ISWM Toolbox

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1. ISWM Guidelines

1.1 Introduction

The ISWM Guidelines are intended for use by waste companies and municipalities in the South Baltic region and beyond, to assist with them meeting national implementation plans of the EU waste management "package" adopted in June 2020. It is based on the experiences of the partners in the Wasteman project.

Traditional tools and problem-solving techniques do not serve their purpose when used to tackle complex or uncertain issues, such as those related to environmental, social or health causes. In light of this, no public organization can tackle these issues alone, either, so bridges must be built to narrow the complexity gap (the one faced by institutions and their capacity to tackle them).

The case of waste management and its relation with the climate and resource crisis pose a challenging situation in search of more sustainable solutions. How can a high-quality service be still delivered, whilst at the same time minimising health and environmental hazards in a climate friendly way?

The Wasteman project is based on the Integrated Sustainable Waste Management (ISWM) framework, which is used when developing or changing a solid waste management system in recognition of its complexity. Hence, ISWM brings this systemic approach to the challenges of waste management aligned with the Wasteman objectives, in seeking a circular model through a human-centric and design-driven manual. ISWM presents a new way to process waste, which implies separation, collection, composting, recycling and disposal of the different waste fractions, as well as including all stakeholders and sustainability aspects.

ISWM identifies three dimensions: stakeholders, waste system elements and sustainability aspects; stressing the fact that not only waste system elements such as generation, separation, etc. should be considered when planning a waste management system but this planning should include the aforementioned dimensions, too.

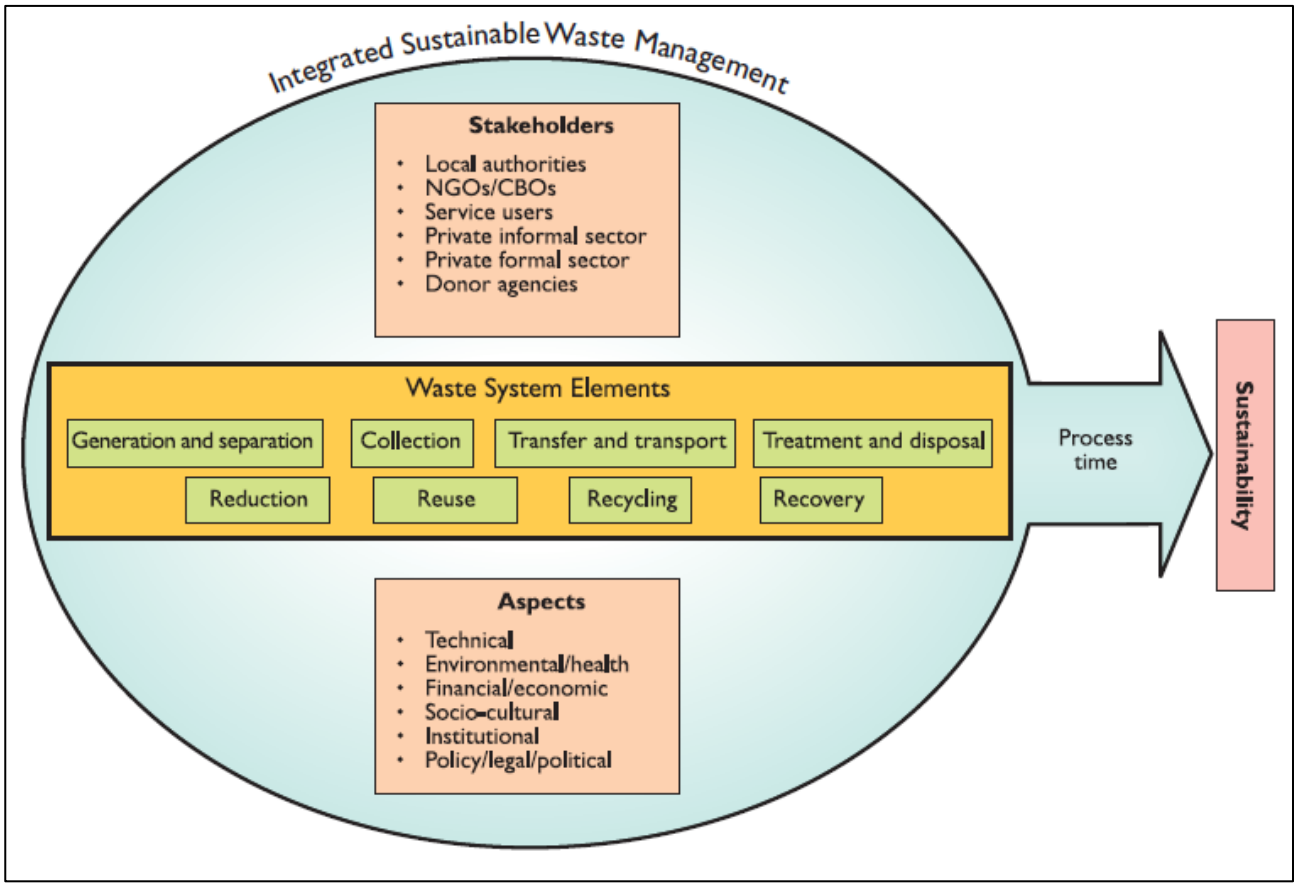


Figure 1. ISWM process and characteristics. Source: UN HABITAT, 2010.

Prior to set a series of ISWM guidelines, the whole systemic approach acknowledges and stresses the sector´s complexity, which relies on different actors that coexist in a dynamic way within waste management. So, it should be understood that what is being presented is of an innovative nature, challenging existing practices and embracing complex system dynamics.

The issues to consider before setting a set of guidelines include, but are not limited to, the following:

- Grouping of all waste management actors, to have organizational integrity;
- Need to have one work process, that includes all actors;
- Consideration of public-private partnerships, identifying their complementarities;
- Consider a clear and concise division or roles and responsibilities;

With this background, this document aims at presenting management guidelines as part of an ISWM toolbox. This is delivered by firstly creating an overview of the EU waste plans and directives on circular economy within EU Member States, especially those affecting the transition at national and municipal levels. After this, an overview of the different plans and legislation in force in the Wasteman project participants´ countries will be presented. The types of tools will be presented that stem from the Wasteman project's experiences, and finally, the document will cover case stories utilizing the tools and developed under Wasteman via different partners in Denmark, Lithuania and Poland.

1.2 Change Management and Framework Conditions for Circular Economy Transitions

When setting the basis for a set of ISWM guidelines, which imply a shift from a linear way of disposing different waste streams, towards a more efficient, circular way of managing waste to close the resource loop, the following is to be considered keeping the ISWM framework in mind.

In this Toolbox, we narrow our focus within the ISWM framework on the elements that are most pressing when it comes to municipalities' transition efforts – specifically, in addressing the recycling targets for different waste fractions and the ways in which the recycling rates are going to be measured in the near future.

The following are important municipal considerations:

- **Organizational change management**, i.e. the way that waste companies and municipalities can or should organize and structure their work in order to transition to circular economy, e.g. within administrative units and teams. As circular economy is a broad concept that goes beyond the traditional boundaries of what a waste company or municipality can handle alone, organizing for change should be mindful of this.
- **Framework conditions at EU level for transitioning from a linear to circular economy**, i.e. institutional set-ups and targets which heavily impact the way that the waste management authorities and other actors in the waste/recycling chain have to conduct their activities now and in the near future.

Closing the Loop – But in Which Manner?

Recycling is a key consideration for waste companies and municipalities in a circular economy transition, as it corresponds with the main role they have in managing waste streams that arrive from upstream producers and consumers of products that ultimately become waste. In a circular economy, emphasis is on slowing, narrowing and closing resource loops[1]. Slowing refers to extending product lifetimes (reuse). Narrowing refers to creating products with minimal resource use (efficiency). Closing refers to circulating discarded materials back into new products (recycling).

Waste companies and municipalities are primarily tasked with ensuring recycling of collected waste, i.e. reaching recycling targets and recycling rates through the closing of resource loops (recycling). However, it is worth considering that there are differences in recycling. In promoting circularity of materials and substituting virgin raw materials, there are many different qualities of recycling, and some types of recycling are better than others. High-value recycling is the most desirable kind of recycling. This is the proposition in a new recycling hierarchy developed by the Danish Society of Engineers in a package of recommendations to promote circular economy at national level in Denmark[2], but with broader application for EU member states in the South

[1] Bocken, N. M., De Pauw, I., Bakker, C., & Van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of industrial and production engineering*, 33(5), 308-320.
[2] The Danish Society of Engineers. (2021). How to ensure high-quality recycling in a circular economy. Retrieved from: idas-strategi-for-cirkulaer-oekonomi-2021-teaser-english-01.pdf

Baltic region and beyond. The recycling hierarchy is presented below, and distinguishes between four forms of recycling A-D, with each step representing a different level of material property preservation.

Although not widely adopted yet within the EU, the recycling hierarchy sets out an ambitious agenda for not only achieving recycling rates as detailed by legislation as will be detailed in the following sections, but ensuring that recycling leads to maximal preservation of material properties.

1.3 EU and National Legislation and Plans

A Roadmap for Zero Waste in the EU

Turning waste into a resource is a priority to a green and circular economy. EU adopted in December 2019 the European Green Deal[3] and in March 2020 one of main building blocks in the Green Deal - a new Circular Economy Action Plan (CEAP) was published[4]

At the moment only around 12% of materials used in EU industry comes from recycling and Eurostat estimates that about 600 million tons could be reused or recycled[5]. Therefore, the focus is to move the industry from a linear to a circular thinking.

The main approach is to establish a "robust and integrated single market for secondary raw materials and by-products" (EU Green Deal).

Circular Action Plans

The process that ended up with new recycling targets and the new CEAP started in December 2014 when the Commission withdrew their communication "Towards a circular economy: A zero waste

[3] The European Green Deal, Brussels, 11.12.2019 COM(2019) 640 final,
[4] A new Circular Economy Action Plan - For a cleaner and more competitive Europe, Brussels, 11.3.2020 COM(2020) 98 final
[5] https://ec.europa.eu/eurostat/web/waste/overview

programme for Europe[6]"and developed the first Circular Actions Plan "Closing the loop - An EU action plan for the Circular Economy[7]" launched a year after in December 2015 in order to start up the long-term transition to a circular Europe

One of the first action plan's main component was waste management resulting in a comprehensive waste package as result of a compromise between member states, the Commission and the EU Parliament (the Trilog) which is expressed in the preamble's recitals to the amendments to the directive on Waste[8] from May 2018, where the linkage to circular economy is clearly expressed. It is recommended to read the preamble in order to understand the rationale behind each amendment and Trilog compromise.

> Recital 1.
> Waste management in the Union should be improved and transformed into sustainable material management, with a view to protecting, preserving and improving the quality of the environment, protecting human health, ensuring prudent, efficient and rational utilisation of natural resources, promoting the principles of the circular economy, enhancing the use of renewable energy, increasing energy efficiency, reducing the dependence of the Union on imported resources, providing new economic opportunities and contributing to long-term competitiveness.
> Source: DIRECTIVE (EU) 2018/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2008/98/EC on waste.

The other main element of package was the amendments to the packaging and packaging waste directive[9].

For those who place packaging's on the EU market the Extended Producers Responsibility (EPR) is considered as the main measure as an economy incentive to streamline the packaging supply chain with focus on reuse and 1:1 recycle packaging materials e.g. PET and also to avoid the planned EU levy on non-recyclable packaging. There is also a focus on packaging and bio-economy and is addressed in the amendments to the packaging and packaging waste directive.

> Recital 7.
> Fostering a sustainable bio-economy can contribute to decreasing the Union's dependence on imported raw materials. Bio-based recyclable packaging and compostable biodegradable packaging could represent an opportunity to promote renewable sources for the production of packaging, where shown to be beneficial from a life- cycle perspective.

[6] Towards a circular economy: A zero waste programme for Europe; Brussels, 25.9.2014 COM(2014) 398 final/2
[7] Closing the loop - An EU action plan for the Circular Economy; Brussels, 2.12.2015 COM(2015) 614 final
[8] DIRECTIVE (EU) 2018/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2008/98/EC on waste
[9] DIRECTIVE (EU) 2018/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste

Source: DIRECTIVE (EU) 2018/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste

Recycling Targets

The recycling targets for municipal waste will be raised from the current target of 50% in 2022 to 65% in 2035 in three stages, and several fractions "to be collected separately" will also be integrated step by step into national collection schemes. With regard to packaging, it must be borne in mind that all packaging marketed on the national market is included in the target of 70% recycling of all packaging material, but differentiated on the various packaging materials, see Figure 2. Recycling targets for municipal waste, 2025 and 2030.

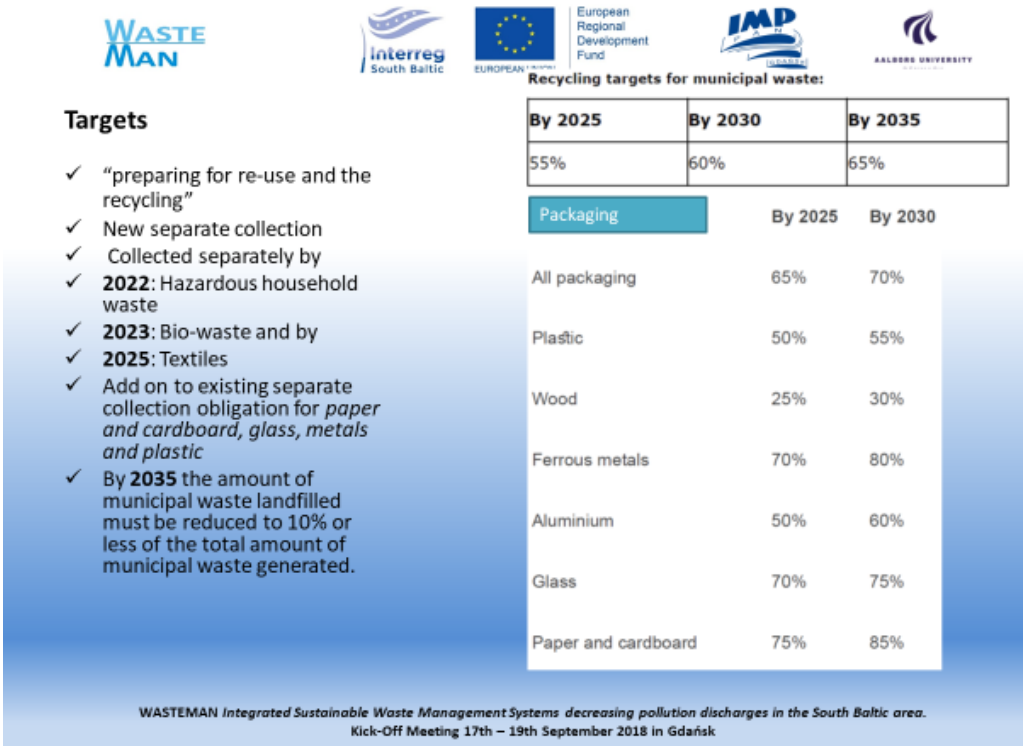


Figure 2. Recycling targets for municipal waste, 2025 and 2030. Source: WASTEMAN.

It is said in article 2 in DIRECTIVE (EU) 2018/851 that "Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 5 July 2020." meaning the national transposition of the targets into the national context including a national waste management plan who distribute the responsibilities from citizens over different administrative levels in order to reach the recycling targets. The national transposition is far from to become completed. The citizens interest is waste varies a lot among the member states, see figure which shows that there is a huge job ahead of all involved in the transition to more circularity in waste management.

Reporting Data

The Commission has decided on a format and calculation rules for reporting recycled municipal waste and waste prepared for reuse[10] that shall be reported to EUROSTAT.

There is an important change in the way the recycling rate of a specific fraction as the calculation point is change as illustrated in Figure 3. Calculation point 2018-2020. Source: WASTEMAN.. It means that the rate is calculated after the separate collected fraction has been sorted at a treatment facility, it means also the only the part that are accepted at an upcycling facility counts as real recycling.

Already in 2024, the Commission shall review the recycling target shown in Figure 4. Recycling interest across the EU. Source: EC., and the data reported to the EUROSTAT will part of the review.

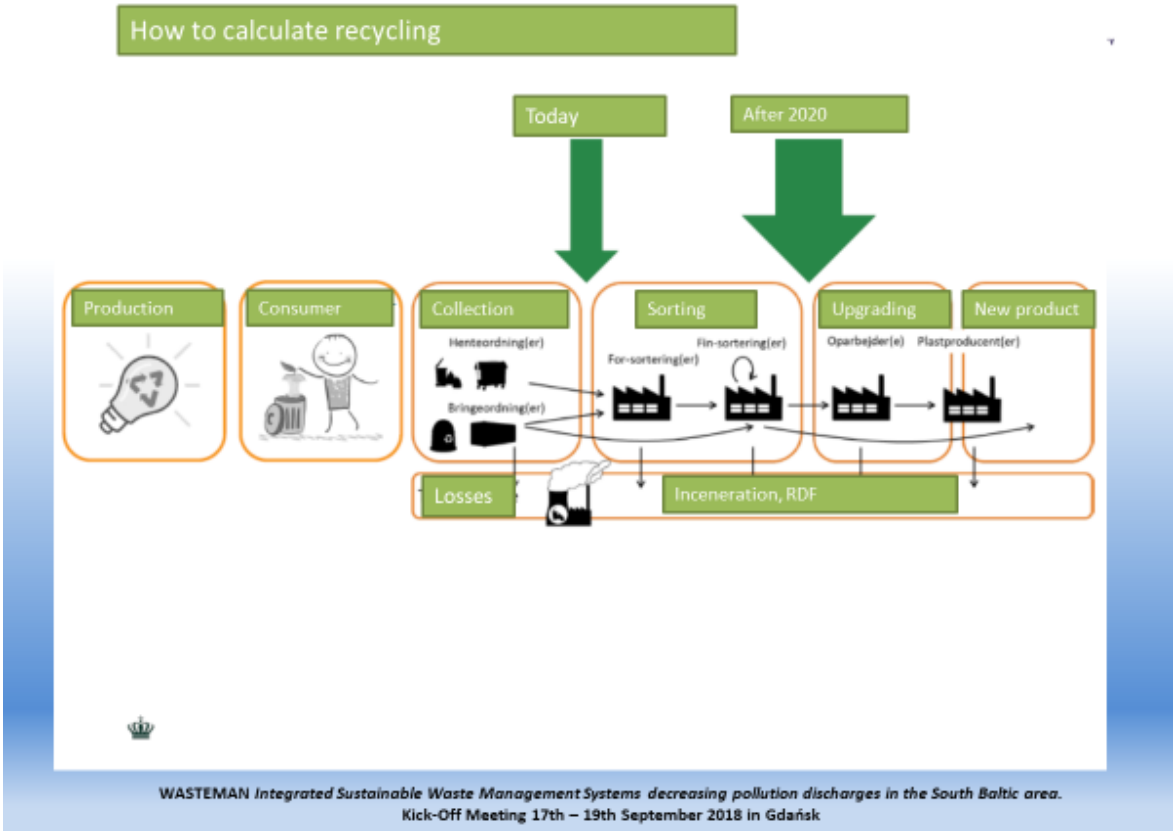


Figure 3. Calculation point 2018-2020. Source: WASTEMAN.

[10] COMMISSION IMPLEMENTING DECISION (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council and repealing Commission Implementing Decision C(2012) 2384

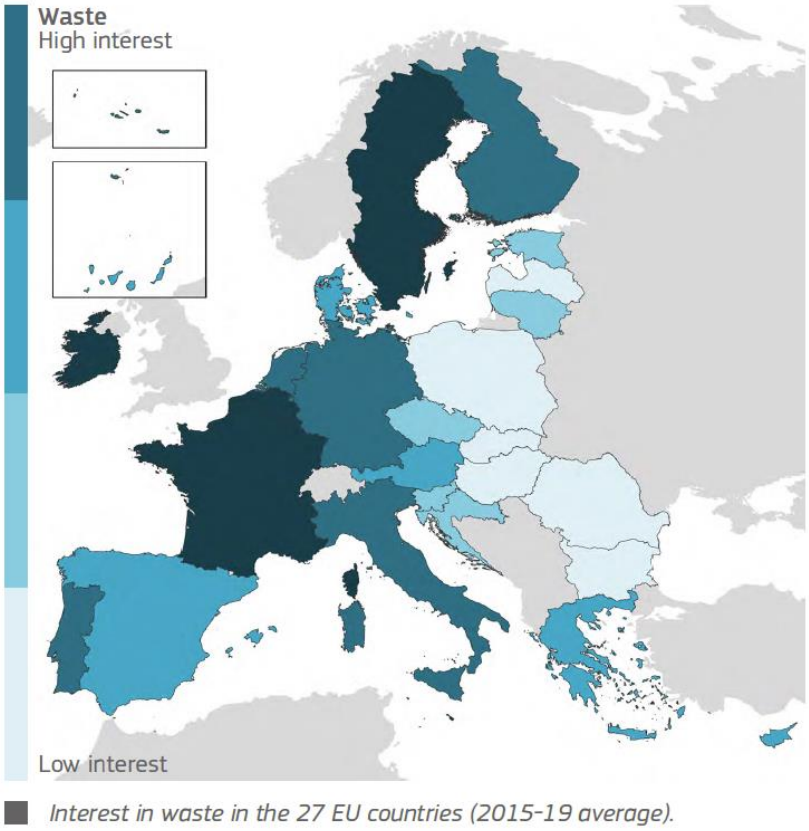


Figure 4. Recycling interest across the EU. Source: EC.

Source: Tracking EU Citizens' Interest in EC Priorities, Using Online Search Data- The European Green Deal, European Commission Joint Research Centre, January 2021[11]

1.3.2 Roadmap Denmark

EU CE Action Plan

The Danish government and a wide majority of the Danish Parliament entered in June 2020 into an agreement aiming at a climate-neutral waste sector by 2030. The measures are more recycling and a reduction of the existing incineration capacity.

The output of the agreement is planned to result in a reduction of Denmark's greenhouse gas emissions with 0.7 million tons by 2030, which is equivalent to removing 280,000 diesel and petrol cars from the roads.[12] The intervention with incineration is to adapt the capacity to the Danish waste volumes, i.e., to cut off imports of RDF if feasible, which in 2030 is expected to lead to a reduction of approx. 30 percent compared to today 2020. The reduction will take place through a competitive "survival of the fittest" model among the existing incineration plants. Additionally it is decided:

- To remove 80 per cent of plastic waste from incineration plants by 2030.

[11] https://www.google.com/search?client=firefox-b-d&q=eu+green+deal+pdf
[12] https://stateofgreen.com/en/partners/state-of-green/news/new-political-agreement-to-ensure-a-green-danish-waste-sector-by-2030/

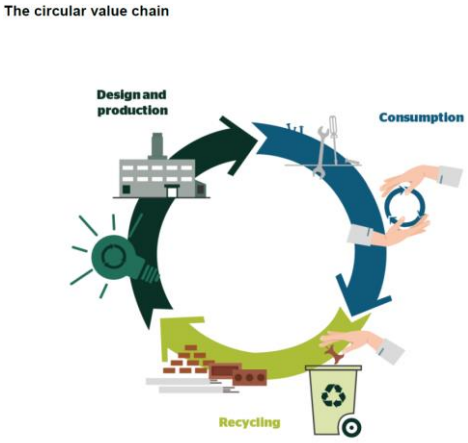
- To avoid bulky waste in waste incineration plants

The agreement also entails a privatization of waste sector. The primary future role of the municipalities will be planning and collection of source-separated household waste, it means that

- Municipalities must not invest in new recycling plants
- Tender requirements for all collected source-separated recyclable from household waste
- Existing public municipal treatment facilities like incineration facilities shall be "companies"[13]

National Plan

The national plan for Denmark is the **National Plan for Prevention and Management of Waste 2020-2032**.[14]



Focus areas of the national waste plan, also known as the action plan for circular economy:

- Less waste and better use of natural resources
- More and better recycling
- Better use of biomass
- A sustainable built environment
- Plastics in a circular economy

Local Governments (Municipalities)

For all municipalities, the following applies:

- Increased and streamlined waste sorting in 10 fractions
- Mandatory and uniform collection schemes, with some flexibility, but same sorting criteria and pictograms – see figure
- Sorting facilities available in the public space

Figure 5. Waste fractions and their pictograms in Denmark: metal, food waste, carton, paper, glass, plastic, residual, hazardous, food & drinks cartons, textile.

The agreement also includes initiatives against plastic waste e.g.

- Target of 50 % reduction of certain plastic takeaway packaging by 2026

[13] https://mim.dk/nyheder/2022/sep/nye-politiske-aftaler-danmark-et-skridt-taettere-paa-en-klimaneutral-affaldssektor/
[14] https://mim.dk/media/222900/faktaark_vision_endocx.pdf

- Target of 50 % recycling of the agricultural sector's plastic waste in 2025 and 80 % in 2030
- Target of 25 % recycling of the construction / construction sector's plastic waste in 2025 and 75 % in 2030

The plan has three focus areas: Biomass, construction and plastic, but includes a total of 126 initiatives covering a wide range concrete objectives and indicators for circular economy.

1.3.3 Roadmap Poland

EU CE Action Plan

The Polish Parliament has implemented Directives (EU) 2018/850, 2018/851, 2018/852 of 30 May in Act 2051 from 17 Nov. 2021, which changed the waste management Act.

The Polish Act 2051 presents the same recycling targets for 2030 as the Directives. As the incineration is in Poland minor issue, the main focus is on reduction of landfilling i.e. the municipalities are responsible for progressive reduction of landfilled waste by:

- 30% by weight in years 2025 – 2029;
- 20% by weight in years 2030 – 2034;
- 10% by weight from 2035 and later.

Besides, the all wastes which can be recycling should not be accepted to landfill by 2030, with exception those which landfilling gives better environmental effect. The Act describes also the methodology for calculation the recycling and reuse level as well as the reporting to EU.

The Act 2051 presents also minimal requirements in relations to EPR (extended producer responsibility) i.e. description of roles and responsibilities of all stakeholders, goals and targets to be reached, reporting system, equal treatment of all producers, etc.

There is a wide discussion related to EPR costs including the collection, transport, reforming and other costs as well as EPR data collections and reporting.

National Plan

National waste plan for Poland was accepted on 1 July 2016 as an Annex to the Resolution No 88 of the Council of Ministers titled **National Waste Management Plan 2022**. It was modified by the Annex which described the investment gap and information on financial resources related to covering cost of exploitation of waste facilities.

A series of changes in various Acts have gone through with municipalities and other stakeholders:

- Act on maintenance of cleanness and order in municipalities;

- Act on legal code of conduct related to increased responsibility and fines for littering public areas;
- Act on penal code related to punishment of anybody who live the danger waste in not proper location;
- Act on environment protection and waste related to the period of waste storing and the settlements for waste management in multifamily buildings;
- Act on extended responsibility of producer for the life cycle of products– these include design and production of recyclable packaging, etc.

Local Goverments (Municipalities)

In order to reach the circular economy, the municipalities postulate different measures, such as:

- deletion of waste ownership by municipalities;
- allowing municipalities to choose the organizational form of waste managing entity, i.e. municipal, private, etc.;
- in house procedure in relation to own entities;
- introduction of deposit system for packaging wherever it is possible, to force the producer to use multiuse packaging;
- legally bind the largescale shopping centres to provide for clients' deposit automats for glass and PET bottles;
- active support by the state the entities active in recycling to overcome present problems;
- to legally bind the producer to use at least few per cent of recycled waste to produce new packaging – in order to increase the demand for recycles materials.

Aside from this, the Association of Polish Cities have issued their position in relation to waste management, which focused on better communication, need for EPR solutions and better economic solutions in relation to waste management in municipalities.

1.3.4 Roadmap Lithuania

EU CE Action Plan

In Lithuania, waste management is currently regulated by two main laws:

- The Waste Management law
- The Packaging and Packaging Waste Management law.

Currently, the Law on Waste Management and the Packaging and Packaging Waste Management law do not implement all EU directives. For this reason, the Lithuanian Parliament plans to amend these laws. That's why important to transpose and implement the provisions of Directives (EU) 2018/852, 2018/851, 2018/850 and 2018/849. In the same way, the Law on Packaging and Packaging Waste Management does not implement all EU directives, so it is important to improve the legislation to comply with the provisions of (EU) 2018/852, 2018/851.

The following criteria shall be followed in planning the development and capacity of waste management facilities in the State Waste Prevention and Management Plan:

- until 2025 increase the amount of municipal waste prepared for re-use and recycled to at least 55% (by weight);
- until 2030 increase the amount of municipal waste prepared for re-use and recycled to at least 60% (by weight);
- until 2035 increase the amount of municipal waste prepared for re-use and recycled to at least 65% (by weight);
- no later than 2025, 31 December at least 65% of all packaging waste (by weight) must be recycled;
- no later than 2030. 31 December at least 70% of all packaging waste (by weight) must be recycled;
- no later than 2035 the amount of municipal waste disposed of in landfills must be reduced and should not exceed 5% or less of the total municipal waste (by weight) generated.

National Plan

Lithuania's National waste plan was approved on June 17 in 2021. This was the national transference of document 851/2018/EU. On June 1 of this year, the **State Waste Prevention and Management 2021-2027** was also approved.

The plan includes measures for the prevention of waste generation, prevention of littering, and measures to increase the use of garbage management, reuse of items, and waste recycling and secondary raw materials. The increase in waste processing and the use of secondary raw materials would be strengthened through the strengthening of extended producer responsibility, the goal was set to establish producer responsibility for textiles and furniture, as well as through green public procurement, with the intention of expanding the environmental requirements for green procurement, including the percentage expression of the use of secondary raw materials.

It should be noted that the **2023-2035 Action Plan for Lithuania's Transition to the Circular Economy** is currently being prepared. This project will be ready in October 2022. It should be noted that VAPTP will be integrated into the mentioned action plan.

Local Governments (Municipalities)

In order to reduce the amount of waste emitted in municipalities, the following measures are used to reduce the amount of waste:

- kitchen waste collection systems are being implemented
- textile waste sorting systems are being expanded
- reuse of used items is being developed
- sorting infrastructure in public places is being developed
- a network of public drinking water stations in municipal attraction centers, public sports grounds, playgrounds and parks is being developed

2.Tools

When considering 'toolbox' tools in waste management, a common framework in the Wasteman project has been the ISWM framework which considers a given waste system as consisting of the following 3 elements. Each tool touches upon one or several parts of the 3 elements:

- *Stakeholders*, where emphasis is on mapping, understanding and engaging with stakeholders such as waste generators (engaged citizens), authorities, civil society organizations, enterprises and the informal sector.
- *Waste System Elements*, where emphasis is on examination of physical components in the stages in the flow of waste from generation and separation, collection, transfer and transport to treatment and disposal using the waste hierarchy.
- *Aspects*, where emphasis is on understanding the framework conditions that can be affected by the waste system in question, i.e. environmental, socio-cultural, institutional, political and legal planning aspects.

The tools developed in the Wasteman project are considered in the next chapter and are presented as Case Stories. The Case Stories show how different countries and actors in the South Baltic region have developed ISWM solutions to meet EU, national and municipal targets and plans for waste management and circular economy as presented in the previous chapter.

Aside from the ISWM framework, the tools are considered with respect to EU Technology Readiness Levels (TRLs) as far as the TRLs can be meaningfully applied to the ISWM solution in question, see Figure 6.

TRL 9	actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space
TRL 8	system complete and qualified
TRL 7	system prototype demonstration in operational environment
TRL 6	technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 5	technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 4	technology validated in lab
TRL 3	experimental proof of concept
TRL 2	technology concept formulated
TRL 1	basic principles observed

Figure 6 - EU Technology Readiness Levels, from Annex G in the EU Horizon 2020 Work Programme 2014-2015

In general, the tools can be categorized as:

- *Technological tools* (Poland, Denmark, Lithuania) which can cover e.g. waste treatment and recycling technologies and applications of waste streams into new products, or new kinds of physical waste infrastructure
- *Community engagement or system tools* (Denmark, Lithuania) which can cover stakeholder-oriented approaches for municipal authorities and decision-makers, or value chain solutions to minimize waste and increase recycling.

An overview of the tools is compiled below:

Technological tools	• **Poland:** Wax-based emulsions from pyrolysis of plastic waste in soils stabilization • **Poland:** Effective microbe-modified organic fraction of MSW as fertilizer • **Denmark:** Shared Waste Collection Systems • **Lithuania:** A company in Tauragė that contributes to cleaner oceans • **Lithuania:** Sewage sludge from Tauragė as a crop fertilizer
Community engagement or system tools	• **Denmark:** Co-Design • **Lithuania:** National deposit systems

Aside from the two different kinds of tools, the Wasteman project has also carried out socio-economic assessments on some of the ISWM solutions. The reports stemming from these socio-economic assessments are not part of this ISWM toolbox document, but they support how the different tools may be considered as sustainable.

3. Case Stories

3.1 Poland

3.1.1 Wax-based emulsions from pyrolysis of plastic waste in soils stabilization

Fig. 1. Manual application of liquid soil stabilisers (emulsion based on plastic waste pyrolysis products – waxes).

INTRODUCTION. One of the main conditions for the functioning of a thriving economy is a well-developed road infrastructure. In the years 2004-2020, over 5,000 km of roads and highways were built in Poland. Currently, when building roads, before laying an asphalt or concrete surface, the ground that is the basis of the road under construction must be compacted and stabilized. There are two basic methods of soil stabilization: in situ and in a stationary node (ex-situ). The method of performing stabilization in place (in-situ) is the most frequently used method due to its convenience and lower price. The most popular type of binder for stabilization is a hydraulic binder (most often cement and various ashes). Such stabilization is performed at a depth of 10-50 cm, achieving the desired load-bearing parameters. In order to improve them, various chemical additives for stabilization are often used, such as ion exchange compounds, additives based on sulfuric acid, additives based on vinyl polymers or even organic additives using lignosulfonates. Unfortunately, the use of such additives is associated with much greater costs, so there is a need for cheaper and equally effective alternatives, which at the same time do not pose more environmental risks. The win-win situation would be for instance recycling the problematic waste-based materials that on one hand are landfilled or impossible to recycle and on the other hand cause problems for the waste producers. Therefore, an interesting issue is the production of stabilization additives from various types of waste materials. The research on innovative plastic waste-based binders has been carried out so far at the Construction Company "WACIŃSKI" via the project: *“Development and implementation of effective stabilizing mixtures for the foundation of road surfaces using fly ashes from the coal-based energy sector in Gdansk” (Regional Development Programme of Pomorskie Voivodeship/ Action 1.1.1 Expansion via innovations)*. This construction company as partner of IMP PAN, effectively applied, processed by IMP PAN, plastic waste products in soil stabilisation.

Fig. 2. Visual effect of waste-based stabilisers affecting the soil sealing influencing its frost resistance

METHODOLOGY. Emulsions of post-pyrolytic waxes from the pyrolysis of waste polyolefins were prepared using the following plastic waste fractions: (1) HDPE (High Density PolyEthylene), (2) post-separated plastic high-calorific fraction (RDF – Refuse Derived Fuel), (3) car tires, (4) clean PE foil. Pyrolysed products were supplied both by the company JANPOL Technologie Ltd and in parallel by IMP PAN. The following soil mechanical parameters were tested at the Construction Company "WACIŃSKI": (1) compressive strength (CS) after 7 days and after 28 days, (2) water absorption (WA) after 4h and 24h, expressed as the amount of water absorbed by the soil and shown in% (g H_2O/ g dry weight of soil) and (3) frost resistance (FR) as compressive strength after 14 freezing cycles, related to the initial compressive strength after 28 days, expressed as % of the initial strength. These parameters are commonly when planning the stabilisation and come from the national standards.

RESULTS. The laboratory mechanical tests confirms the positive influence of these waste products on some parameters of stabilized soil (eg. compressive strength and sealing). The positive effect of selected additives has been observed for both cohesive (clays, silts) and non-cohesive soils (sands, gravels). Each of these plastic waste post-pyrolytic wax/water emulsions have been tested as a stand-alone stabilizer (+5 treatments and the analysis of full set of 3 mentioned above key parameters) as well as hybrids with other waste additives (+10 treatments and the analysis of full set of 3 mentioned above key parameters)). Emulsions from clean PE foil show the best effect: 37% increase in compression strength for cohesive soils (clay) and 55% increase for non-cohesive soils (sand), then followed by RDF-based emulsions (33% more compression strength for clay and 42% more for sands) and HDPE-based emulsions (31% more for clay, 16% more for sand). In addition, the sealing parameter (based on ability to reduce water absorption and soaking) having a direct effect on capillary forces was also visibly improved as frost resistance ranged between 70% and 93% (with 46% for the control sample), which is closely related to the low water absorption (0.35%-8.00%) for these soils amended with stabilisers.

The positive result of this research allows us to hope for new additions to the stabilization of waste origin and that they will contribute to the improvement of the quality of road infrastructure along with a neutral impact on the soil environment and positive impact on plastic waste upcycling. The areas of further attention are (1) obtaining the permits for the potential manufacturer for

processing the plastic waste into pyrolysis products or importing them, emulsification and purification/ stabilisation, (2) products recognition and approval by national certification for hydraulic soil binders, (3) benchmarking and parity with conventional soil stabilization products. Environmental risk considerations are not the main concern as the potential amount of plastic waste wax in the form of water emulsion, introduced to the soil subsurface is less than 0.5 kg/ m^2, and only insignificant amounts (below the national limits) of heavy metals and organic contaminants were found in the leachates.

This proposal is in line with the objectives of the **Circular Economy Action Plan**, which focuses on the sectors using a high amount of resources, where the potential for improvement is high, like plastics, textiles, construction and buildings. The Plan even has a separate Plastics policy. The proposal is also coherent with the **EU Green Deal**, namely it supports reduction of net greenhouse gasses emissions by 2050 and helps decoupling the economic growth from resource use by upcycling plastic waste products in roads. This action is in line with the **Waste Framework Directive**, where EU countries are obliged among others: for re-use and the recycling of municipal waste to a minimum of 55 %, 60% and 65% by weight by 2025, 2030 and 2035, respectively. The Directive also requires that waste will be managed without endangering human health or harming the environment, without risk to water, air, soil, plants or animals. The Directive criteria also specify when certain wastes cease to be waste and become a product, or a secondary raw material.

READINESS. The Technology Readiness Level (TRL) of this technology is around 6; the laboratory tests are finished and the real scale roadworks are to be started soon. Still some technical problems e.g. development of an automatic dosage system for emulsions are to be solved (Fig. 1 shows manual way of emulsion application for the research reasons). The technology is closely related to the Integrated Solid Waste Management (ISWM) framework. As the intended use is for local and national roads construction, national and local authorities are responsible for decision-making and citizens (drivers) are the final users. The covered Waste System Elements are: plastic **waste treatment** via pyrolysis and **recycling** as post-pyrolytic products (waxes) purification and preparation of steady emulsions,. “Financial/ Economic” benefits are expected due to savings in no use of commercial additives and making revenue on waste utilisation. Whereas “Sociocultural”, “Institutional”, “Policy/ legal/ political” factors need to be considered if scaled out and applied in real scale.

ISWM Framework Positioning of the Case Story

Stakeholders: Citizens, Local Authorities

Waste System Elements: Waste treatment, Recycling, Reuse

Aspects: Technical, Environmental, Financial, Socio-cultural, Institutional, Policy/legal

Lessons learned:

- Plastic waste-based pyrolytic products such as waxes effectively influence on soil stability parameters (compression strength, sealing, frost resistance) prior to road construction,
- Pyrolysis is not yet widely applied to waste products due to legislative and environmental reasons, what can be a barrier for technology development,
- Limited cost of input substrates of waste products is expected as normally plastic waste would need to be utilised elsewhere, what in Poland nowadays costs ca. 500-1500 PLN/ t
- The economics of thermal destruction (pyrolysis) of RDF has to been taken into account,

3.1.2 Effective microbe-modified organic fraction of MSW as fertilizer

The green areas in cities and urban areas are becoming a higher concern for city planners, urbanists and local authorities as progressing climate change induces new actions towards better rainwater infiltration, circulation as well as the comfort of the local city climate. In parallel the quantity of solid biowaste remains at a high level. In Poland, in 2018 approximately 3.5 million tonnes of biowaste is available for novel management techniques, one of which may be Effective Microbes (EM) modification of the organic fraction of municipal solid waste (OF-MSW) and production of fertiliser for urban green areas. Returning nutrients, contained in OF-MSW, back into soil close to the nutrients loop, is an environmentally friendly solution for its utilisation. The story below shows that such a scenario works even under winter conditions.

This proposal is in line with the objectives of the Circular Economy Action Plan, which focuses on the sectors using a high amount of resources, where the potential for improvement is high, like water and nutrients. The proposal is also coherent with the EU Green Deal, namely it replaces the inorganic fertilisers (currently produced by heavy chemical industry) with organic ones derived from waste. This contributes to the aim of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. Moreover, clean water, healthy soil and biodiversity would be maintained. This action is in line with the Waste Framework Directive, where EU countries are obliged among others: for re-use and the recycling of municipal waste to a minimum of 55 %, 60% and 65% by weight by 2025, 2030 and 2035, respectively. The Directive also requires that waste will be managed without endangering human health or harming the environment, without risk to water, air, soil, plants or animals. The Directive criteria also specify when certain wastes cease to be waste and become a product, or a secondary raw material.

The study was undertaken by IMP-PAN. The OF-MSW was treated with effective microorganisms on-site, pelletized and dried for use as an organic fertilizer. The goal of later studies was: (1) to verify the fertilizing value of the OF-MSW modified by Effective Microorganisms (EM), (2) to compare its efficiency under winter conditions (October – April) to that of market accessible NPK mineral fertilizer, (3) to evaluate the residual effect on soil after OF-MSW fertilizer application. The dosages were carefully planned: (1) normal dose (the one recommended by the mineral fertilizer supplier - 20 kgN/ ha), (2) maximum allowable dose (according to the Polish legislation - 170 kg N/ ha), (3) an overdose in order to prove the effect of overfertilization.

Fig. 3. Mixing the applied novel stabilisers with soil using conventional technique.

The verification methodology was as follows: soil for each out of 39 pots (presented at the photo above) was prepared by mixing pre-sieved sand with peat in 5:1 gravimetric ratio. Then the prepared micronutrients (salts of K, Ca, Mg, Mn, Zn, Cu, S, B, Na, Mo) were added. Subsequently, fertilizers were added according to amounts ranging from 20 to 370 kg N/ha; then 80 seeds (ca. 0.5 g) of grass were placed on top and covered with the topsoil. Soil moisture was maintained at Field Capacity (ca. 35% cm^3 H_2O/cm^3 soil eg. 22% w/w) by watering with deionised water. Harvesting was performed after 30, 90 and 180 days of growth in a greenhouse for biomass yield and NK uptake analysis. Finally, the residual soil properties (NK, pH, EC) were analysed.

In general, the findings after 180 days of growth (3 harvests) indicate slower mobilization of nutrients from the organic waste-based fertilizer and subsequent gradual growth of grass biomass over time (with maximum after Harvest 2) and across the application rates (maximum at 170 kg N/ha). Cumulatively for the dose higher than 170 kg N/ha, the EM-modified OF-MSW resulted in ca. 50% higher growths and up to 80% higher N uptakes than for mineral fertilizer – no overfertilization effect was found for OF-MSW fertilizer! This is in sharp contrast to the mineral fertilizer, which resulted in fast growth of grass in the very beginning and only up to 70 kg N/ha (Harvest 1 and 2), after which the response curve shows a slow decline (the grass does not react to doses larger than 70 kg N/ha). Overfertilization was observed only for the mineral fertilizer.

Ryegrass responses to mineral fertilizer (up) and EM-MSW-OF fertilizer (down). Harvest 2.

Nitrogen utilization: the N content in grass samples was increasing linearly with growing fertilizer dose. When applying mineral fertilizer 70 ÷ 200 kg N/ha, ca. 20% more N was determined in plants in relation to the ones grown on the organic fertilizer. However, the total N uptake per area for both

fertilizers provided equal N uptake (12 kg N/ ha) at 120 kg N/ ha application rate (ca. 10% of the input). The positive, noticeable effect of organic waste-based fertilizer was reflected in up to two times better N utilization at higher dosages as compared to the mineral one. This proves that OF-MSW based fertilizer would cause less nutrients leaching and more retention in plants, preventing eutrophication of water bodies.

The residual Nitrogen content in the soil was slightly (20%) higher after the EM-modified OF-MSW application than for the mineral one. The more fertilizer is applied, the more N is left in the soil. The residual N in soils treated with the mineral fertilizer is rather stable over the whole spectrum of fertilizer application rates, which is the result of its fast mineralization, uptake, water and air emissions. Even though this is not reflected in better grass growths in the whole range of dosages.

In general, the calculated total N amount in soil per area is more noticeable after organic fertilizer application. This indicates that this substantial bank of probably organically bound N, remaining in the soil, still results in increased growths at very high application rates for the organic fertilizer.

The TRL (Technology Readiness Levels) of the EM-modified OF-MSW fertiliser production and application is assessed to be at the level of 7; it is rather easy to apply on land but it still requires the development of efficient high-scale equipment for pelleting or granulation of the pre-dried solid waste and its subsequent final drying. The required input energy could be for instance harvested from the nearby biogas plant.

ISWM Framework Positioning of the Case Story

Stakeholders: Citizens, Local Authorities

Waste System Elements: Waste treatment, Recycling, Recovery

Aspects: Technical, Environmental, Financial, Socio-cultural, Institutional, Policy/legal

Management of OF-MSW by means of fertilization of urban green areas is closely related to the ISWM (Integrated Sustainable Waste Management) framework. As the intended use is for urban green areas, local authorities are responsible for decision-making and citizens are the final users. The covered Waste System Elements are: Treatment with effective microorganisms on-site, pelletizing and drying (waste collection plant), then **recycling** of nutrients in a form of fertiliser and organic matter into the soil and subsequent Recovery of nitrogen, potassium, phosphorus and other microelements by grass. “Financial/ Economic” benefits are expected due to savings in reduced mineral fertilizer usage. Whereas “Sociocultural”, “Institutional”, “Policy/ legal/ political” factors need to be considered if scaled out and applied in real life.

Lessons learned:

1. Fertilizers based on separated at source OF-MSW are a good candidate for bringing back the nutrients to the environment,
2. Using OF-MSW as organic fertilizers even at higher dosages does not limit grass growth unlike mineral fertilizers.
3. OF-MSW fertilizers provided up to two times better N utilization at higher dosages as compared to mineral fertilizers. This proves its lower vulnerability to nutrient losses via leaching, thereby reducing the risk of eutrophication of water bodies.

4. The verification was done under winter conditions, so analogical experiment carried out in spring and summer are required (planned),
5. Further investigation to compare the effect of real-scale OF-MSW (sorted at a plant, not at the source), possibly anaerobically digested, on grass growth to check for any inhibiting effects (microplastic, heavy metals, organic pollutants effect on grass growth and its uptake), is required.

3.2 Denmark

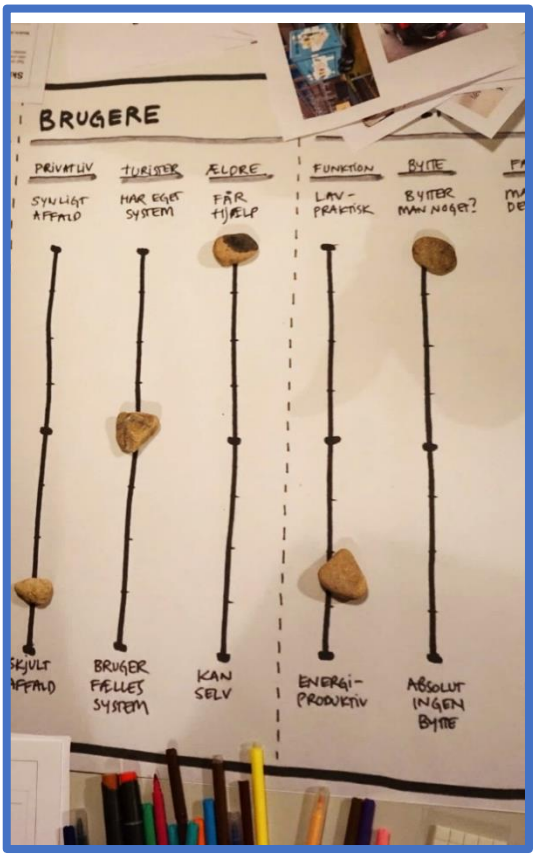
3.2.1 Co-Design

BOFA is a municipal waste management entity on the island of Bornholm, Denmark, which has a goal to be without waste by 2032. In order to reach the goal, a separate collection of household waste is a necessity, but to introduce a new waste collection system it is important to ensure that it is aligned with local interests, values, behavior, norms, etc. among the populace that is expected to make use of these systems. For this reason, a co-design process with citizens is important to ensure a high social acceptance of new solutions.

Public involvement and commitment have been highlighted as crucial for the success of the European Green Deal and ensuring lasting changes. Citizens are a major driving force of the transition; therefore, Living Labs in Bornholm contribute to the objectives set in the broader political landscape.

The co-design process was carried out in the project with the assistance of a design team at BOFA consisting of staff at BOFA as well as intermediaries with specialized competencies within various aspects of co-design.

Co-design is a novel approach for waste authorities (and public authorities in general) to come up with solutions for the target groups (beneficiaries) that they service. Instead of a traditional top-down decision-making and solution development process, co-design involves citizen interaction, participation etc. through carefully nurtured processes using design thinking as an active element in e.g. field activities, workshops, scenario mapping, ideation, prototyping, feedback. In the project, co-design activities were carried out prior to the set-up of the Living Labs e.g. a "design sprint" inspired process in one town, and a series of structured focus group sessions in informal settings in another town as well as public meetings. Especially the design of the shared waste collection system prototypes was emphasized. Since no technologies are involved in the co-design process, the estimation of TRL is not relevant.



ISWM Framework Positioning of the Case Story

Stakeholders: Citizens, Public Authorities

Waste System Elements: Generation and Separation, Collection

Aspects: Technical, Environmental, Financial, Socio-cultural

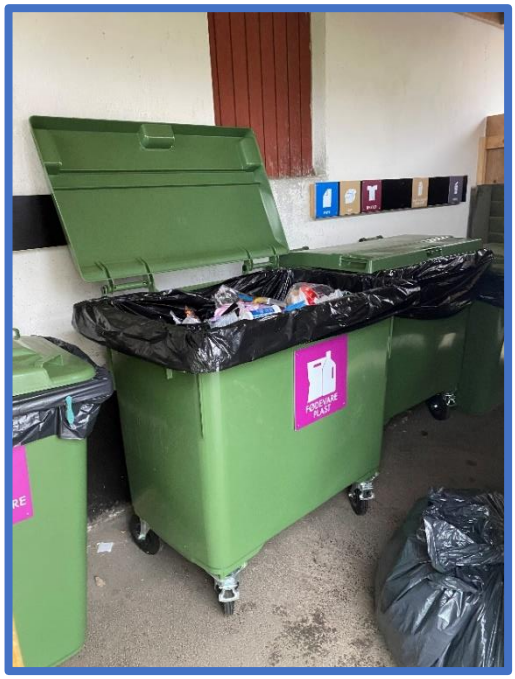
In regards to the ISWM framework, the focus of co-design activities lies within the engagement of stakeholders, foremost, the citizens which would be one of the end-users of the new waste collection system. Many experts were invited to give their contribution and viewpoint on the co-design process, however, there was an inability to find a common solution. Through the lens of waste system elements, the co-design process put emphasis on the generation and separation of waste and waste collection. Furthermore, such aspects as "technical", "environmental/health", "financial" and "socio-cultural" were considered in order to design a solution that fits in the local context and is socially accepted. Policy and institutional aspects can be argued to be out of the scope of the WASTEMAN project, however, lessons from the project will be applied in the future work at BOFA, for example, in preparation for a new waste plan to create a transparent framework which promotes sustainable waste management, as well as, encourages the involvement of stakeholders and promotes intersectoral interactions.

BOFA and public authorities in general stand to gain massively from building up competencies in-house with respect to co-design of solutions that impact citizens' daily lives and routines. This is because the approach addresses a possible or perceived democratic deficit in traditional public authority decision-making. However, it requires an organization to be able to have the required competencies and be able to operate without using a traditional mode of decision-making and solution development (i.e. shift its way of thinking).

Lessons learned:

1. It was difficult to discuss technical and detailed issues in a public forum, and the complexity added to the misunderstandings in the conversations between professionals and citizens, therefore an improved method for such communication should be developed.
2. The traditional panel debate discussions created a lot of tension with a "you against us" type of discussion between citizens and the waste company BOFA running the project. Therefore, different meeting formats were preferred ranging from meetings with the boards of community organizations, conferences, panel debates, creative workshops, walk and talks, a movie screening and exhibitions.
3. The combined communication to participants through own media (Facebook +web), direct mails and public posters with press coverage worked well. The latter in particular seemed to increase attention and the positive attitudes among citizens toward engaging in the Living Labs.

3.2.2 Shared Waste Collection Systems



Shared Waste Collection System (SWCS) are planned to be implemented in the response to several challenges. First of all, there have been problems with accessing households for door-to-door waste collection in certain towns with medieval characteristics in Bornholm. Furthermore, in response to EU and national legislation, BOFA as a local waste management authority in Bornholm, is set to implement a new waste collections system of 12 waste fractions (previously 5) which in practice is going to be solved with large-scale roll-out of SWCS in medieval towns and summer cottage areas. It is important for SWCS to be implemented in a sustainable manner – in this way, BOFA can align with its own vision by 2032 of a waste-free Bornholm and achieve the recycling rates etc. as mandated in EU policy and legislation.

The Waste Framework Directive dictates recycling targets to be achieved by all Member States (as well as new measurement methodologies to be implemented). At this stage, in the waste chain dealing with household waste collection, there is a moderate risk that with shared waste collection systems that the collected waste will have higher impurity rates compared with door-to-door collection, which will have ripple effects downstream, i.e. poor recycling rates. However, the project showed that there wasn't necessarily much ground for this worry.

During project, three different prototypes for the SWCS were constructed; two of them were mobile (movable) and one stationary prototype. The differences were in the waste fractions that could be disposed of in each of the prototypes. For example, in one town, the mobile prototype contained only cumbersome fractions such as biowaste and residual waste while at the same time stationary waste station covered the rest of the "dry" fractions. On the other hand, in another town, the mobile prototype contained all the 11 waste fractions; small-sized electronics (WEEE), batteries, textiles, plastics used for food packaging, other plastics, biowaste, paper, cardboard, metal, glass and residual waste. The prototypes were demonstrated in operational

environment and therefore corresponds to TRL 7. These prototypes were tested in Living Labs for 10 weeks in the autumn of 2020 with voluntary participation of citizens.

Within this case, the following ISWM system elements are covered - collection, transfer & transport, treatment & disposal, re-use and recycling of waste gathered in Living Labs. Through Living Labs, BOFA introduced separate sorting and collection of 11 waste fractions (previously 5) through which recycling is increased and therefore negative environmental impacts (aspects) are decreased. Introduction of SWCS is a direct response of technical aspects of limited space and a challenging urban environment that needs to be considered. Additionally, the introduction of the SWCS has the potential to reduce costs compared to door-to-door collection therefore the financial/economic aspects are organized towards the most efficient system. Socio-cultural aspects were considered during co-design and those were attempted to be integrated into the shared waste collection sites. Similarly, as in case of Co-Design, Policy and institutional aspects can be argued to be out of the scope of the WASTEMAN project.

ISWM Framework Positioning of the Case Story

Stakeholders: Citizens, Public Authorities

Waste System Elements: Collection, Transfer and Transport, Treatment and Disposal, Re-use, Recycling

Aspects: Environmental, Technical, Financial, Socio-cultural

BOFA intends to roll out SWCS to cover 3000 summer cottage households and 2500 households in towns on Bornholm in connection with the new waste collection scheme with 12 fractions to be implemented in 2022. As a result of the project in which SWCS were tested, it was supported that the environmental impact of the Bornholm waste collection and treatment system would be positive since a significant percentage of household waste streams could be diverted to recycling pathways as opposed to waste incineration. During the Living Lab test, it was ensured that the collected waste was recycled and incineration avoided where possible. Although a number of households expressed some dissatisfaction with the aesthetics of the prototypes, there was a general positive/neutral reaction to the extra time and the extra distances involved with SWCS. The prototypes were especially popular among schoolchildren in the dissemination activities that took place after the living labs.

Lessons learned:

1. The design of the shared waste collection sites has a big importance for the citizens. The shared waste collection sites have to fit in well in the urban environment, preferably it has to be hidden, with roof, with enough space for citizens, equipped with light and bins that are easy to dispose waste in.
2. The biggest issues for citizens were within disposal of residual waste and biowaste, which they wish to have as close to home as possible, whereas most of the citizens do not mind to walk extra to dispose of other waste fractions.

3.3 Lithuania

3.3.1 A company in Tauragė that contributes to cleaner oceans

Climate change and biodiversity loss today are problems that are hitting media headlines. Scientists declare shorter and shorter deadlines for us to take action, change our habits, means of transportation, and organize our mass production. Recently, the European Commission approved the European Green deal. It's a broad multisectoral strategic plan that helps us, Europeans, to fight climate change, pollution and to reach levels of circularity in our economy, where resources are used efficiently.

The aims of this plan are:

- Europe has to become a climate neutral continent by 2050 (by not emitting more CO_2 than its natural areas can absorb)
- Economic growth should be decoupled from the usage of resources;
- While implementing those changes, no person and no area should be left behind

To make any new item, we need resources. Today we have reached our limits, where saving resources, reusing and recycling is not an option – it must become a new normal. The European Waste Framework Directive states that to begin with, we should avoid making waste. If you are carrying on with an activity that produces waste, it should be reused. If there's no possibility for that neither – recycled. If the waste cannot be recycled, then it can be incinerated to create energy. Only if no other option is possible should it be taken to landfill. These principles are known as the waste hierarchy.

If all the Europe's waste were to be treated according to this hierarchy, there would be less risk for human health, the waste would not contaminate the environment, e.g. underground water wells, and it would not emit additional greenhouse gas.

The principles of circular economy oblige us to use an item as long as it is possible, to fix or repair it, sew it, etc. There are still many sectors where items used are broken or torn every day, only due to the specifics of the activity. One of these sectors is fishing or fish farms and the fishing nets used in these activities. Old fisherman knew how to sew nets but in recent times nets became made from yarn. Today, segments of plastic nets are repaired. They are left in the open sea and become traps for marine animals and birds.

For this reason the Norwegian company "Nofir" collects discarded nets and various gear from fisherman and fish farms and recycles them or – if it is not impossible – utilizes them in a proper way. A big division of this company operates in Lithuanian town Tauragė, where around 10 000 tons of discarded nets are sorted out in a year. The company was established to gather old fishing gear from the coasts of Norway, but then received a financial boost from European Union. Financing helped to spread its activity to the whole of Europe and even other continents. Since the start of their activity "Nofir" has gathered almost 48 000 tons of nets (453 tones have been gathered from Lithuanian fisherman and small businesses). These amounts of nets do not create risk for marine animals and birds anymore.

In the Tauragė plant discarded nets are weighed and analyzed. Special equipment can show composition of the net (usually PE, PP, PA6, PA66).

Some nets and also ropes, steel parts, metal chains, plastic tubes (used in fish tanks) can be recyled. Those are not deemed as hazardous waste, although few years ago "Nofir" received an official permit to treat impregnated parts of the nets, which are covered in copper oxide, a hazardous material. What is the composition of plastic in the net? Illuminating nets with infrared rays helps to answer this question easily.

Discarded nets are driven to the Tauragė recycling plant by auto transport. Then they are weighed outside in the special lot or inside (if confirmed to be hazardous waste, i.e. impregnated by copper oxide).

In the meantime, nets that are not covered in copper oxide are washed with a high pressure water stream and then dried. After drying they are cut into one-meter long pieces, some pressed with a secondary material press. They are then sorted into waste that is appropriate for recycling, ferrous metals, non-ferrous metals and various parts that cannot be recycled. In the sorting process, floats, various parts of the net, stainless steel parts or ropes are picked out and given to companies that use them for making textile products or even clothing.

P6 type plastic (nylon) is pressed into big sheets, weighting almost half of a tonne, while plastic tubes are shredded to flakes.

What happens with the polluted nets? Those that are impregnated with copper oxide are analyzed. If the pollution does not overstep the boundary of 25 percent of the whole mass, nets are cut into

the 3 meter length stripes and sewn together. Then such stripes are washed in a closed stainless steel camera, with the water from 8 high-pressure blades. "Nofir" pays attention to the water that is left after this washing procedure – it is cleaned by chemicals and a magnetic-mechanic process (being treated with different materials, pollutants are combines into larger particles and can be filtered out). The process may sound complex, but it allows the company to use the same water repeatedly to wash the nets. Water circulates in a closed system, is filtrated and used again for the same purpose. What is filtered is made into sludge, which later is passed to waste handlers[15].

No unpleasant odors are spread while washing the nets, because some of them are washed indoors and sludge from the washing process is gathered in a closed tank. As nets are cut into longer pieces, this process does not create micro plastic particles.

So what are nylon nets used for? After recycling they can be made into thread, which is then woven into new clothes, carpets, furniture parts (e.g. hammocks), and shopping bags. Recycled nylon is called "Econyl" and this material became quite popular when models wearing garments from it showed up in the collections by the "H&M" company. When T-shirts are produced from secondary material in this manner, 170 000 tones of CO_2 are saved because there is no need to produce new nylon from oil.

Parts that are not suitable for any recycling, are sent for incineration close by, at Klaipėda's incineration plant, „Fortum". In winter this company provides heating to many of Klaipėda's houses.

Communication between different companies (even the smallest startups) pushes us closer to the common aim to use things as longer as it is possible. For example, the net recycling company „Bracenet" produces belts for cameras from the net rope it receives from „Nofir".

ISWM Framework Positioning of the Case Story

Stakeholders: Private companies, public authorities?

Waste System Elements: Collection, Transfer and Transport, Treatment and disposal, Recycling

Aspects: Environment

In regards with ISMW framework, the stakeholders in this case was private company, also the beneficiaries – service users, buyers of recycled fishing gear material. The system includes elements of waste collection, transfer and transport, treatment and disposal, so as the recycling of waste. This case covers technical and environmental aspect of waste management. Technical – in a way that a new technology had to be created for recycling the gear that seemed unusual, environmental – that it help to use a resource that is harmful to the marine animals and birds if left in the marine environment.

While operating, this company creates jobs in Tauragė, cleans oceans, recycles waste gathered and, in collaboration with partners, create new prospective products. This is an example for businesses to follow.

[15] This corresponds to Technology Readiness Level (TRL) 9.

Lessons learned:

1. The collection of waste – even the hazardous type of waste – can be useful not only for the environment, but also from the business perspective – useful material can be reclaimed and returned into a circular economy.
2. The recycling work helps to create new green jobs even in distant small regions. In this case – big Norwegian company chose small Lithuanian town Tauragė for building its recycling unit.
3. The nets are not only sold as a recycled material (nylon or other type of plastic), new collaborations was born in the recycling process, such as „econyl“ material later used by company „“H&M”, or selling metal parts, knots for the artists. This shows that it is essential to spread a word about an idea or technology, always search for possible collaborations, because sometimes the only obstacle for the technology to come to life is the lack of partners

3.3.2 Sewage sludge from Tauragė as a crop fertilizer

The European Green Deal is a strategy for sustainable growth, which has gained new purpose after the pandemic hit. After learning to live with masks and physical distancing people have to start their businesses and production again, but this time – in a more sustainable way. Europe must reach the goal to cut carbon emissions to 0 by 2050, minimize pollution and live in a cleaner, healthier environment, with cleaner water and soil.

While implementing European Green Deal, some of the biggest changes are planned in construction and renovation, clean energy, mobility, biodiversity and farming areas. The new farming strategy is called „From farm to fork". Would you like to eat healthier products that were grown without chemical fertilizers? Would you like crops and vegetables that are more resistant to climate change while growing? Would you like to throw away less food and solve the food-wasting problem? A majority of you would reply „Yes" to these questions.

From ancient times, farmers knew that animal manure goes back into the soil – this helps to grow new yields. They applied this method. Yet the desire to grow more and more has led farmers to utilize chemical fertilizers. Those chemicals eradicated not only the threats to the yield – fungi, insects eating the plant leaves), but also all the biological diversity around. For this reason the strategy „From farm to Fork" obliges farmers to use less pesticides or antimicrobials, enlarge areas dedicated to organic farmlands and help typical farmland insects and birds to return, i.e. restore the biodiversity.

Meanwhile, production plants are urged to recycle products and materials and adopt new technologies that would allow reusing at least some parts of the former products or production waste. If this is impossible – at least to use waste to get energy (through waste incineration).

With the technologies that are available today, fertilizer can be produced not only from calf manure, but also from sewage sludge. The amounts of these waste types are enormous and difficult to reduce. „Tauragės vandenys“ is already using technologies to produce fertilizer from sewage. A limited liability company provides clean drinking water to the region, collects sewage and cleans it.

At the moment the company provides services for two towns – Tauragė and Skaudvilė – and for 31 villages in the region. 95 % of the water provided is in exclusively good quality, because it comes from deep underground wells. „Tauragės vandenys“ is responsible for more than 320 kilometers of a water supply and sewage pipes network. It provides services for more than 30 thousand citizens. This results in company needing to clean about 5000 – 8000 cubic meters of sewage every day.

In „Tauragės vandenys“ sewage plants, around 800 tonnes of sewage sludge accumulates every year and more than 4 tonnes every day. If it is not used as an energy source or fertilizer, such sludge should be taken to local landfils. Luckily the company has found a way to receive a benefit from the sludge and recycle it.

In the sewage plant, the sludge is treated without using any chemical substances. It is turned to dry material and energy (biogas). Dry material is used as a fertilizer – sludge pellets are rich in nutrients and plants absorbs them slowly, so they receive the materials they need for longer period. Also this fertilizer holds moisture in the soil and is not washed out with the precipitation water, as with chemical fertilizers.

In the sewage treatment plant fecal based wastewater is filtrated, deodorised, and sanitized. But how does this process look like? Firstly, the collected sewage sludge is thickened, in order to reduce the amount of water in this material four-fold.

Then this mass goes to the mixing and filtrating reservoir, where aditional particles, such as hair, ear buds, paper or small glass parts are taken out. The special sludge bars filter those particles, but in order to ensure none of them are left, sludge is additionally shredded.

After filtering and shredding sludge is treated in in an anaerobic digester. It is put into special tanks and in the warm (+36 ° Celsius), dark environment with no oxygen, bacteria eats the organic material in the sludge. This process takes 20 days. Biogas is produced during this process, while organics material is consumed. The biogas produced in this process is the energy source that is used primarily for „Tauragės vandenys“ own needs – to run sludge decaying tanks and sludge driers, and to produce electricity for sludge treatement plants. Bacteria produces around 1500 m^3 of biogas a day. It‘s not only the source of clean energy, produced without creating pollution – sludge treatment in closed tanks prevents methane gas from being emitted into the atmosphere. If sewage sludge was left in open reservoirs – it would emit methane, which accelerates global temperature rising 20 times more than CO_2.

But there are further steps in the whole sludge treatment process. Sludge is dried with a huge screw press (similar to juicing a fruit in the juicer) and has 5 times less water after this process. Then the sludge is turned into small granules and poured into big bags. This material by this time has already produced some energy (biogas). Now there are two ways to use the rest of it – some of the material is given to producers such as „Akmenės cementas“, who use sludge granules for incineration which produces energy and then use the remaining ashes in the production of cement. Another way to use the material is to provide those granules to farmers as a fertilizer.

At the moment the company provides services for two towns – Tauragė and Skaudvilė – and for 31 villages in the region. 95 % of the water provided is in exclusively good quality, because it comes from deep underground wells. „Tauragės vandenys“ is responsible for more than 320 kilometers of a water supply and sewage pipes network. It provides services for more than 30 thousand citizens. This results in company needing to clean about 5000 – 8000 cubic meters of sewage every day. In „Tauragės vandenys“ sewage plants, around 800 tonnes of sewage sludge accumulates every year and more than 4 tonnes every day. If it is not used as an energy source or fertilizer, such sludge should be taken to local landfills. Luckily the company has found a way to receive a benefit from the sludge and recycle it.

ISWM Framework Positioning of the Case Story

Stakeholders: Public authorities

Waste System Elements: Collection, Transfer and Transport, Treatment and disposal, Recycling

Aspects: Environment

If sewage sludge was left in open reservoirs – it would emit methane, which accelerates global temperature rising 20 times more than CO2. Sludge pellets are rich in nutrients and plants absorbs them slowly. Also this fertilizer holds moisture in the soil and is not washed out with the precipitation water, as with chemical fertilizers.Recycling of sewage sludge can look like a quite simple process from outside, but it is a technology created by long trials and research.

Sewage waste is the type of waste we barely can reduce. Huge amounts of it flows to sewage treatment plants every day. But we can use innovative biotechnology and turn sewage into energy or fertilizer for future crops and vegetables in line with the European Union‘s „Farm to fork“ strategy.

Lessons learned:

1. Wastewater sludge turned into a natural fertilizer is a step towards circular economy and also more sustainable farming practices.
2. Manure, fecal waste has always been a natural fertilizer. When the technology allows to clean the wastewater efficiently, the usage of wastewater as a fertilizer destroys the myths that it is something unhygienic, polluted and that it can‘t be used further.
3. General public becomes more aware of “how this works” – they are interested in wastewater reuse, cleaning and sanitizing processes, they want to know how the wastewater they have produced is treated further.

3.3.3 National Deposit systems

Plastic was invented only 100 years ago. Its use has grown explosively, and now bans have come into force, prohibiting single-use plastics such as knives and forks. Plastic has become a problem and harms not only marine animals – tiny particles of micro plastic that have degraded from a bigger piece are already found in the bodies of humans.

On the other hand, we cannot prohibit the usage of all plastic packaging. Some of the packaging is essential for ensuring hygiene and vacuum, which allows products not to spoil until opening. Yet the European Green Deal urges the acceleration of achieving higher recycling rates for various plastics and other materials. In this case, the virgin or primary materials are saved, as well as the CO_2 emissions from producing new packaging materials or released through waste incineration. Europeans would live in a cleaner environment.

Circular economy aims at minimum for all materials and items produced to be returned to the production cycle and 100 % recycled. This would allow not using any new materials in the production process. Customers can acquire products, wrapped into light, durable packaging but landfills and oceans would not be filled with plastic everyday – because everything that is thrown away, must get back to recycling cycle. This is known as ‘closing the loop’.

In 2016 the new public entity “Deposit system administrator” was created by the associations of private beverage production companies and deposit system was launched in Lithuania. The introduction of deposit system solved a number of these problems – the system could be also called one of the best examples of circular economy. Citizens return around 90 percent of plastic bottles and aluminum cans that retailers have released into the market. After doing this. the citizens receive

a 10 euro cents deposit. The deposit is paid by the customer while buying the bottle, so you cannot avoid this fee. During last year, if one were to count piece by piece, Lithuanians have returned more than 2 billion plastic bottles, aluminum cans and glass bottles in total. Bottles that can be returned to so-called taromats have a special „D" sign on them and a code. Then all of these packages become the property of the „Deposit system administrator". They travel long way to the logistics center in Vilnius, the capital of Lithuania, where the materials are sorted out, washed and pressed.

After this process the journey of closing the loop continues, as they are carried to Lithuanian or foreign factories and recycled. For example, aluminum cans can be recycled numerous times. In the words of the „Deposit system administrator" the same can that is returned to a taromat could be standing on a shelf full of drink in just 60 days . From the viewpoint of technology readiness level this system had reached the last level (9) as it continues to successfully operate for 5 years in a row.

Every year the number of bottles released into the market is growing, but so is the number of returned ones. In 2020 citizens of the small Lithuanian town Tauragė had returned 4,3 million of PET bottles, 3,68 million of aluminum cans, more than 350 thousands glass bottles and 1500 items from steel.

Packages collected through deposit system are clean and undamaged – that's why recyclers value them, because one of the problems of materials found in sorting containers is that they are dirty. Clean packaging eases the recycling process.

Citizens of Lithuania got actively involved in using the deposit system from the first year. Now 95 percent of surveyed Lithuanians say this system has urged them to sort out various other waste – not only the ones that can be returned back to taromats.

ISWM Framework Positioning of the Case Story

Stakeholders: Public authorities, private companies, citizens

Waste System Elements: Collection, Transfer and Transport

Aspects: Environment

In regards to the ISWM framework, in this case private companies had funded the creation of deposit system while taking their responsibility to collect the packages of their goods released into the marked. With the legal support from the public authorities, investment was made for the deposit system, creating a taromat machine network throughout Lithuania. Public was immediately involved because they were financially rewarded for acting responsibly and helping to return packages.

The new system covers the elements of collection and the transfer and transport in the later stages, because some of the materials has to be transported abroad in order to be recycled.

System had used the financial aspect – financial motivation to reach the aims of cleaner environment and reduce resources needed for the production of new packages.

Lessons learned:

1. The Lithuanian deposit system is an example how to reach high rates of collection of packaging – there are delegations coming from other countries to learn from Lithuania's case and practice. There are discussions about whether the deposit system should expand,

including, for example, glass bottles from strong alcoholic drinks, because the system had visibly reduced littering problem.

2. System is one of the effective ways to encourage citizens to treat their waste sustainably and to educate them. People are motivated by the financial return but there are also new habits created in the families where kids collect packaging and receive money for their needs. Leaning on this principle, we can attribute value to any kind of waste to support returning it to the system - circular economy in practice.
3. As people collect plastic, aluminum and glass packages separately, knowing that they have to be undamaged in order to be accepted by the machines, it resulted in cleaner packages that led to higher recycling rates.