic material is performed by visual recognition. After forming a group of plastics, they are sorted according to the packaging type (jars, bottles, rigid packaging, foam, films, combined packaging). Sorting of post-consumer packaging wastes can best be performed in a closed space with air circulation. The closed space reduces the risk odour emissions and spread of infectious materials to other workspaces.

Note: Post-consumer packaging wastes pose several health risks for investigators that sort these materials which can be controlled by choosing the correct safety measures. The employees need access to personal protection tools like gloves, safety goggles, mouth caps, lab coats, etc.

4) **Identification and sorting of plastic waste according to polymer (resin) type**

For identification of plastic (resin) waste type trinamiX handhold NIR scanner will be used (https://trinamixsensing.com/plasticsorting). Every plastic object needs to be held in the light beam of the NIR scanner. The light is targeted on the largest component of the object. The object is held as close as possible to the reflective tile and slowly turned until a clear scanning result is obtained. In most cases a result can be otained within one second. Large pieces of thin plastic film should be folded to obtain a longer optical path for the NIR scanner.

The trinamiX Plastic Pack identifies the most common plastic types in post-consumer waste: PET HDPE LDPE, PVC, PP. The trinamiX Plastic Pack ^{Plus} recognises an extended range of plastic types: HDPE, LDPE, PP, PVC, PS, PET-A, PET-G, PA.6, PB, PBT, PEEK, PU, ABS, ABS-PA PC PC-ABS, SAN, SBS/SEBS, ASA PAI, PPS, PEI PESU PSU, PPSU PI PVDF, PMMA, PLA. The trinamiX Plastic Pack ^{Max} in addition to previous model qualifies mixes of PE and PP in %, measures PA content in multilayer foils. The TrinamiX module for identification of compostable plastic can distinguish between compostable (Cellulose Acetate, PAP, PBAT, PLA, PPB and Starch) and non-compostable plastics.

The implementation of NIR scanners reveals a limitation in their capability to recognize a specific category of plastics. This category predominantly consists of black-colored plastics but may also include other dark shades or highly contaminated plastics. Those plastics are added to the category for “non-NIR-detectable and residual plastics”. It's noteworthy that the accuracy of NIR scanner results takes precedence over plastic labeling, as the recycling symbols on plastic packaging are not always applied correctly.

5) **Weighting of sorted plastics**

Following the sorting of the samples, the individual constituents must be weighed separately, and these weights need to be registered. This process requires the use of appropriate balances and a dedicated, clean workspace for documenting the weights. After sorting, the constituents can be recombined.

The amounts of plastics marked for recycling, incineration, and landfilling are then calculated based on the obtained results.

6) **Reporting**

The reporting should contain the following information:

- Reference to the Sorting Protocol
- Results (including percentage of each fraction) & Discussion
- The photographs are welcome whenever useful for documenting specific situations.

4. BIOPLASTICS IN WASTE MANAGEMENT FRAMEWORKS

Bioplastics, such as bio-based (BBP), biodegradable and compostable (BDCP) plastics may be a more sustainable alternative compared to fossil-based, non-biodegradable plastics. However, they also pose various sustainability challenges and trade-offs that must be carefully assessed and considered. The currently developed and available bioplastics exhibit properties comparable to conventional plastics, yet they surpass them in terms of degradability. It is evident that as policy makers aim at reducing plastic waste, bioplastics emerge as an environmentally friendly alternative, particularly in contrast to conventional plastic products, which, while cost-effective and convenient for societal use, are becoming increasingly untenable due to their lifecycle impact and adverse effects on human health and the environment.

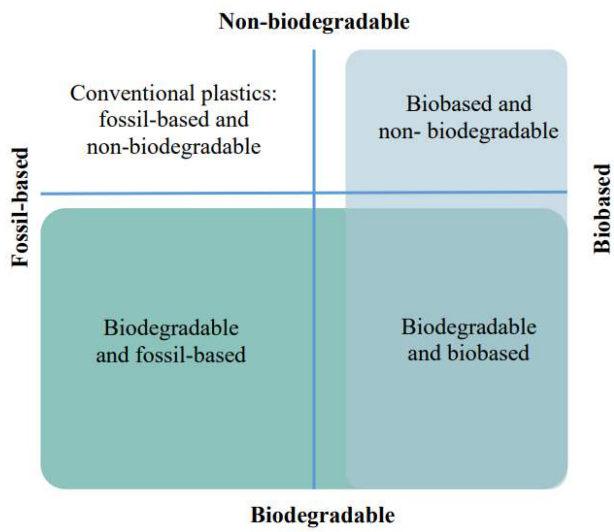

Fig.25 **Bioplastics -** alternatives to conventional (fossil-based) plastics

There is widespread confusion among consumers about these different types of plastics. The umbrella term "bioplastics" is often used to describe very different materials, and the terms "biobased", "biodegradable" and "compostable" may be misleading.

Biobased plastics are fully or partially made from biological resources, rather than fossil raw materials. They are not necessarily biodegradable or compostable. It is important to examine the full life cycle of biobased plastics, to ensure that they are beneficial to the environment beyond the reduction in use of fossil resources, this includes changes in land use.

Biodegradable plastics are able to biodegrade under certain conditions at their end of life.

Compostable plastics – fall under the category of biodegradable plastics – they generally undergo decomposition in industrial composting facilities, requiring prior collection. Biodegradable and compostable plastics, whether derived from biological resources or fossil raw materials, are recommended for use when reduction, reuse or recycling is not feasible, aligning with the circular economy and waste hierarchy principles (European Commission, 2022a).

4.1. Baseline to bioplastic materials

Bioplastics currently represent roughly 0.5 percent of the over 400 million tonnes of plastic produced annually. After a period of stagnation over the past few years, the overall global plastic production is picking up again in 2023. This development is driven by rising demand combined with the emergence of more sophisticated applications and products. Global bioplastics production capacity is set to increase significantly from around 2.22 million tonnes in 2022 to approximately 7.43 million tonnes in 2028 (Plastics Europe, 2023).

Bioplastics are used for an increasing variety of applications, ranging from packaging and consumer products to electronics, automotive, and textiles. Packaging remains the largest market segment for bioplastics with 43 percent (934 000 tonnes) of the total bioplastics market in 2023.

Bioplastics that are certified according to the harmonized European standard EN 13432 (or EN 14995) are suitable for organic recycling and will completely biodegrade in an industrial composting plants, with no adverse effects on the process or on the final product (compost).

Currently, there are no legal acts on EU level providing regulation specifically to bioplastic waste, but provisions of both EU Action Plan for Circular Economy and EU Strategy for Plastics in the Circular Economy form opportune grounds for their adoption. Meanwhile, there are some provisions in the legislation pertaining to biodegradable and compostable packaging (BIO-PLASTICS EUROPE Horizon 2020):

- The revised Directive 2008/98/EC on waste allows biodegradable and compostable packaging to be collected together with the bio-waste and recycled in industrial composting and anaerobic digestion.
- The revised Directive 94/62/EC on packaging and packaging waste Directive defines compostable and biodegradable packaging: „packaging waste processed for the purpose of composting shall be of such a biodegradable nature that it does not hinder the separate collection and the composting process or activity into which it is introduced" and "biodegradable packaging waste shall be of such a nature that it is capable of undergoing physical, chemical, thermal or biological decomposition such that most of the finished compost ultimately decomposes into carbon dioxide, biomass and water. Oxo-degradable plastic packaging shall not be considered as biodegradable."

The EU policy framework for bioplastics (European Commission, 2022b) aims to contribute to a sustainable plastics economy by:

- Improving the understanding around these materials and clarifying where these plastics can bring genuine environmental benefits, under which conditions and applications.
- Guiding citizens, public authorities and businesses in their policy, purchasing or investing decisions.

- Preventing differences at national level and fragmentation of the market by promoting a shared understanding across the EU on the production and use of these plastics.

4.2. Management of bioplastic waste

If biodegradable and compostable plastics are not collected separately, they can contaminate plastic recycling, organic waste streams, and the environment. To deal with this contamination, effective identification and sorting of these different polymer types is required to ensure they are separated and composted at end of life (European Bioplastics, 2023).

There are several technologies applied for plastic **identification and sorting of compostable plastics** (manual sorting, gravity-based sorting, centrifugal sorting, flotation sorting, air-gravity based sorting, triboelectric sorting, image-based identification, digital watermark, NIR spectroscopy, hyperspectral imaging, tracer-based sorting). To be effective they need to be part of, and fit into, the existing waste management system.

In the absence of tracer standards or digital watermarking NIR is one of the most effective techniques for sorting bioplastics without any surface pre-treatment. The NIR wavelength range is 700–2,500 nm. In this region, the absorbance and reflectance of light in NIR spectral range is due to overtone or combination vibrations of the C-H, O-H, N-H, and C-O bonds in polymers. The observed NIR spectra can be characteristically attributed to specific plastic resins, thus enabling identification of bioplastics.

The trinamiX group has developed mobile NIR spectroscopy solution for compostable plastics. The solution can distinguish between compostable (Cellulose Acetate, PAP, PBAT, PLA, PPB and Starch) and non-compostable plastics. The advantages of this technique are the reliable and rapid identification with a low environmental impact. It could also be used to identify conventional plastics in compost.

Fig.26 Hand-held trinamiX spectroscopy solution for identification of compostable plastics

Two industrial processes are typically used to process bioplastics: **industrial composting** (IC) and **anaerobic digestion** (AD). IC facilities are designed to undertake aerobic composting of organic matter (food and garden waste) to produce compost. Compostable plastics must be compliant with EN 13432 which is designed to be compatible with industrial composting systems. AD facilities are designed to undertake anaerobic composting of organic matter to produce biogas (CO_2 and methane) and digestate. They are generally not suitable for compostable plastics but some biodegradable plastics are biodigestable in these systems. Home composting is an informal method of composting that takes place in a domestic setting where temperatures and levels of humidity are generally lower and less controlled than industrial settings. Some plastics are marketed and certified as “home compostable”, but these are a small subset of the bioplastics sold in the market such as tea bags and food caddy liners.

Experts highlighted five scenarios where **effective sorting technologies for compostable plastic** are needed to help improve the recycling and composting rates and reduce contamination (https://www.frontiersin.org/articles/10.3389/frsus.2022.901885/full).

Scenario 1 - Home composting

There is little evidence that home composting is a sustainable way to manage bioplastics. This is because the conditions in home compost need to be managed very carefully to successfully compost such plastics. The European Committee for Standardization (CEN) has prepared a standard on home composting indicating that only small items such as tea bags are considered compatible with home composting under well managed conditions.

Scenario 2 - Compostable plastics comingled with recyclable plastics

Compostable plastics often contaminate the recycling of conventional plastics such as HDPE and PET reducing their value. Due to low proportion of compostable plastics in the market, recyclers have not yet invested in equipment to sort and separate compostable plastics. However, if the trend of compostable products continues to increase the automatic separation collection and sorting of compostable plastics may be required.

Scenario 3 - Compostable plastics are comingled with food waste
Separate food waste collections are an important component of sustainability plans for developed economies since they divert organic waste from landfill where it creates greenhouse warming gases. If organic waste is delivered to anaerobic digestion (AD) it is used to create biogas. Within in-vessel composting (IVC) facilities organic waste is turned into compost which is used as a soil fertilizer. AD facilities are not designed to process compostable plastics and all bioplastics including compostable and biodegradable plastics are removed in the pre-screening process. IVC facilities are able to accept compostable plastics, however they do not have automatic sorting and separating technology to distinguish between compostable and non-compostable packaging.

Scenario 4 – Compostable plastics are comingled with garden waste
Open air windrow (OAW) process is usually used to compost garden waste. In the current system garden waste is delivered to composting facilities. They are visually inspected to remove plastic contaminants, shredded and shaped into a windrow on a non-permeable surface to produce compost. Loads of garden waste arriving with high levels of contaminants (plastic bags) are typically rejected and send to landfill or incineration. Ideally an automatic sorting system could be used to reduce the number of rejected loads by detecting compostable plastics and sending them to IVC facilities for composting.

Scenario 5 – Detecting microplastic in compost
When composting various types of organic residues, the finished product always contains a certain amount of contamination such as flakes of plastic film. These contaminants need to be reduced in order to improve compost quality. Currently, density sorting is applied to screen the compost and reduce contamination. However, the levels of contaminants from the current screening process are unacceptably high. To improve the accuracy of the current system advanced sorting technologies could be used. The spectral based sorting technology has been confirmed as a useful screening tool for identifying type of plastic recovered from the digestates that pass the 2 mm sieve.

4.3. Workshops 'Historic Cities Against Plastic Waste (HISCAP)'

BALTIPLAST Interreg Baltic Sea Region Project together with the partners from BIO-PLASTICS EUROPE Horizon 2020 arranged workshops on new perspectives of biobased plastics, aiming at clarifying understanding and potential application of bioplastics in the context of circular economy. The workshops 'Historic Cities Against Plastic Waste (HISCAP)' were organized at Tallinn University of Technology, Estonia (October 3, 2023) and Hilton Garden Inn Vilnius City Centre, Lithuania (October 5, 2023).

The workshops gathered representatives from municipalities, waste management companies and experts in the field. The participants had the opportunity to get acquainted with the EU policy and legal acts related to bioplastics as alternative to fossil-based plastics. The practitioners from Tallinn Municipality shared insights into the municipality's best practices in circular economy and effective plastics management. Academics from Tallinn University of Technology (TalTech) and Kaunas University of Technology (KTU) shared information on innovative bioplastic materials as well as impacts of bioplastics on existing waste management frameworks. The workshops provided a platform for engaging discussions, knowledge sharing, and networking among participants. The discussions held during the workshops undoubtably contributed to the better understanding of bioplastics as alternative to fossil-based plastics, at the same time workshops raised issues related to degradation and composting of bioplastics.

At the end of the workshops' participants were provided with questionnaires for expression of insights into management of bioplastics. Participants also indicated level of preparedness for introduction of innovative biobased materials at their municipalities/organizations. Eight respondents in Tallinn and ten respondents in Vilnius provided following answers*:

Questions	**Answers**	**Tallinn**	**Vilnius**	**Total**
How familiar were you with the concept of biobased and biodegradable plastics prior to attending the workshop?	Very familiar	3	1	4
	Somewhat familiar	4	1	5
	Not very familiar	-	7	7
	Not familiar at all	1	1	2
How open is your municipality / organization to changing to separate plastic collection systems?	Very open	1	-	1
	Somewhat open	5	-	5
	Neutral	2	2	4
	Not very open	-	3	3
	Not open at all	-	5	5
Have you previously explored the integration of bioplastics in your municipality/organization waste management practices?	Yes, extensively	-	-	-
	Yes, to some extent	6	-	6
	No, but interested	2	1	3
	No, not at all	-	9	9
To what extent do you believe the workshop content will help your municipality/ organization in implementing bioplastics effectively?	Very helpful	1	1	2
	Somewhat helpful	2	8	10
	Neutral	1	1	2
	Not very helpful	4	-	4
How prepared is your municipality/organization to integrate bioplastics into its waste management practices?	Very unprepared	1	5	6
	Unprepared	6	3	9
	Moderately prepared	-	1	1
	Prepared	1	1	2
	Very prepared	-	-	-
Has the current legal framework regarding plastic waste promoted the implementation of bioplastics in waste management in your municipality?	Strongly supportive	-	-	-
	Moderately supportive	3	1	4
	Slightly supportive	1	1	2
	Not supportive at all	4	8	12
Which of the following areas do you find most interesting and suitable for your municipality/organization to implement innovative bioplastic materials?	Food packaging	3	5	8
	Household small items	2	3	5
	Single-use plastic items	3	7	10
	Agriculture	3	4	7
	Environmental benefits	-	8	8
	Cost-effectiveness	3	5	8

What factors influence your municipality/organization interest in adopting innovative bioplastics?	Compliance with regulations	7	5	12
	Public awareness and demand	2	5	12
	Other	-	1	1
How do you envision bioplastics contributing to your municipality/organization current sustainability goals and waste reduction?	Significantly	1	5	6
	Moderately	-	2	2
	Minimally	2	2	4
	Not at all	5	1	6
What challenges or barriers do you anticipate in the integration and treatment of bioplastics in your municipality/organization?	Lack of knowledge	5	9	14
	Infrastructure limitations	6	6	12
	Budget constraints	5	6	11
	Regulatory barriers	3	5	8
	Public resistance	1	5	6
	Other	-	1	1

*For some of the questions respondents had possibility select several answers

CONCLUSIONS

The analysis of legal and operational aspects of plastic waste management in the BSR countries revealed shortcomings in existing municipal plastic waste management systems, specifically in terms of insufficient volumes and quality of plastic waste collection and sorting. Better and more harmonized separate collection and sorting of plastic waste provides prerequisites for turning plastics waste into a high-value resource.

Statistical data (2019) indicate that the highest plastic collection rate among BSR countries is in Germany (73%), while Estonia (31%), Sweden (29%), Lithuania (27%) and Finland (21%) demonstrate respectively high levels of plastic waste collection. The lowest plastic collection rate was indicated in Latvia (13%), however after introduction of beverage container deposit system (January 1, 2022) collection of post-consumer plastics has considerably increased.

The morphological analysis of plastics in mixed and separately collected waste streams performed in Kaunas, Tallinn and Daugavpils revealed that collection rate of separately collected plastics is in average twice higher compared to plastics collected in mixed waste streams.

An estimation of plastic waste distribution in terms of waste disposal methods at the above mentioned municipalities indicated:

- In Kaunas 10% of plastic waste is recycled, 8% - landfilled and 82% - incinerated;
- In Tallinn 13% of plastic waste is recycled, 8% - landfilled and 79% - incinerated;
- In Daugavpils 3% of plastic waste is recycled, 59% - landfilled and 38% - incinerated.

The proposed solution for plastic sorting involves portable NIR spectrometer trinamiX, which aligns well with the project aims and provides an innovative technical/technological perspective for plastic waste sorting at the municipal level. The portability of the device enhances its applicability in various target groups. The trinamiX solution is also a good decision aid for municipalities/companies that do not need a large, stationary sorting plant, but a flexible and mobile solutions.

Alternative plastics, such as bioplastics may be a more sustainable alternative to fossil-based, non-biodegradable plastics. However, they also present their own sustainability challenges and trade-offs that must be carefully assessed and considered. Specialized facilities and processes are necessary as existing waste sorting facilities are not equipped to handle the specific characteristics of biobased and biodegradable plastics.

The advancements of trinamiX solution for distinguishing between compostable and non-compostable plastics provide assumptions for efficient compostable plastics management on the municipal level. Communication with the participants of the workshops 'Historic Cities Against Plastic Waste (HISCAP)' revealed that major challenges for implementation of innovative bioplastic materials in municipality/organization activities are lack of knowledge, limitations of infrastructure and budget constraints.

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ANNEX

GOA 1.4

WHAT IS OUR SOLUTION?

01

▸ THE PLASTIC IDENTIFICATION TOOL

Mobile near-infrared (NIR) spectroscopy tool combines mobile hardware, data analysis, and material expertise to identify and distinguish a broad range of plastic types to support the path towards a circular economy. The tool enables a quick and more accurate on-site sorting of plastic waste into separate and valuable material streams.

02

▸ DATA ON TYPES OF PLASTICS

The data collected throughout the plastic categorization campaigns by applying the identification tool will be used:

- as decision aid at small/medium size facilities that do not need a large, stationary sorting plant, but a flexible and mobile solution to estimate the potential of increased sorting rates (e.g. recycling yards).
- as a “process control“ device used by the management staff at big facilities to check/validate accuracy of industrial plastic sorting processes.

WHAT IS OUR

SOLUTION?

STEPS TOWARDS INCREASING RATES OF MUNICIPAL SORTED PLASTIC WASTE BY TRINAMIX

01

ASSESSMENT OF CURRENT PLASTIC FLOWS AND SORTING PROCESSES

Understand the amounts and types of plastics being collected and sorted, the equipment used for it, and the efficiency of operations.

Identification of areas where improvements are needed.

02

INTRODUCTION OF TRINAMIX TOOL

Train the staff to operate and maintain the trinamiX tool effectively and ensure it is properly calibrated for accurate plastic identification.

03

SAMPLE COLLECTION AND DATA ANALYSIS

- Gather a representative sample of the plastic waste.
- Establish efficient collecting points or routes for plastic waste pickup.
- Ensure the samples cover a wide range of plastic types.
- Record and interpret the spectroscopic data obtained for each sample.
- Deploy the calibrated trinamiX equipment for real-time plastic sorting.

04

▶ ASSESSMENT OF PROGRESS

Obtain comprehensive data on plastic type by applying the trinamiX tool and compare to data obtained during mapping and manual categorization of plastic waste at big municipal waste management facilities in Tallinn, Daugavpils and Kaunas.

Identify areas and perform plastic waste sorting at municipal facilities that need flexible and mobile solutions. Typical areas of assessment will be:

- general identification and sorting of plastics at large-sized waste reception sites in the cities
- identification and separation of PA6 and PA66
- fishery gear recycling
- identification and separation of bio-plastics

05

▶ PROGRAM ADJUSTMENT

Analyze the collected data to identify areas for improvement in the sorting process.

Consider expanding the program to cover additional areas within the municipality based on the success of the pilot phase.

06

▶ COMMUNICATION AND REPORTING

Keep stakeholders, including local officials and the community, informed about the progress and outcomes of the trinamiX-based piloting.

Collect and report results and best practices in a catalogue.