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Abbreviations and Acronyms

AI	Artificial intelligence
CAPEX	Capital expenditure
CDW	Construction and demolition waste
C&D	Construction and demolition
DDRS	Digital deposit return scheme
DG REFORM	Directorate-General for Structural Reform Support
DRS	Deposit return scheme
EC	European Commission
EEA	European Environment Agency
EU	European Union
EWC	European Waste Catalogue
EPR	Extended producer responsibility
GPS	Global positioning system
IOT	Internet of things
IT	Information technology
KOTKAS	Environmental Decision Information System
KPI	Key performance indicator
MBT	Mechanical biological treatment
MoE	Ministry of Environment
MRF	Materials recovery facility
MSW	Municipal solid waste
NACE	Statistical classification of economic activities in the European Community
NIR	Near Infrared
OECD	Organisation for Economic Cooperation and Development
PAKIS	Packaging Register
PET	Polyethylene terephthalate
PRO	Producer responsibility organisation
PROTO	Products of concern
RVM	Reverse vending machines
R&D	Research and development
R-D	Recovery-disposal
UK	United Kingdom
UN	United Nations
UV	Ultra-violet
WB	World Bank
WEEE	Waste, electrical and electronic equipment
WFD	Waste Framework Directive

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Executive Summary

Current situation

For the scope of this report, the relevant waste legislation and bodies responsible for its implementation are outlined as follows:

- The framework for waste management policy in Estonia reflects the implementation of EU Directives.
- The Waste Act provides the general requirements for waste management, including permitting and waste data reporting procedures.
- The Packaging Act stipulates the responsibilities for record keeping of packaging material. Producer responsibility organisations (PROs) must provide relevant authorities with information on behalf of obliged producers about quantities of packaging placed on the market, packaging waste collected, re-used, recycled and recovered.
- Estonia's Ministry of the Environment (MoE) is the central institution responsible for the policy and regulatory framework for waste management. The Environmental Board (and formerly the Environmental Inspectorate) is the lead body for enforcement of waste legislation, inspecting waste facilities and issuing of waste permits. The Environmental Agency is responsible for gathering information on waste generation and handling through waste data systems and registers, and for producing all required environmental reports.

Various European Directives and Regulations have obligations with regard to Member States' reporting on waste statistics. For example, the EU's Waste Framework Directive includes a target for certain fractions of MSW.

The primary system used for collecting and management waste data in Estonia is the 'Environmental Decision Information System', KOTKAS (formerly JATS) in which basic information on the production and handling of waste is collected and processed. This information is gathered directly from service providers and operators for collection, transporting, and disposal of waste.

Key issues and shortcomings of the current system are identified as follows:

- The current system for documentation, data reporting, and data processing provides aggregated data at the national level. However; there is no unified data management system at the local level, leading to lack of traceability and over-simplification.
- Although the data meets EU reporting requirements, the disaggregation of data required does not always align, leading to estimations and onerous calculating methods.
- There are some concerns around the quality of reported data, particularly the input of raw data into the centralized system which lacks third-party verification.
- Government oversight and enforcement have not been sufficiently strong to address these problems, and as a result, there is a mismatch in the data provided by waste management companies.

New technology and best practice

In recent years, innovation has brought an array of new technologies to market that can improve waste data collection, management and reporting. Some key developments include vehicle technology of on-board weighing and GPS tracking, smart e-bin, smart waste tracking, MRF scanning, data dashboards and real-time monitoring, and innovations around deposit return scheme technology. Alongside these, technology can support the management and reporting of waste data to serve more audiences and provide bespoke insight to any user. Introducing such technology should be carefully planned so that it adds value and does not create an unmanageable and overwhelming source of data. However, these technologies could be deployed to address many of the issues identified above.

Recommendations

Short-term:

- **Address local waste data collection issues.** Create a single standardised data management system for waste handlers to collect data for KOTKAS. Develop features for waste tracking, data traceability and verification, and automated validation checks with non-compliance notices for the data manager (i.e. the MoE).
- **Continue to develop KOTKAS as a single central location of waste data**, and make data accessible to relevant parties in granular or aggregated form. Avoid introducing separate systems and duplicating data. If there are gaps or deficiencies in granular data that affect regional or national summaries, address these gaps as a priority so that data is complete and can be aggregated to different level without the need for additional estimates.
- **Address issues of scope and granularity in packaging waste data.** Review requirements under national packaging EPR legislation and EU Directives, e.g. breakdown of packaging waste by source and collection type. Engage PROs on mandating new reporting requirements. Update data submission templates and reporting for MoE annual activity reports.
- **Ensure a functioning chain of responsibility for high quality and timely waste data reporting**, from the lowest level of granular waste data collection up to municipal and national government. Two key parts of the chain to address are:
    - *Data collection:* typically waste contractors and treatment facility operators. Review/update legislation on data reporting requirements, in particular data submission, validation and correction requirements and response timescales. In particular, address issues around response time for verifying and updating erroneous data. Provide online portals with KPIs to monitor how individual operators perform against these requirements and require/encourage municipalities to build the KPIs into waste contracts, with minimum performance requirements and penalties for non-compliance, e.g. part of contract fees being linked to KPI performance ideally with a sliding scale to incentivise high performance. Provide functionality within the KOTKAS system which requires data verification of reports by municipality before sign-off.
    - *Municipalities.* Provide municipalities with tools and support to verify data submitted to KOTKAS by their waste contractors. Ensure there are consequences to municipalities for poor data

handling performance, which will motivate municipalities to better manage their contractors (using the means outlined above).

- **Create functionality for the Environment Agency to correct data as a last resort** if the data submission party fails to do so.
- **Minimise poorly categorised data and other forms of low quality data.** Reduce quantity of waste categorised as 'unspecified treatment' or 'unknown origin/municipality of the collection' in national reports by ensuring better traceability at local level. Utilise municipalities in verification of data at submission to provide greater understanding of movement of waste, from collection to treatment, by waste contractors.

Medium-term:

- **Introduce electronic waste transfer notes** to collect transactional data on the full waste value chain.
- **Increase and automate granular waste data collection and submission to KOTKAS.** Review EU Directives and National strategy to foresee future data needs, e.g. introduction of EPR for new waste streams such as fishing gear, textiles, certain C&D wastes, etc. or eco-modulation of producer fees under EPR reform, which may be based on 'recyclability' of packaging and other factors. When new legislation is drafted, start to adapt KOTKAS to incorporate new datasets and fields so as to maintain a single dataset for waste legislation compliance and reporting needs.
- **Benchmark municipality-level performance**, identify outliers, and investigate reasons for high and low performance. Address issues identified and share best practice.

Long-term (bear these goals in mind when designing short- and medium- term actions):

- **Take advantage of new technologies available** for waste data collection, waste monitoring, tracking, and reporting. Carefully design roll-out of such technologies to avoid duplication of data (and potential disparities) and ensure successful integration with national systems. Focus on key areas of data gaps or data quality issues, such as greater granularity on source of data (waste generator type and location, aligning with EU and national waste categorisation schemes such as Waste Framework Directive methods for categorising MSW).
- **Use near real-time data feeds from new technologies to create dashboards and monitoring systems** that can remotely identify and respond to waste crime. For example, compare waste permits to live operations and notify operators if they are reporting waste types they are not licensed for, or are approaching their permit limits on quantities of waste. Automate mass-balance checks on individual operators to identify potential criminal activity, such as flytipping or illegal waste treatment, triggering the need for closer investigation or an in-person site inspection.
- **In order to support the transition to the circular economy, create a centralised data centre for national material flows** – raw materials, finished and semi-finished products and waste, taking account of import, exports and national production, as well as consumables and process losses (such as evaporation of wet waste, and incineration of waste). Aim to produce a comprehensive view of material flows through the economy and through the geography, from which national circular economy strategies can be targeted and performance measured.

- **Aim to align data categories** where possible, e.g. align EWC codes with industrial categories (such as NACE codes) used to record non-waste material flows, to allow a direct comparison and unification of data. This may require additional data requirements at waste data collection, e.g. NACE code of waste generator, but this would not be onerous if new waste technology were utilised – as described elsewhere in this report.

1 Introduction

The World Bank was engaged by the European Commission on behalf of the Government of Estonia to undertake a review of its waste management system, in light of current projections that Estonia may fall short of European Union recycling targets. The World Bank is assessing the current municipal solid waste management system, analyzing the potential options, proposing policy recommendations, and developing an action plan to improve the effectiveness and circularity of the solid waste management system in Estonia. This includes a review of the system in an integrated and holistic manner, considering waste management operations, the legal framework, institutional arrangements, technical solutions, communications, data management and reporting, and financing. This report specifically focuses on information management and is part of Output 2 which entails policy recommendations and a proposed action plan for the municipal waste sector broadly.

This report focuses on the waste management-related data and information systems as they currently operate and to provide recommendations on how they could be improved. It presents the outcomes of the review. It comprises:

1. A landscape review of existing waste data systems in Estonia and an assessment of key gaps and challenges faced by the existing system (Section 2)
2. Suggested recommendations for improving Estonia's waste data and information system over the short, medium and long term (Section 3).
3. A review of new technology and innovation in waste data management (Section 4).

2 Landscape review

2.1 Waste data and reporting needs in Estonia

2.1.1 National reporting and legislation

EU legislation sets the framework for waste management policy in Estonia, and most of the requirements of the EU Waste Framework Directive (2008/98/EC) have been directly transposed into national legislation. The Waste Act[1], which came into force in 2004, provides the general requirements for waste management, including prevention of waste generation and adverse impacts, appropriate collection, treatment and disposal of different waste types, permitting procedures and provision of fines or penalties where violations occur.

The Waste Act specifies mandatory reporting procedures. Chapter 10 (§ 116 – 118) of the Waste Act deals with maintenance of records and reporting, while various other sections deal with specific reports such as waste permits and packaging. Waste permit holders and producers of hazardous waste are required to keep regular records of the type, quantity, properties and origin of the waste generated, collected, stored or temporarily stored, transported, treated, recovered or disposed of in the course of their activities. If waste is transferred to other waste handlers, records must also be kept of the destination, frequency of collection, modes of transport of and recovery and disposal operations regarding the waste. Entities which

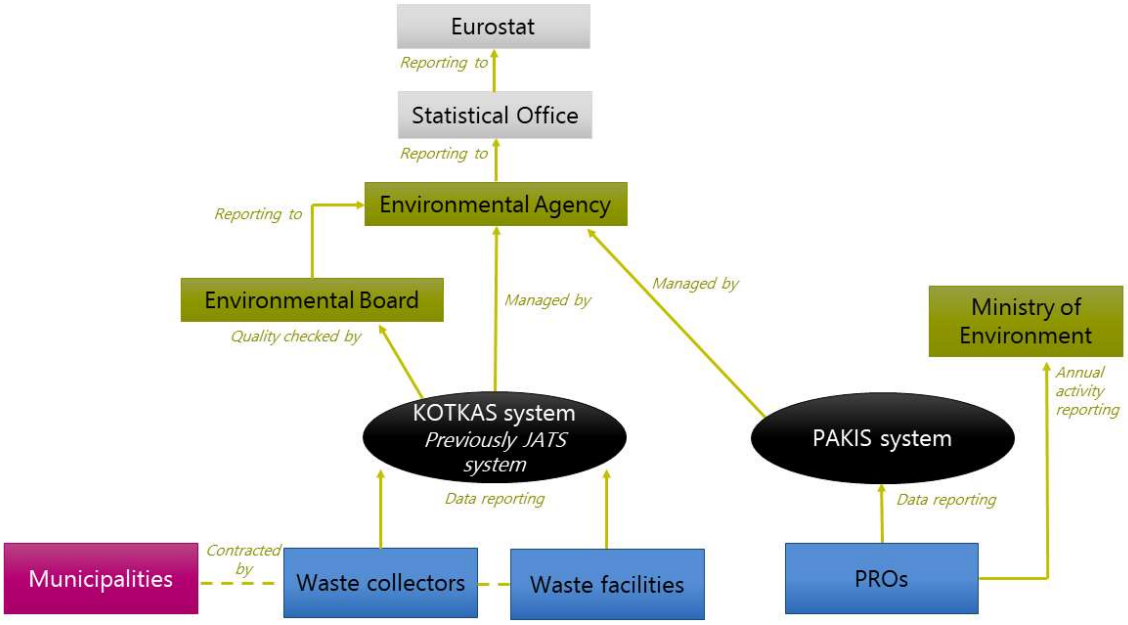
[1] Waste Act, https://www.riigiteataja.ee/en/eli/521122020002/consolide

produce certain quantities of waste, but do not require an environmental protection license or permit, are also required to provide data where requested.

Packaging waste requirements are established under the 2004 Packaging Act and the 1996 Packaging Excise Duty Act, both of which transpose the EU Directive on Packaging and Packaging Waste (94/62/EC). § 24 of the Packaging Act stipulates in detail the responsibilities for record keeping of a range of entities that might place packaging material in the market. PROs must provide relevant authorities with information on behalf of obliged packaging undertakings about quantities of packaging placed on the market and information about quantities of packaging waste collected, re-used, recycled and recovered.

The Packaging Register (PAKIS) is a database concerning the packaging of packaged goods placed on the market (as fully defined in the Packaging Act). In addition to the Packaging Register, PROs must also submit annual activity reports to the Ministry of the Environment (MoE) and publish their annual report and financials on their website. Estonia has EPR for five other types of "products of concern" (as defined in the Waste Act): waste electrical and electronic equipment (WEEE), used end-of-life vehicles and their parts, used tires, waste agricultural plastic, and batteries and accumulators. There is a register for products of concern (PROTO) to determine the recovery and disposal of products of concern placed on the market.

Figure 1: Schematic illustration: current waste data and information flows

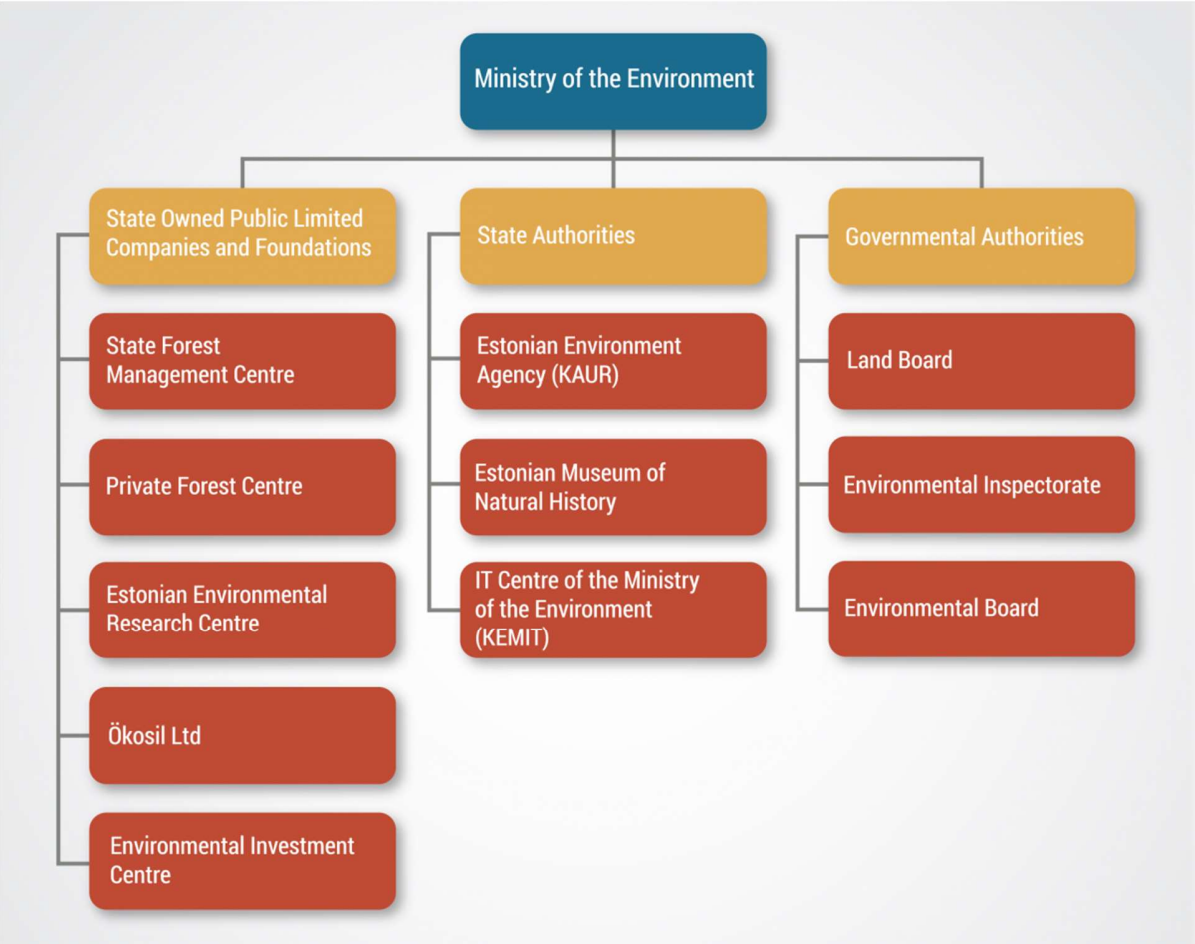


2.1.2 Governing bodies

Estonia's Ministry of the Environment (MoE) is the central institution responsible for the policy and regulatory framework for waste management. The MoE is responsible primarily for environmental policy and legislative development, land management, natural resource protection, compliance monitoring and

enforcement, and environmental monitoring. Institutions which fall under the jurisdiction of the MoE include the Environmental Board, Estonian Environment Agency, Land Board, State Forest Management Centre, Private Forest Centre and Estonian Environmental Research Centre.

Figure 2: Ministry of the Environment administrative structure[2]. Note that the Environmental Inspectorate and Environmental Board were combined in 2021.



Prior to 2021, the Environmental Inspectorate was the lead body for enforcement of waste legislation; inspecting waste facilities, shipments and reviewing documents from waste handlers. This agency has since merged with the Environmental Board, whose functions include the issuing of environmental permits, environmental impact assessments, environmental monitoring and controls on environmental taxation. The permit for landfill operations, as any other waste management operation, is issued by the Environmental Board.

The Environmental Agency is responsible for gathering, processing and analysing environmental information, including waste generation and handling. Waste data is collected and processed in several information systems and registers administered by the Environment Agency. The primary system is the

[2] https://www.envir.ee/en/ministry-contact/administrative-area

'Environmental Decision Information System', KOTKAS (formerly JATS - Waste Reporting Information System) in which basic information on the production and handling of waste is collected and processed. This information gathered directly from service providers and operators for collection, transporting, and disposal of waste. The Environment Agency also manages the packaging register for recovered and recycled packaging waste and other EPR covered products on behalf of producers and producer responsibility organisations (PROs).

The Environmental Agency produces all required environmental reports. Waste and packaging waste reports are produced for domestic use by authorities, municipalities, waste management companies, other stakeholders. National reports and compliance reports are meanwhile produced for the UN, OECD, EU and EEA, some of which are produced in co-operation with the Statistical Office.

2.1.3 EU reporting requirements

Various European Directives and Regulations have obligations with regard to Member States' reporting on waste statistics. Key EU reporting obligations fall under the Waste Statistics Regulation, Waste Framework Directive, Landfill Directive, Waste Shipments Regulation and the Producer Responsibility Initiative Directives (packaging, end-of-life vehicles, waste electrical and electronic equipment and batteries & accumulators). Each piece of legislation has its own reporting deadlines and rules and calculation methods for reporting on whether targets have been met.

The MoE and the Environmental Agency report Estonian waste management data to Eurostat. As set forth by EU Directives, the following reports are required:

- Municipal waste generations and recovery/recycling, C&D waste generations and recovery
- Landfilling of the biodegradable waste
- Packaging waste generations and recovery/recycling, use of the certain plastic bags
- Batteries and accumulators waste generations, collection, and recovery/recycling
- End-of-waste vehicles waste generated, recovery and recycling

The EU's Waste Framework Directive includes a target for certain fractions of MSW. EU Member States may choose between four different methodologies to calculate compliance with the target, considering four alternative waste streams and fractions[3]:

1. paper, metal, plastic and glass household waste;
2. paper, metal, plastic, glass household waste and other single types of household waste or of similar waste from other origins;
3. household waste;
4. municipal waste

Estonia applied Method 1 to calculate the 2020 preparation for re-use and recycling targets for household and similar waste, set at '*a minimum of overall 50 % by weight'* in Article 11(2)(a) of EU Waste Framework Directive 2008/98/EC (WFD). This method assumes the target is limited to household waste only;

[3] Commission Decision 2011/753/EU establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC).

however, a provision in the Waste Act now includes similar waste. Separating household waste from similar waste is difficult given mixed-use buildings and the reporting system is not aligned since PROs do not regularly report for different waste channels. The achieved recycling rate in 2018 for recyclable waste fractions of household waste comprising of paper and cardboard, plastics, glass and metal was 48%, presenting a reduction of 4% compared to previous two years. The 2025 and later recycling targets will be calculated towards the total amount of municipal waste generated, or Method 4. In 2018, the achieved recycling rate for all fractions of MSW in Estonia was 28% and has remained relatively consistent over the past 5 years. The figure is considerably below the European Union (EU) average of 46%. Packaging waste from commercial establishments is not regarded as similar to household waste and thus not included in the definition of municipal waste. Separate targets for the recycling and recovery of packaging waste apply.

2.2 Current systems

2.2.1 Reporting procedures

Local governments are responsible for municipal waste management in Estonia, organising collections, transport and treatment within their territories. Municipalities contract the collection and transport of municipal solid waste to private companies, which also own many key treatment facilities such as landfills and mechanical biological treatment (MBT) facilities. In some regions, namely Tallinn, Pärnu and Järva County, these facilities are owned by municipalities themselves.

Under permitting legislation, service providers and operators for collection, transportation, and disposal of waste must provide information to the Environmental Agency. Municipal waste data is collected at waste facility sites where sorting, baling, and any other treatment such as composting or incineration takes place. Operators are obliged to keep respective records of waste moving in and out of the facility based on their own weighbridge results or with regards to weighing at receiving facilities of forwarded materials. Companies transporting waste to the facilities report the type of waste transported, the quantity, and the company which handed over the waste. Waste treatment facilities report once per year covering waste type, quantities in/out, operations and stored quantities. Landfills report four times per year on the type of waste landfilled, who the waste is received from, and how it is managed, and this information is consolidated into a single annual report.

2.2.2 Data management system

Previously, the Environmental Agency managed the Internet-based 'Waste reporting information system' JATS[4]. In 2020, a new reporting system was implemented, known as the 'Environmental Decisions Information System', KOTKAS[5]. This database allows the country to monitor the movement of waste flows through multiple steps from the producers or waste to the final waste handler. Applications for waste permits must also be submitted in KOTKAS, the Information System for Environmental Decisions.

[4] https://jats.keskkonnainfo.ee/main.php?public=1

[5] https://kotkas.envir.ee/

Only registered users may access the reporting section, and first-time users must first enter into a user agreement. Reports are entered either directly through the electronic system, or through an MS Excel import form. Data is provided in tonnes and is generally collected following 6-digit classification of the European List of Wastes (2000/532/EC)[6] and recovery (R) or disposal (D) as defined in the EU Waste Framework Directive 2008/98[7]. It therefore covers any waste with which the reporting entity has dealt with during the period of the report.

Most of the summarised data is provided by free access and can be queried by any interested person to retrieve consolidated information based on a variety of markers such as municipality, county, by recovery-disposal (R-D) codes, by waste or waste group codes and basic material type. Company level reports are available only for authorised users such as public services or research bodies. Environmental supervision agencies and the controller and processor of the environmental decisions information system have the right to have access to source documents for records and to consolidated data.

2.2.3 Quality control

Until recently, the management of compliance to waste reporting procedure was operated across the Environmental Board and Environmental Agency, in a two-tier process. However, the administration of waste data and quality checking is currently in the process of being migrated under sole control of the Environmental Agency.

In previous procedure, the Environmental Board was provided first level control of the submitted data. If an initial report is considered 'understandable and transparent', only then could it be accepted for further processing. If there are irregularities or something is unclear within the data, the issuer will be contacted to amend. Failure to submit a waste report, comply with procedure of waste reporting, or submission of incorrect data is punishable by a fine, as defined within § 120 of the Waste Act.

The second level of control was given to the Environment Agency, who may flag inconsistencies within the compilation of summarised reports. Typical issues include disparities of the tonnages forwarded and received between two companies or misreporting of waste codes. Within the previous JATS system, the Environment Agency would be able to fix reports based on explanatory information provided by the issuer of the waste report. In the new KOTKAS system, corrections to the data can only be made by the original reporter therefore ensuring corrections are made within an allocated time can be difficult to enforce.

2.2.4 Packaging data

Under EPR legislation, as directed by the 2004 Packaging Act and 1996 Packaging Excise Duty Act, PROs must provide relevant authorities with information on behalf of obliged packaging undertakings about quantities of packaging placed on the market and information about quantities of packaging waste collected, re-used, recycled and recovered. Producers can join one of three PROs for packaging: OÜ Eesti

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[6] Guidance on classification of waste according to EWC-Stat categories, https://ec.europa.eu/eurostat/documents/342366/351806/Guidance-on-EWCStat-categories-2010.pdf/0e7cd3fc-c05c-47a7-818f-1c2421e55604

[7] Classification found in Annexes I and II of the WFD (2008/98/EC).

Pakendiringlus (EPR), MTÜ Eesti Taaskasutusorganisatsioon (ETO) or Tootjavastutusorganisatsioon OÜ (TVO), to collect, recover and recycle their waste. PROs collaborate with municipalities by providing collection containers for municipal civic amenity sites, supermarkets and other retail locations. In addition, the Eesti Pandipakend (Estonian Deposit Packaging) organises a deposit-refund system for glass, plastic and aluminium beverage containers.

Data is submitted to the Packaging Register (PAKIS)[8], which is managed by the Environmental Agency. The following verified data is required each calendar year by type of packaging and packaging material:

- the weight of reusable packaging,
- the weight of packaging of the goods placed on the market, and
- data on the recovery of packaging waste.

The input of data works in a similar manner to the KOTKAS system, in that only registered users may access the reporting section, and first-time users must first enter into a user agreement. Data submitted to the packaging register must however be verified and assessed for accuracy by an independent auditor. The audit requirements apply to all packaging undertakings placing more than 20 tonnes of packaging per year on the market. Producers whose reported packaging weight is under that level are exempt of the auditing obligation.

In addition to the Packaging Register, PROs must also submit annual activity reports to the MoE and publish their annual report and financials on their website. There is no requirement for these annual activity reports to be audited, but the following information should be included:

- the packaging waste collected at the place of generation of waste and collected and recovered through the public container network;
- the agreements with local authorities for organizing collection services at national level;
- information about installed packaging waste collection sites; and
- the packaging recovery service charges and changes in the purchase prices of packaging material from the previous calendar year.

The Environmental Agency is responsible for reporting packaging waste quantities based on packaging waste statistics and waste analysis.

2.2.5 Construction and demolition waste

Data on the generation and treatment of construction and demolition waste (CDW) in Estonia is collected directly from the waste management entities holding valid waste permits according to the Waste Act. They are obliged to submit reports on their waste-related activities at least once a year into the 'Environmental Decision Information System', KOTKAS where the amounts of waste generated, treated and exported/imported in Estonia are reported by waste code. The reporting of data directly from entities performing waste management operations ensures that all sectors of the economy are covered. However, illegal disposal of CDW by individuals, i.e. fly-tipping cases, are cleaned-up and reported within the waste reports.

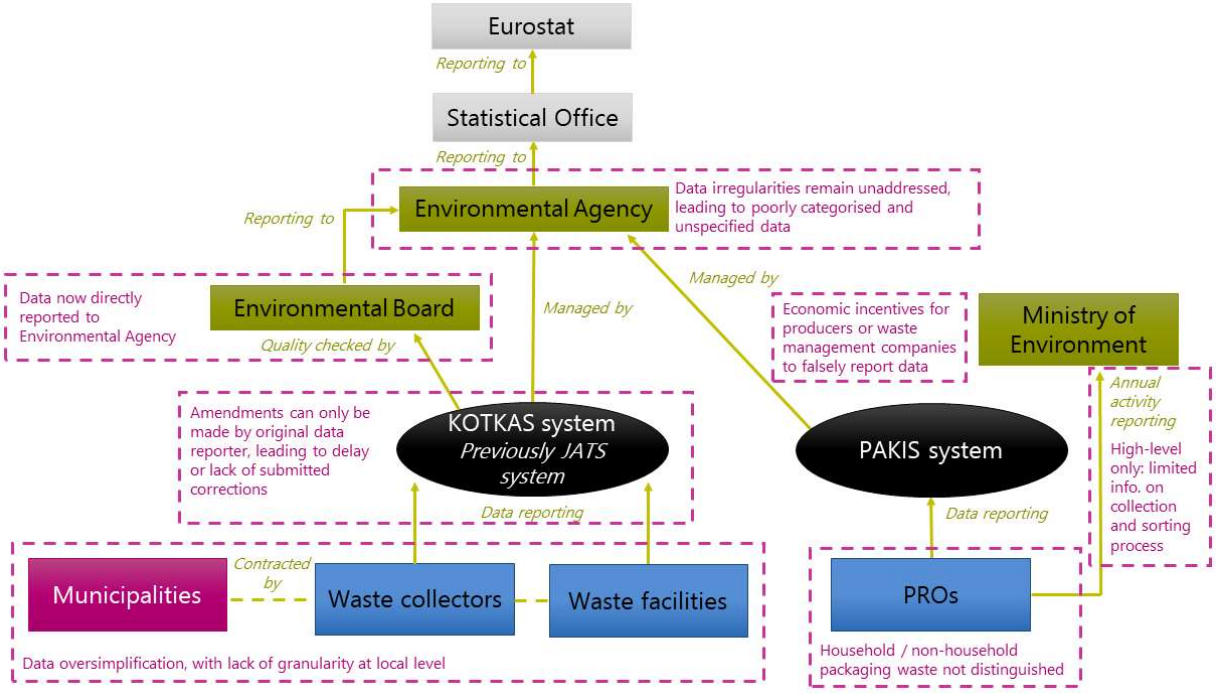
[8] https://pakis.envir.ee/pakis/main/welcome

2.3 Gap analysis

Estonia faces several challenges in the management of waste data. The current system for documentation, data reporting, and data processing provides aggregated data from waste handlers and permit holders at the national level however, there is no unified data management system at the local level, leading to lack of traceability and over-simplification. Although the data meets EU reporting requirements, the disaggregation of data required does not always align, leading to estimations and onerous calculating methods. There are some concerns around the quality of reported data, particularly the input of raw data into the centralized system which lacks third-party verification. A change in reporting procedure, whereby all data is now presented directly to the Environmental Agency without first level control and correction by the Environmental Board, has been shown to negatively impact on data quality. Government oversight and enforcement have not been sufficiently strong to address these problems, and as a result, there is a mismatch in the data provided by waste management companies.

The issues are presented in Figure 3 and explored in the sections below:

Figure 3: Schematic illustration: key issues arising in current waste data system



2.3.1 Granularity of data

Local governments do not have a data reporting role in the current system, and without data collection or aggregation at local level, disaggregated figures and reports at local level is virtually non-existent.

Municipalities with more than 1,500 residents are obliged to contract out waste collection and transport to private companies through a competitive tendering process, who are in turn responsible for providing

waste data information to the Environmental Agency. In most cases municipalities do not regulate the destination of the waste, hence it has become practice for the collection company to decide. Companies transporting waste must report the type of waste transported, the quantity, and the company which handed over the waste, however in practice, the data is often oversimplified. For example, where a full truck load is received by a facility, total tonnages may be reported to one municipality rather than divided between individual clients on the collection round.

The issue of granularity of information extends to packaging waste. Information contained in the annual activity reports submitted to the MoE are at a high-level on the total quantities of packaging placed on the market and quantities of packaging waste recycled and recovered by category of material. The activity reports contain limited information on how the separate collection and sorting is actually organised and implemented and how the targets were achieved. In the 2018 reports, only Eesti Pakendiringlus presented information broken down by packaging waste collected at the place of generation versus through the public container network. Understanding the breakdown in packaging waste quantities collected via different collection channels and divided between households and commercial/industrial sources is necessary since the fee structure of PROs also differs for consumer packaging and for group and transport packaging. It is also an important factor in calculating the preparation for re-use and recycling targets as defined by the EU Waste Framework Directive.

2.3.2 Alignment with EU reporting requirements

At the EU level, the Waste Framework Directive sets targets for recycling of municipal wastes which are expected to be transposed in local legislation. This directive is reflected in the Waste Act, in particular § 136[3], par. 1, stating that from 1 January 2020: the paper, metal, plastic and glass waste originating from households and other waste collected by type originating from households and similar waste originating from other sources must be recovered by way of preparation for reuse or recycling – at least 50 percent of the total weight of such waste per calendar year. Calculation of these figures can be difficult where current reporting systems do not provide the level of granularity required to accurately estimate these figures.

One particular issue is that the current reporting system for PROs does not align with the selected method for calculation of preparation for re-use and recycling targets for household waste. The quantities of non-household packaging waste at source reported by PROs shall not be taken into account when calculating targets for household waste. However, PROs do not report separately on the quantities of recycled household packaging waste. It is necessary to understand the sources of materials going to public containers to distinguish between households and other generators such as commercial sources.

C&D waste targets are defined in the Waste Act (§ 136, par. 2), and backfilling operations and the landfill gate fees have enabled the 70 % recovery rate target to be exceeded. However, traceability of the data can be difficult to undertake. Certain amounts of CDW remain unreported, mainly through illegal activities of private persons or non-legally permitted legal entities[9]. There are certain amounts of CDW which although are reported treated, no specific treatment method is indicated in the database ('unspecified

[9] https://ec.europa.eu/environment/pdf/waste/studies/deliverables/CDW_Estonia_Factsheet_Final.pdf

treatment'). In this case this amount of CDW is not included in any specific treatment option (R-D codes) and is not counted for the calculation of the targets.

According to Commission Decision 2011/753/EU, Member States are required to report separately the amounts of CDW used for backfilling from the amounts of CDW prepared for reuse, recycled and material recovered. However, there is no available data in the waste register concerning the treatment option of backfilling. Instead, complementary data from other databases such as environmental permits and analysis of permitted activity on site is used for the calculation of the CDW backfilled. As a result, the data is at risk of developing discrepancies.

2.3.3 Quality and misreporting of data

The most serious problem is associated with the quality of initial data submitted by the waste management companies and a mismatch of data between reports, whether through negligence or deliberate mishandling. A small minority of companies do not report waste data, despite an obligation to do so. There are also occasions where some companies may submit deliberately false or fraudulent data, which may include different weightings, incorrect waste coding or treatment. The completeness and quality of data has been highlighted as an area of concern by The National Audit Office[10].

There are several reasons why companies may exploit waste data reporting:

- All packaging placed on the market in Estonia is subject to a Packaging Excise Duty to be paid to the Tax and Customs Board. Packaging is exempt from this tax if it has reached certain recovery targets, hence there may be economic incentives for companies to falsely report that targets have been met.
- Each PRO owns their own waste collection system, and the materials collected within the packaging containers collected belong to the PRO. For separately collected waste, the material ownership is subsequently agreed according to the contract signed between the PRO and collection service provider. Typically, material is owned and sold on behalf of the waste management company, who in turn receives a recycling certificate. As these certificates provide a financial income, data reporters may see the opportunity to inflate recycling figures on which these are based in order to receive more revenue.
- Internet sales provide opportunities for 'free-riders' to avoid associated EPR fees, since these companies do not provide information regarding e-commerce sales and packaging across borders. The tonnage placed on market by 'free-riders' goes unreported.
- Packaging companies may consider it economically beneficial to reduce the amounts of goods placed on market in packaging report as this provides the basis for the calculation of the recovery fees to be paid for PROs.

The issues of misreporting can be exacerbated by the process in which data is submitted. In order to report a certain amount of waste as recycled (or exported for recycling), it must first be shown in some reports as 'collected'. Therefore, in addition to inflated recycling figures, there may also be rises in the amount of

[10] NAO (2013), Maintenance and Development of Information Systems in Area of Government of Ministry of the Environment, National Audit Office, Tallinn, 4 November 2013.

material collected at source. Evidence for this can be demonstrated with a comparison of 'waste collected, kg per inhabitant' between similar and often neighbouring municipalities, where figures from the data can be shown to differ substantially but common sense would expect similar values.

2.3.4 Enforcement

Private companies play a substantial role in the waste management sector in Estonia. While the municipalities are responsible for organising the collection of MSW and defining how the waste should be treated, collections and transport are managed by contracted private companies. The disadvantage of this system is that it limits the municipalities' involvement, leading to a lack of enforcement when it comes to performance. It is suggested that local governments do not typically check all waste generation sources, whether the waste is sorted or collected separately, or whether transportation operators comply with the rules[11]. Lack of control in reporting processes means that municipalities have little incentive to pursue issues flagged in the data provided by waste management companies.

The Environmental Board is entitled so far to the first control of submitted waste reports. Where the data does not meet the standard or where an issue is identified, the reporter will be asked to review and amend the information. If the issuer of the report does not respond and act, a penalty could be applied. However, there seems to be little in the way of enforcement, with corrections sometimes done only in part and often after the given timeframe. As a result, a significant proportion of the final reports show 'unspecified treatment' or 'unknown origin/municipality of the collection' against reported data.

The Environmental Inspectorate (part of the Environmental Board from 2021) has previously stated that, due to lack of resourcing, inspections of compliance of waste permit holders are prioritised by internal risk assessments, which are not made publicly available. Previous versions of § 119 of the Waste Act required each waste permit holders to be inspected once per year, however, the latest version limits the requirement of annual inspections to Category A facilities (i.e., where there is risk of a major accident or where hazardous waste exceeds a certain limit) and compliance of PRO activities.

2.3.5 Data systems

There are some concerns around the quality of reported data, particularly the input of raw data into the centralised system. As data is self-reported, entities might code waste differently which could result in inaccurate aggregated data. As the report in the web-format is digitally signed by representative of the issuer of the report and there is no third person or independent verification, the information provided can be 'signed off' without audit.

Procedures within the latest electronic reporting system, KOTKAS, have led to a number of issues in data quality and control. The latest system is developed in a way that corrections may only be carried out by the original reporter. In the previous JATS system, the Environmental Agency would contact the waste management companies in the event of data irregularities and correct the report upon explanation. An unintended consequence of restricting access to the original reporter means that calls for corrections may be delayed or ignored by the waste management company.

[11] https://www.eionet.europa.eu/etcs/etc-wmge/products/other-products/docs/estonia_msw_2016.pdf

There are also ambiguity issues through use of the 'undefined treatment' ('Määratlemata käitlus') column in the summary tables of the waste reports. In the 2019 report for 'Group 20- Municipal waste', this labelling accounts for nearly 10% of the 'Total generation' of collected waste[12]. While this column can account for discrepancies due to physical or biological processes, such as drying, within the course of waste treatment, the figure can also account for data irregularities which remain uncorrected.

[12] Example of a recent waste report, https://jats.keskkonnainfo.ee/failid/2019_1_ewc.pdf

3 New technology and best practice

Two themes key span the issues identified in the current system. The first is that waste data needs to be collected at a granular level in much more detail and shared with other parties. The second theme is that better tools are needed for validating and verifying data submitted, e.g. with automated checks and balances, identifying outliers and discrepancies, and a greater level of overview, data cleansing and subsequent analysis and insight. This second theme will be increasingly important as the volume of waste data increases. These issues can be addressed by increasing waste data collection and collation, and can be implemented with a minimum of human resources by making use of the latest technology in this area. The latest technology and international best practice is explored around these two themes in the sections below.

3.1 Granular waste data collection, latest technology and innovation

3.1.1 Electronic waste transfer notes

Storing the details of waste transfers electronically allows them to be more easily collated, checked, and shared. Ideally, all waste transfers notes would be submitted to a central system, i.e. KOTKAS, and aggregated to produce regional and national reports. The granularity and analysis possible on such data would help identify and resolve gaps and errors in the data, leading to higher data quality and avoiding discrepancies between national and local waste datasets.

Figure 4: Weighbridges are key points to generate electronic waste transfer notes

Electronic waste transfer notes could be entered manually by the responsible parties, e.g. via a website. However, this process could be automated and the granularity and richness of data collected could be improved using some of the technologies below.

3.1.2 Internet of things, blockchain and artificial intelligence

These technologies and concepts currently only play a minor role in waste technology. However, they are likely to be the foundation of future innovation, particularly in creating an ecosystem of new supportive and interactive technologies.

The internet of things (IOT) refers to the large quantity of devices that are now linked via the internet. Mobile phones are ubiquitous but increasingly other consumer devices are also link to the cloud and managed via Smart Home systems, and in industry manufacturing, logistics distribution, stock control and

sales are managed via devices linked to the cloud. Buildings are increasingly energy and climate controlled too, and governments are adding devices in urban areas to monitor traffic, air pollution and other metrics. This IOT provides an opportunity to gather a lot more data on resources and waste than previously possible.

Figure 5: Internet of things

Many are excited by the prospect of tracking the movement of resources through the economy, and particularly tracking materials from resource extraction, refinement, manufacturing, distribution, sales, use, and the waste value chain. While this is not currently common practice, blockchain may provide a technological platform for such ambitions. Traditional IT systems use a centralised database to store information, with carefully controlled access to read and write data. Blockchain instead uses a distributed ledger of transactions that is duplicated and distributed across the entire network. New records are added as a new block at the head of a chain. This can be employed to track materials, adding a new block when a product is sold or transported through the value chain, potentially recording the full provenance of products and materials in the blockchain.

Figure 6: Blockchain

The quantity of data recorded by the IOT and blockchain material tracking is several orders of magnitude greater than has been centrally available in previous decades. So called 'Big Data' requires new means to extract meaning, insight and value. Analysis and presentation of data is important, as discussed in section 3.2. Companies within the resources and waste industries are looking towards artificial intelligence, commonly shorthand for 'machine learning', to help interpret these large data sets and make real-time decisions that humans would not be capable of.

3.1.3 Vehicle technology – on-board weighing and cameras

Digital sensors attached to the bin lift mechanism on waste vehicles can be used to provide ultra-granular data on waste arisings. This can enable pay-as-you-throw charging mechanisms, rather than pay-per-bin or pay-monthly. It could also, in theory, be linked to household data and industrial classification of commercial waste collections to address current issues about mixing waste on collection vehicles from different sources, obfuscating the waste generator type, and leading to erroneous and confusing waste data.

Companies are also developing sophisticated route optimisation software feeding data from cameras mounted on the back of waste vehicles into GIS software to find optimal routes, saving time, money, and vehicle emissions.

Figure 7: Vehicle technology and on-board weighing[13]

3.1.4 Smart e-bins

'Smart' recycling on-the-go bins (e-bins) are relatively new technology used to separated recyclate from the street scene and parks, which would otherwise be placed in the residual waste stream. They typically have an electronically controlled aperture that only opens to receive recyclable materials, thereby address common issues with contamination and increasing recycling quality. Smart bins are more expensive than regular on-the-go bins and require a power source and internet link. Their contents would need to be kept separate from the contents of residual waste bins on collection in order to maintain material quality.

Costs for this smart E-bin are **£4,500** per unit, with operational costs of about £675 per year (15% of capex). Installation costs have been estimated at £1,350 and have a lifetime of between 5 and 10 years.

[13] https://www.amcsgroup.com/solutions/vehicle-technology/

Figure 8: Example E-bin.

Source: RLG

A cheaper smart bin is produced by Recircula Solutions, pictured in Figure 9 below. It can be retrofitted onto any waste container, including curbside recycling bins. Average costs per unit including a solar cell and connectivity kits are **£460**, with operational costs of about £75 per year (more maintenance and to replace the batteries, if used). The devices have a lifetime of between 4 and 6 years. It is estimated that installation takes approximately 15 minutes per device; while installation costs would depend on the hourly cost of the technician.

Figure 9: RecySmart Technology.

Source: Recircula Solutions

Another smart bin technology utilises a sensor in the bin which detects how full the bin is and communicates this data via cloud. This is most suitable to larger bins, such as commercial and institutional waste collection, allowing just-in-time route optimisation to reduce transport miles, costs and emissions.

Figure 10: Smart bins for route optimisation

3.1.5 Smart waste tracking

Technology is currently being developed to track waste materials through the value chain from waste generation, collection and treatment through to final destination. In its most basic form, all that is required is digital waste transfer notes identifying the waste type, quantity, and the two parties involved in the transfer of waste. However, data collected by other technologies described here could provide further detail and insight in the system.

The main benefits of smart waste tracking are being able to understand material movements through the economy and geography in great detail, identify and tackle criminal practice, and manage waste regulation with greater ease and reduced cost, e.g. centrally comparing tonnages against waste permit limits. Tracking waste beyond point of export will also help to minimise the risk of dumping, burning and other illegal practice of waste exported for recycling.

Challenges include how to manage points in the waste value chain where separate wastes are combined – e.g. for transport or when arriving at a waste treatment facility, and when wastes are separated, e.g. at waste sorting facilities. Smart waste tracking is currently the focus of a UK Government R&D project, with two prototypes in development[14].

3.1.6 MRF scanning, cameras and AI-vision

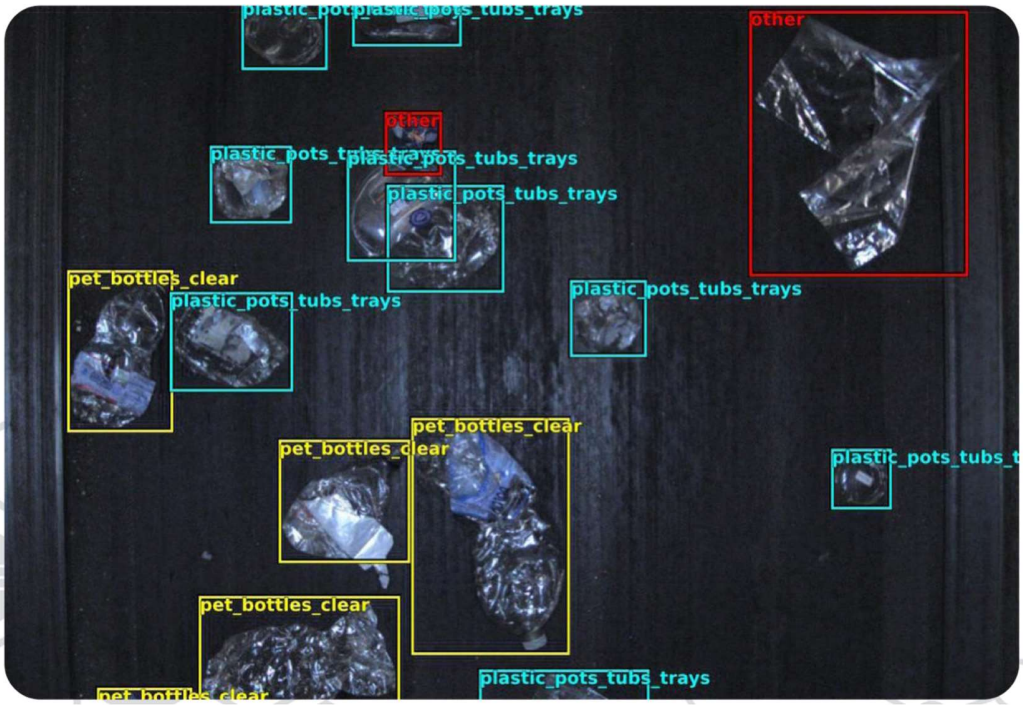
Materials recovery facilities (MRFs) sort mixed recycling into separate materials and quality grades. The value added by such facilities is dictated by the material composition of input material and the ability to

[14] https://www.gov.uk/government/collections/waste-management-smart-tracking-of-waste-govtech-catalyst

sort quickly and effectively into high-quality outputs. Advanced scanning technology, such as UV-paint markers, QR-codes (See Digital DRS below), and AI-vision are at the forefront of innovation.

AI-vision in particular is seen as a low-cost technology, using simple and cheap cameras common to mobile phones, and identifying products though machine learning algorithms. Linked to sorting technology this has the potential to produce very high quality recyclate, enabling closed-loop and even food-to-food grade recycling. There are also wider implications in terms of EPR and the ability to modulate producer's fees based on actual recycling performance of their products.

Figure 11: AI-vision by Grey Parrot[15]



Other advancements are seen with the introduction of Near Infrared (NIR) spectroscopy technology, which can be used to determine the material composition of waste down to individual polymers, even in multi-material composite packaging such as layered plastic film often used in food packaging[16]. The reduction in price of such technology is making it affordable for bespoke applications in understanding common packaging formats and their recyclability[17], sorting clothing by fibre type for textile recycling[18], and the technology is now being introduced in MRFs for sorting general waste and recycling.

[15] https://www.greyparrot.ai/waste-composition-analysis-software

[16] https://www.resourcefutures.co.uk/time-to-de-mystify-plastic-film/

[17] https://www.resourcefutures.co.uk/resource-futures-supports-europes-largest-plastic-waste-composition-study-with-near-infrared-technology/

[18] https://www.spectralengines.com/blog/efficient-textile-recycling-with-nir-spectroscopy

Figure 12: NIR Plastics Analyser, used to identify polymer types in the field

3.1.7 Data dashboards and near real-time monitoring

Governments and waste contractors are increasingly using data dashboards to monitor waste operations in near real-time, viewing KPIs and analysis on waste operations, with live data feeds from IOT enabled waste vehicles and devices. An example is shown in Figure 13**Tõrge! Ei leia viiteallikat.** from Los Angeles "recycLA" waste and recycling program. Information on the number and type of waste vehicles in use was of particular use to LA as the scheme intended to reduce vehicle miles and improve air quality through franchise zoning for commercial waste collections. In Dubai, waste vehicles are fitted with GPS and tracked in real-time to stamp out illegal dumping of waste in the desert.[19]

[19] https://gulfnews.com/uae/environment/trucks-gps-tracking-cuts-illegal-garbage-dumping-1.884990

Figure 13: recycLA Environmental Dashboard

3.1.8 Deposit return schemes, reverse vending machines and digital innovation

Under a deposit return schemes (DRS), consumers pay a monetary deposit when buying a product which is refunded to them when they return the empty packaging. This is typically applied to drinks containers, but can in theory be used with any fast moving consumer good. With the introduction of a DRS, consumers are financially incentivised to return drinks containers to a recycling point in order to redeem a small deposit they have paid on the item. This has the potential to reduce littering and boost recycling of the relevant material. A common form of DRS found in Europe and the USA requires consumers to return containers via reverse vending machines (RVMs) or manual take back points (such as convenience stores).

Figure 14: Reverse vending machine

Estonia has an established a DRS for beverage packaging. The scheme covers single-use and refillable beverage packages, including plastics (mainly PET), cans (aluminium and steel), and glass. It has achieved packaging high return rates of around the 85% -97% in the last two reporting years, matching and surpassing some of the best European DRS schemes. However, some countries are now looking to digital solutions to deliver the benefits of a DRS at much lower cost and reducing the risk of fraud. Digital DRS (DDRS) is yet to be proved at national scale, but if viable and capable of delivering considerable benefits then this may prove to be a future direction for DRS in Estonia.

Under a DDRS the deposit would be redeemed by the consumer scanning a unique code via a smartphone app. To show that the consumer is disposing of the waste correctly they can scan a corresponding QR code on the recycling bins for their home or a bin in the street, or use GPS to demonstrate they are next to an appropriate recycling bin. Each packaging container would carry a unique code, such as a QR code, to which the deposit would be directly linked. This significantly reduces the risk of fraud as the deposit cannot be claimed twice from the same code, and much more difficult to fake deposit codes. The code also enables tracking of each individual container through the economy if manufacturing, distribution and sales systems can be unified with the DDRS data. A DDRS can integrate easily with existing waste collection and treatment infrastructure in a country rather than requiring large capital expenditure in new RVM technology, thereby significantly reducing costs. Resource Futures estimates that DDRS can half the cost of DRS in the UK (£3 billion vs £6 billion across 11 years), largely because the cost of RVMs is so high

(£1.8bn CAPEX in the UK over 11 years)[20] [21]. It is also potentially easier for the public who can return containers through curbside collections and street bins rather than transporting them to RVMs and retail points.

Figure 15: QR code scanning for a digital DRS

3.2 Data interrogation and public reporting

As the volume of waste data increases, so does the potential for different analysis and views. However, the means of summarising the data and drawing insight must also be refined. Some latest approaches and best practice are described below.

3.2.1 Means of presentation

Many governments attempt to track waste generation by different economic sectors. This is often based on assumptions and surveys rather than empirical evidence, but nonetheless can provide a valuable view of total waste generation. The figures presented in this section provide several different examples of data presentation styles which can furnish a more informed understanding waste generation and its treatment.

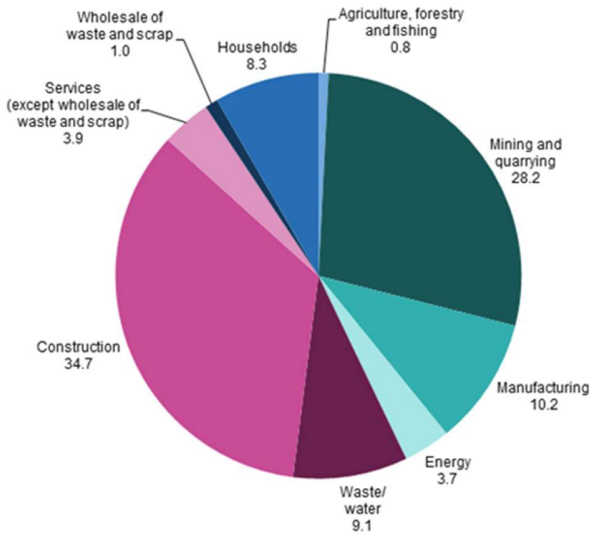
The pie chart presented in the first example below provides a simple breakdown which can be useful to gain a snapshot of top waste producing sectors (

[20] https://www.brysonrecycling.org/news/industry-working-group-contributes-to-consultation-on-drs-with-new-report

[21] https://www.brysonrecycling.org/downloads/DDRS_Impact_Assessment.pdf

Figure 16).

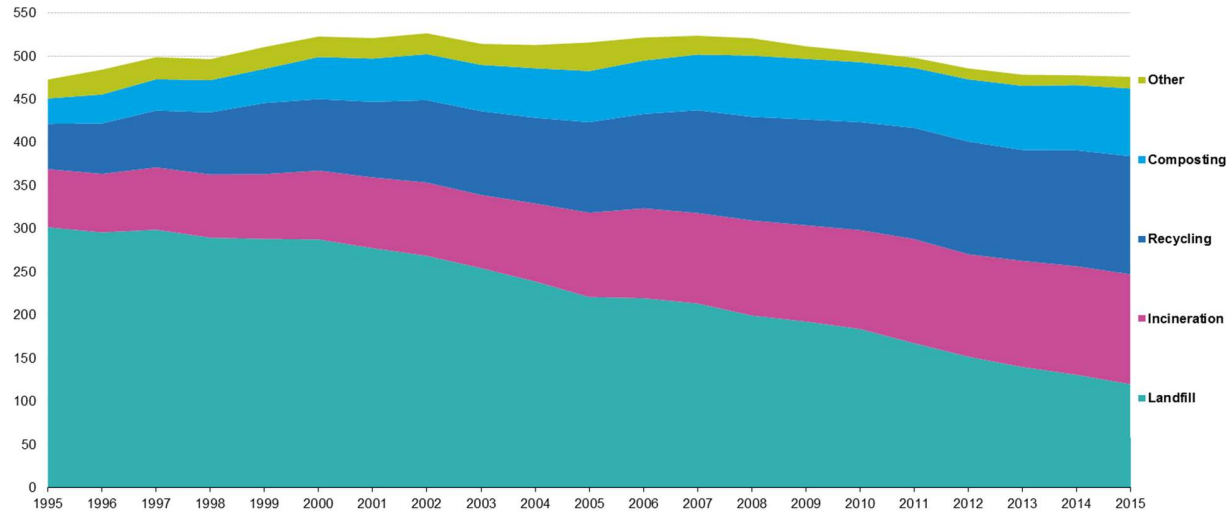
Figure 16: Waste generation by economic activities and households, EU-28, 2014 (%)



Source: Eurostat (code: env_wasgen)

A stacked area chart time series, as shown in Figure 17, is effective in communicating the progression of waste treatment over time.

Figure 17: Municipal waste treatment, by type of treatment, EU-27, (kg per capita), 1995-2015

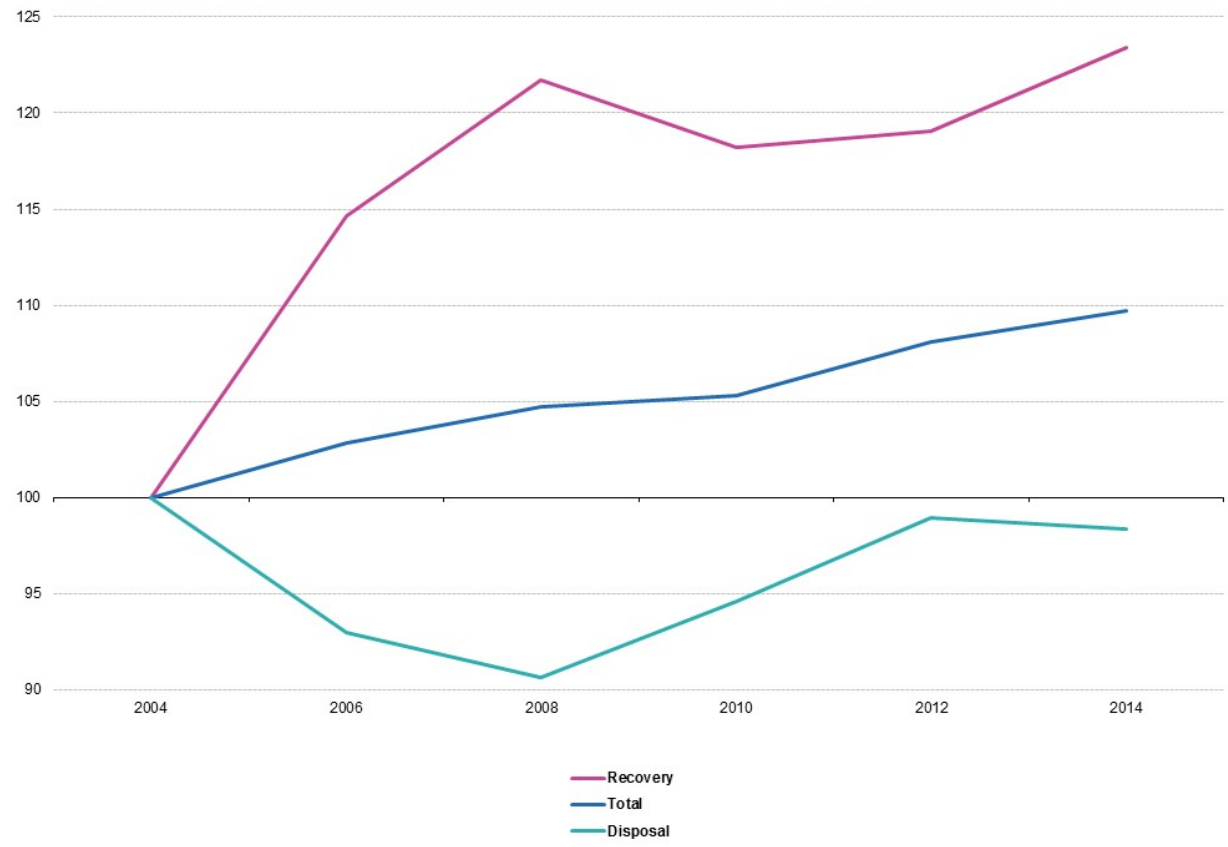


Source: Eurostat

Alternatively,

Figure 18 presents a baseline year (index=100) and shows relative changes in performance in subsequent years. This could be used to show multiple series that do not share the same units, e.g. recycling rate (%), waste generation (tonnes) and greenhouse gas emissions (T-CO2e).

Figure 18: Development of waste treatment, EU-28, 2004-2014 (2004 = 100)



Source: Eurostat (online data code: env_wastrt)

Charts and figures are effective at communicating overall trends and help to engage a non-technical audience. Tables of the underlying data are typically also provided for further detail and to enable quantitative analysis.

Table 1: Waste generation by economic activities and households, 2014

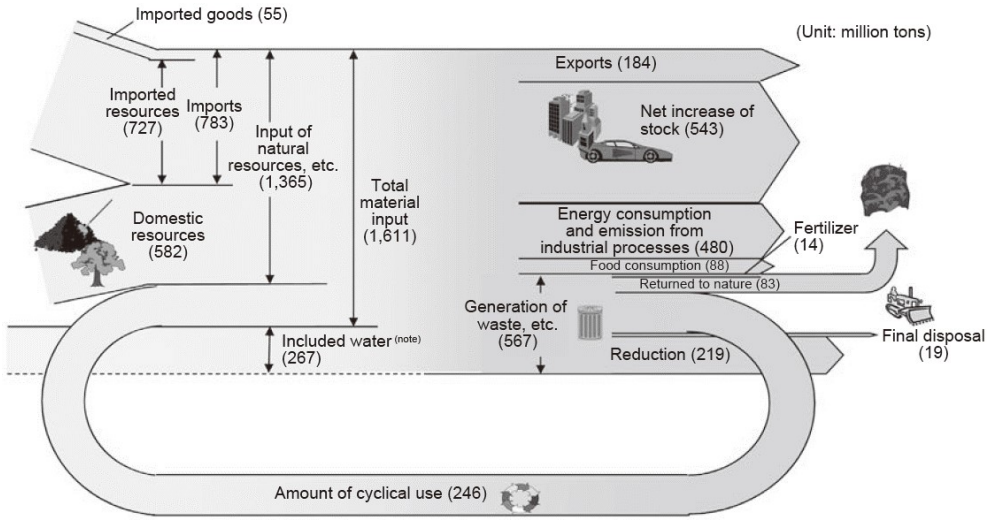
	Total		Mining and quarrying	Manufacturing	Energy	Construction and demolition	Other economic activities	Households
	(million tonnes)	(kg per inhabitant)			(%)			
EU-28	2 502.9	4 931	28.1	10.2	3.7	34.7	14.9	8.3
Belgium	65.6	5 838	0.1	21.7	2.1	40.2	27.3	8.6
Bulgaria (1)	179.7	24 872	88.6	:	5.1	0.7	4.0	1.5
Czech Republic	23.4	2 223	1.0	18.8	4.3	40.2	21.8	13.9
Denmark	20.1	3 558	0.1	6.4	5.4	52.6	18.5	17.1
Germany	387.5	4 785	1.9	15.8	2.6	53.3	16.9	9.5
Estonia	21.8	16 587	36.3	20.2	32.6	3.1	5.6	2.2
Ireland (1)	15.2	3 285	17.8	:	2.1	12.4	57.6	10.0
Greece	69.8	6 404	67.9	7.0	15.6	0.7	2.3	6.5
Spain	110.5	2 378	16.9	13.4	4.8	18.5	28.3	18.3
France	324.5	4 913	0.7	6.7	0.5	70.2	13.1	8.8
Croatia (1)	3.7	879	0.1	:	3.2	16.6	48.9	31.2
Italy	159.1	2 617	0.6	16.7	2.0	32.5	29.5	18.6
Cyprus (2)	2.1	2 406	:	:	:	31.0	48.9	20.2
Latvia	2.6	1 315	0.2	9.4	27.8	17.3	18.3	27.1
Lithuania	6.2	2 114	0.4	42.1	1.6	7.0	30.1	18.7
Luxembourg	7.1	12 713	1.8	4.0	0.0	84.5	6.1	3.4
Hungary	16.7	1 688	0.5	16.2	13.9	20.7	31.0	17.7
Malta (1)	1.7	3 896	2.2	:	0.2	74.5	13.8	9.3
Netherlands	133.2	7 901	0.1	10.1	1.3	68.1	14.1	6.4
Austria	55.9	6 541	0.1	9.7	0.9	72.1	9.8	7.5
Poland	179.0	4 710	42.3	17.6	12.2	9.5	13.7	4.6
Portugal	14.6	1 402	1.9	17.9	1.2	10.3	36.3	32.3
Romania (1)	175.6	8 820	87.0	:	4.0	0.6	6.2	2.2
Slovenia	4.7	2 273	0.2	28.1	13.5	17.4	28.9	12.0
Slovakia (1)	8.9	1 636	3.2	:	6.1	15.6	55.4	19.6
Finland	96.0	17 572	65.4	10.7	1.5	17.0	3.7	1.7
Sweden	167.0	17 226	83.2	3.4	1.1	5.3	4.5	2.5
United Kingdom	251.0	3 885	10.5	3.2	1.3	48.0	26.0	11.0
Iceland (3)	4.5	1 651	0.0	17.6	0.3	2.1	36.1	44.0
Liechtenstein	0.6	14 919	1.7	2.0	0.1	0.0	0.4	95.9
Norway (1)	11.7	2 283	2.8	:	1.3	23.0	52.7	20.3
Montenegro	1.2	1 872	22.5	5.2	31.7	9.2	15.3	16.1
Former Yugoslav Republic of Macedonia	2.2	1 058	3.4	67.9	23.3	0.5	4.9	0.0
Serbia	49.1	6 890	84.5	1.8	9.1	0.6	0.7	3.3
Turkey (*)	73.1	947	4.2	:	32.8	:	20.2	42.8
Bosnia and Herzegovina	0.5	1 161	1.6	27.2	71.1	0.0	0.0	0.0
Kosovo (UNSCR 1244)	1.0	574	19.3	7.0	0.0	0.3	26.3	47.0

(1) Other economic activities includes also manufacturing.
(2) Other economic activities includes also mining, quarrying, manufacturing and energy.
(3) 2012.
(*) Other economic activities includes also manufacturing, construction and demolition.
Source: Eurostat (online data code: env_wasgen)

What is not apparent in the summary charts and tables is the real nature of resource and waste management value chains. Materials are typically transported through multiple points and owners before reaching their final destination – i.e. either waste disposal or recycling/reuse. Governments are increasingly making use of Sankey-inspired figures, an example of which is shown in

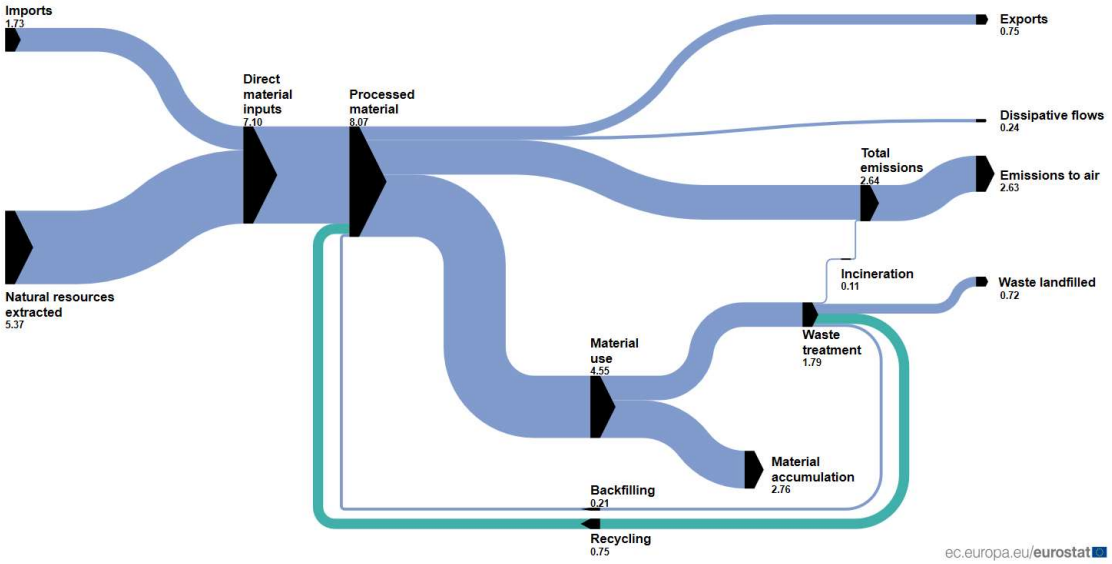
Figure 19 showing a high-level view of national material flows including waste generation, disposal, waste reduction and cyclical use.

Figure 19: Illustration of material flow in Japan in FY 2010 [22]



The EU provides a similar view of resources and waste treatment, as shown in Figure 20.

Figure 20: Material flows true scale in Gt/year (billion tonnes per year) in 2018, EU27[23]



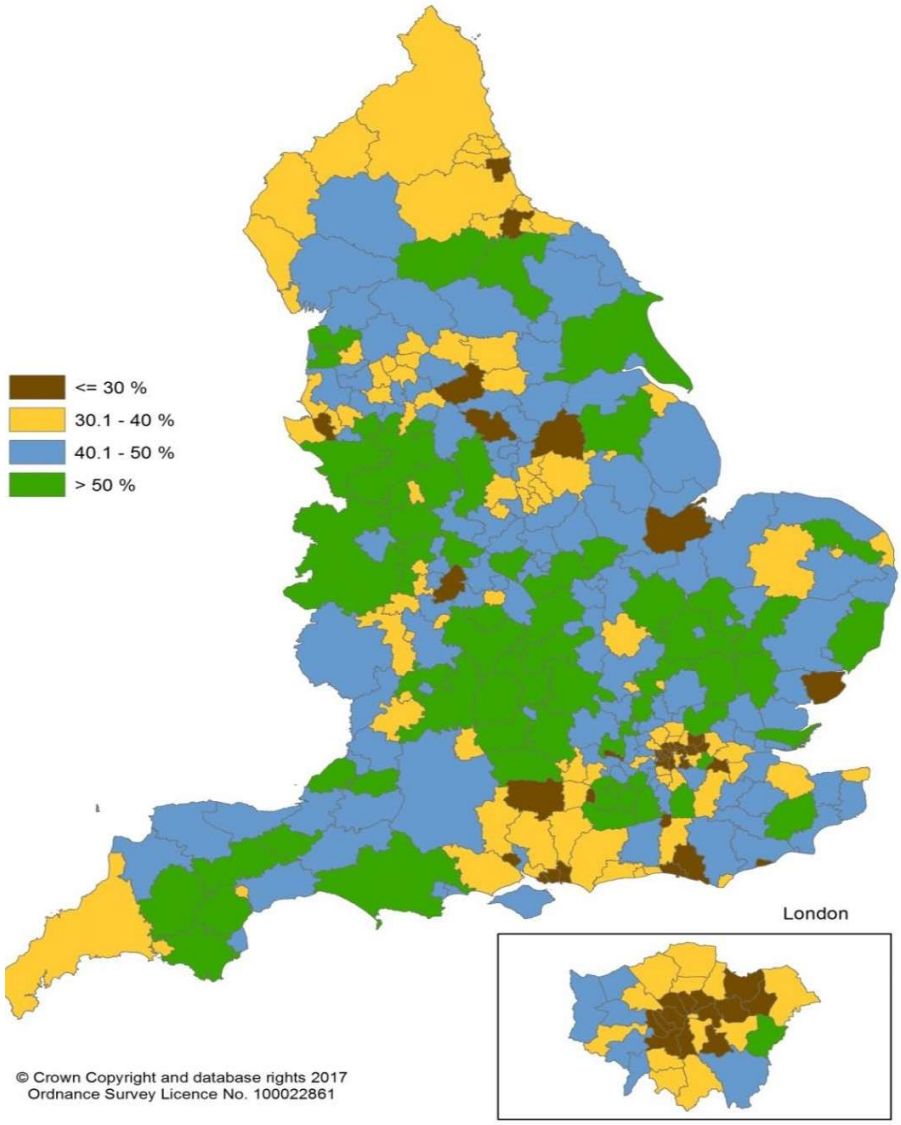
[22] Government of Japan Ministry of the Environment (2013), The Fundamental Plan for Establishing a Sound Material-Cycle Society, 3rd edition, https://www.env.go.jp/en/recycle/smcs/3rd-f_plan.pdf

[23] https://ec.europa.eu/eurostat/web/circular-economy/material-flow-diagram

Mapping is useful to show sub-national performance (i.e. regional or municipal performance) or the location of key infrastructure. An example from England is shown in

Figure 21 showing local government recycling performance.

Figure 21: Percentage of household waste sent for recycling, preparation for reuse or composting, England[24]



[24] DEFRA (2017), Digest of Waste and Resource Statistics – 2017 Edition, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/607416/Digest_of_Waste_and_Resource_Statistics__2017_rev.pdf

Infographics are increasingly popular for engaging the general public on waste statistics, sticking to very high-level and commonly understood metrics, such as those shown in Figure 22.

Figure 22: Sample infographic of key waste statistics

Source: Welsh national report[25]

3.2.2 Annual statistics bulletins with quality reports

Annual statistics bulletins are a very common means for reporting waste and resources data. These are often published by the national statistics agency, supported by the department for environment, to ensure that official statistics meet the highest standards of trustworthiness, quality and public value. It is best practice to accompany a statistics bulletin with a quality report detailing exactly how the data was collected, data sources used, any data gaps and assumptions used, methodology applied, and areas of discrepancy and uncertainty. For example: Member states provide data to Eurostat accompanied by quality reports, as described below: [26]

> *Each set of waste data from the member states has a quality report attached, which is mandatory according to EU Waste Regulation EC 2150/2002. In these reports the member states describe the methodology used, derivations between different years, uncertainties etc. for the total waste statistics.*

A quality report allows the technical reader to understand exactly how to interpret the data, how to extract key information and what caveats they should bear in mind in its use.

3.2.3 Data portals and data interrogators

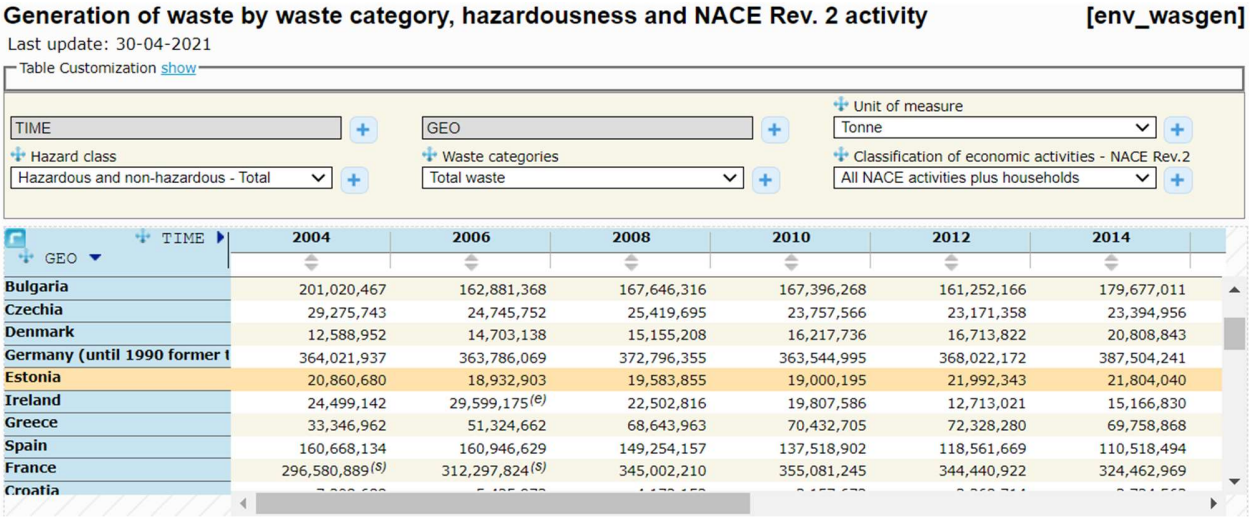
As waste data improves in terms of quality, scope and granularity it quickly becomes impossible to communicate it within a static report such as a statistics bulletin. Governments employ data portals and

[25] Welsh Government, Local Authority Municipal Waste Management, http://gov.wales/docs/statistics/2017/171019-local-authority-municipal-waste-management-2016-17-en.pdf

[26] Hanssen et. al (2013), Review of EUROSTATs reporting method and statistics

data interrogators to allow the user to seek the exact data they need in terms of data series, categories, timespan, etc. These tools are typically public access websites with an interactive table in which the user can drop data sets, adjust filters, and outputs results. Such unrestricted access to detailed and high quality data can deliver value e.g. to support private sector investment, local government decision making, and national strategy. An example of the EU Eurostat Data Explorer is shown in Figure 23.

Figure 23: EU Eurostat Data Explorer[27]



Generation of waste by waste category, hazardousness and NACE Rev. 2 activity **[env_wasgen]**

Last update: 30-04-2021

Table Customization show

TIME | GEO | Unit of measure: Tonne

Hazard class: Hazardous and non-hazardous - Total | Waste categories: Total waste | Classification of economic activities - NACE Rev.2: All NACE activities plus households

GEO \ TIME	2004	2006	2008	2010	2012	2014
Bulgaria	201,020,467	162,881,368	167,646,316	167,396,268	161,252,166	179,677,011
Czechia	29,275,743	24,745,752	25,419,695	23,757,566	23,171,358	23,394,956
Denmark	12,588,952	14,703,138	15,155,208	16,217,736	16,713,822	20,808,843
Germany (until 1990 former t	364,021,937	363,786,069	372,796,355	363,544,995	368,022,172	387,504,241
Estonia	20,860,680	18,932,903	19,583,855	19,000,195	21,992,343	21,804,040
Ireland	24,499,142	29,599,175 (e)	22,502,816	19,807,586	12,713,021	15,166,830
Greece	33,346,962	51,324,662	68,643,963	70,432,705	72,328,280	69,758,868
Spain	160,668,134	160,946,629	149,254,157	137,518,902	118,561,669	110,518,494
France	296,580,889 (s)	312,297,824 (s)	345,002,210	355,081,245	344,440,922	324,462,969
Croatia						

3.2.4 Communications campaigns

Further value can be derived from waste data and statistics when used in communications and behaviour change campaigns. Some key approaches are set out below:

- **Hyper-local communications** – The more specific and targeted the communications message is to the recipient then the greater the potential for effective behaviour change. For example, the current recycling rate of the municipality could be communicated highlighting the increase needed to meet the next target. Even more personalised communications could be created, e.g. information for new parents on how to manage nappies and other baby-related waste, information of reusable nappies and access to second hand baby clothes, toys, etc.; or targeted information for students moving into or away from a university town. Platforms such as Facebook allow for such targeted communications.
- **Nudge theory and personalised communications** - Small, but very specific 'nudges' towards improving waste behaviour can be effective, particularly when also highlighting a social norm for people to comply with. For example, if on-board weighing is integrated into waste collection vehicles (see Section 3.1.3) then communications could be tailored to the individual household, e.g. communicating their total waste generation and recycling rate, and comparing it to other households of a similar size on their street. The recipient will feel compelled to 'fit in' with their

[27] https://ec.europa.eu/eurostat/web/waste/data/database

neighbours and improve their recycling behaviour if they are below par. Houses with a very low recycling rate could receive information about the first steps to take – e.g. practical ideas to reduce food waste and the money they can save by doing so, instructions on what materials to recycle and which bin to place them in. Households with high recycling rates could receive information on how to avoid purchasing products with plastic film packaging, how to manage waste batteries and electronics, etc.

- **Simple and relatable messages** – It is very hard for the average person to estimate how much waste they create, how much is recycled, or the carbon emissions and global warming impact of their actions. Communications messages should be simple and relatable. For example, instead of talking about kg of waste, talk about how many worlds would be needed if everyone in the world had that level of consumption and waste. Instead of talking about how many tonnes of CO2 could be saved by recycling, talk about how this is equivalent to taking 1,000 cars off the road, or closing coal-fired power station.

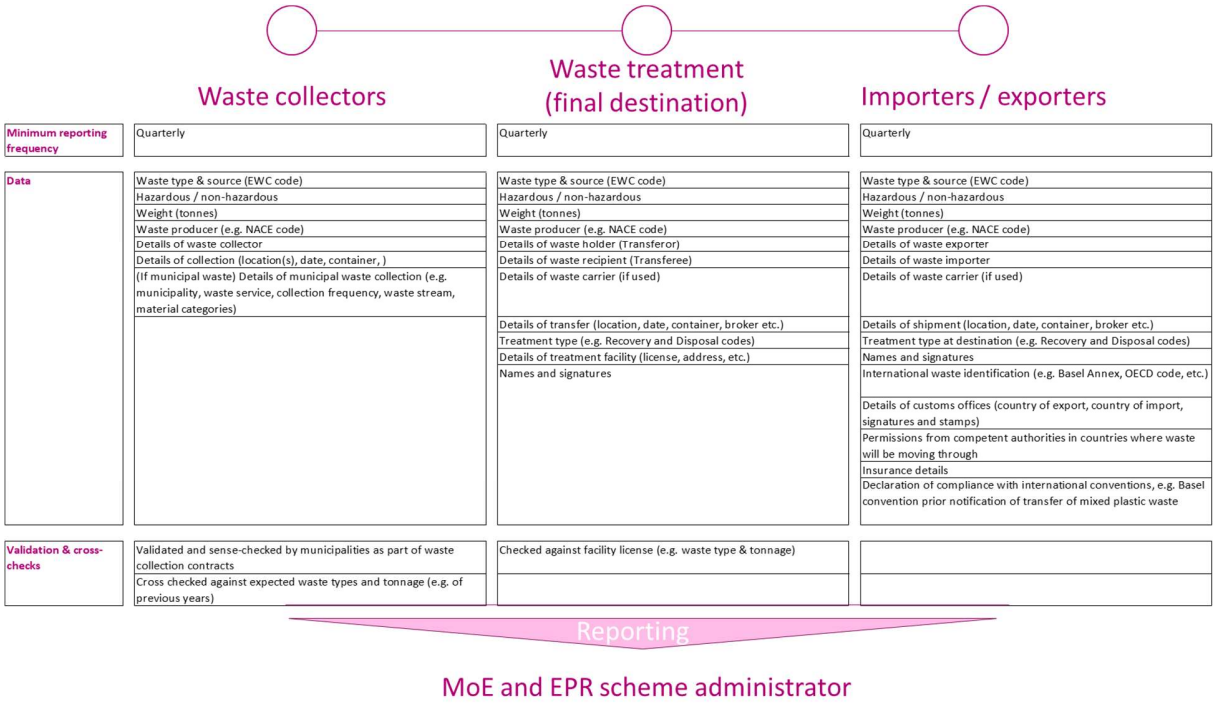
4 Waste data action plan

The system of waste data management no longer meets the needs of national or EU reporting. Waste data collection is not sufficiently robust in its coverage, detail, and quality, and there is a lack of monitoring, enforcement and follow-up. Important gaps persist, possibly due to legislative gaps and a lack of human resources. An incremental action plan to improve waste data collection and management is presented in three stages: short, medium, and long-term. The timescales of delivering these changes depends on the ambition and resources available. Indeed, the long-term plan could be achieved within 5-10 years given the right support.

4.1 Short-term

The fundamentals of national waste data relate to waste collection, the final destination of waste, and the import and export of waste materials. If comprehensive, detailed and high quality data is reported at these three points in the value chain then a robust understanding of waste arising, treatment and recycling rates can be gained. Suggested waste data, reporting frequency and validation steps are illustrated in Figure 24 based on international best practice. Additional data may be required, as relates to environmental regulations in Estonia.

Figure 24: Basic data reporting from key stakeholders



This level of data reporting provides an overview of waste management but masks the intermediary steps of waste passing between different operators and going through intermediary treatment processes. As recycling rates increase the waste value chain typically becomes more complicated as more materials are separated and treated at different facilities specialising in specific materials and processes.

An illustration of a waste value chain is shown in

Figure 25, taken from the smart waste tracking project Vastum that is currently being developed by environmental consultancy Anthesis. The figure shows multiple stages in the value chain, with waste collected from the waste producer by a waste carrier and transported to the receiving site. The receiving site might be a waste bulking and transfer station or, in some cases, it might be direct-delivered to a waste recovery of disposal facility. The waste may be transferred between waste operators at this point, with a corresponding financial transaction, or the waste collector may own the receiving site and/or further steps in the value chain. The figure shows the value chain branching as a result of the sorting of waste into different materials and the subsequent onward journey of separated wastes. Import and export of waste is not represented in the figure.

Figure 25: Waste value chain

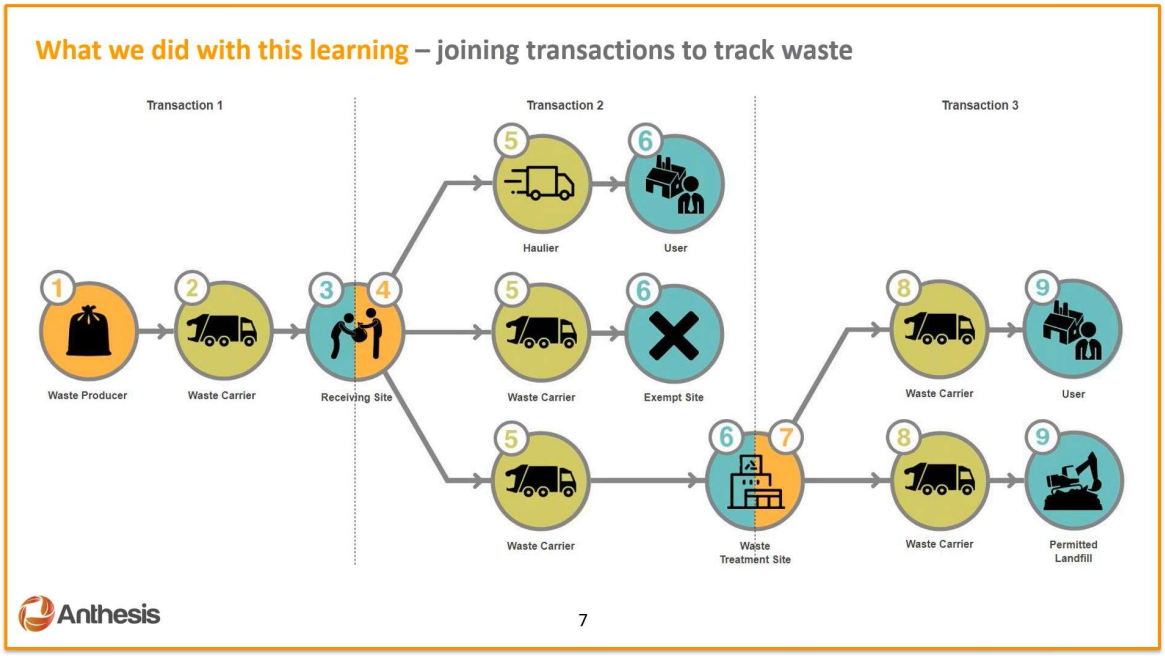
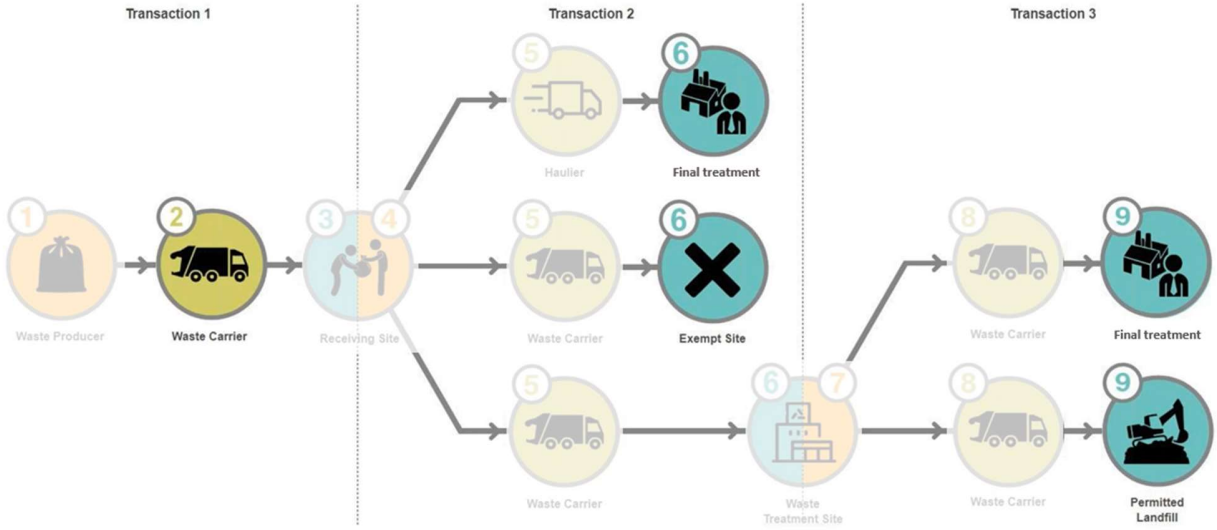


Figure 26 illustrates the points in the value chain that would be represented in the short-term action plan, with waste collectors and waste treatment facilities at the final destination of waste reporting data. As the figure shows, this captures data from the economic operators at the start and the end of the waste value chain, but the intermediary steps remain opaque due to the lack of data collected at those points.

Figure 26: Data captured in the by waste collectors and final destination waste treatment facilities



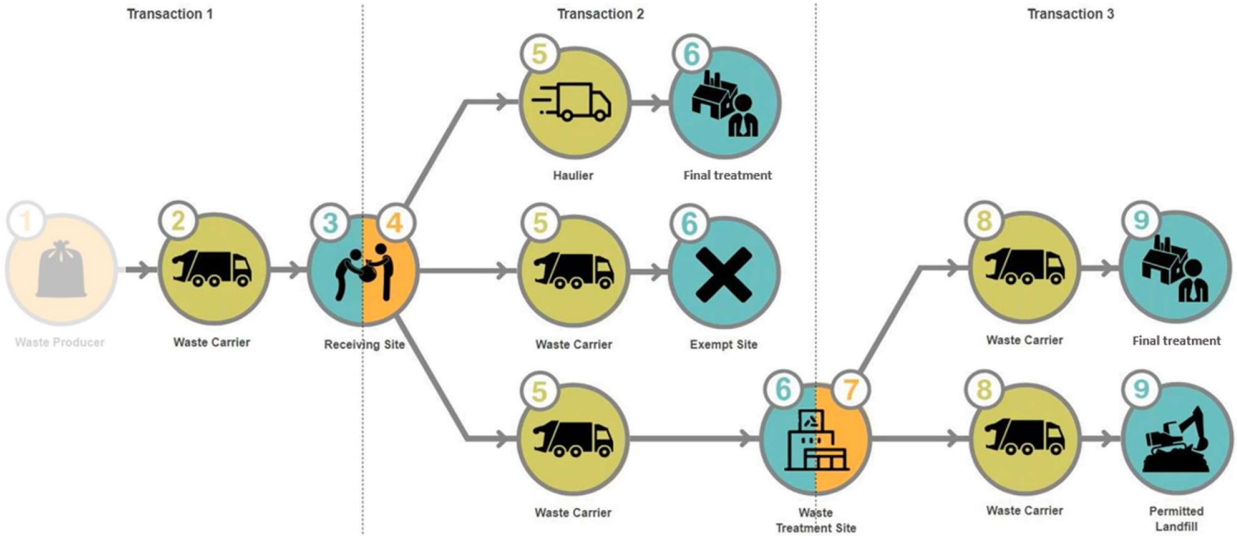
In light of research findings, particularly those presented in Section 2, the following recommendations are given to support waste data collection and reporting in the short-term:

- **Address local waste data collection issues.** Create a single standardised data management system for waste handlers to collect data for KOTKAS. Develop features for waste tracking, data traceability and verification, and automated validation checks with non-compliance notices for the data manager (i.e. the MoE).
- **Continue to develop KOTKAS as a single central location of waste data**, and make data accessible to relevant parties in granular or aggregated form. Avoid introducing separate systems and duplicating data. If there are gaps or deficiencies in granular data that affect regional or national summaries, address these gaps as a priority so that data is complete and can be aggregated to different level without the need for additional estimates.
- **Address issues of scope and granularity in packaging waste data.** Review requirements under national packaging EPR legislation and EU Directives, e.g. breakdown of packaging waste by source and collection type. Engage PROs on mandating new reporting requirements. Update data submission templates and reporting for MoE annual activity reports.
- **Ensure a functioning chain of responsibility for high quality and timely waste data reporting**, from the lowest level of granular waste data collection up to municipal and national government. Two key parts of the chain to address are:
    - *Data collection:* typically waste contractors and treatment facility operators. Review/update legislation on data reporting requirements, in particular data submission, validation and correction requirements and response timescales. In particular, address issues around response time for verifying and updating erroneous data. Provide online portals with KPIs to monitor how individual operators perform against these requirements and require/encourage municipalities to build the KPIs into waste contracts, with minimum performance requirements and penalties for non-compliance, e.g. part of contract fees being linked to KPI performance ideally with a sliding scale to incentivise high performance. Provide functionality within the KOTKAS system which requires data verification of reports by municipality before sign-off
    - *Municipalities.* Provide municipalities with tools and support to verify data submitted to KOTKAS by their waste contractors. Ensure there are consequences to municipalities for poor data handling performance, which will motivate municipalities to better manage their contractors (using the means outlined above).
- **Create functionality for the Environment Agency to correct data as a last resort** if the data submission party fails to do so.
- **Minimise poorly categorised data and other forms of low quality data.** Reduce quantity of waste categorised as 'unspecified treatment' or 'unknown origin/municipality of the collection' in national reports by ensuring better traceability at local level. Utilise municipalities in verification of data at submission to provide greater understanding of movement of waste, from collection to treatment, by waste contractors.

4.2 Medium-term

In the medium-term, it is recommended that waste data collection and reporting move to a transactional model wherein each movement of waste is reported in standard format so that the full value chain becomes clear as waste passes between different operators, is separated into different materials, and undergoes one or more treatment processes before its final destination in recovery or disposal. Ideally, this would extend beyond the point of export and follow the waste to its final destination in foreign counties. This would ensure waste is treated responsibly, reducing the risk around illegal landfills and burning of waste, but it is recognised that this is currently difficult to monitor and enforce.

Figure 27: Transactional data reporting in the waste value chain



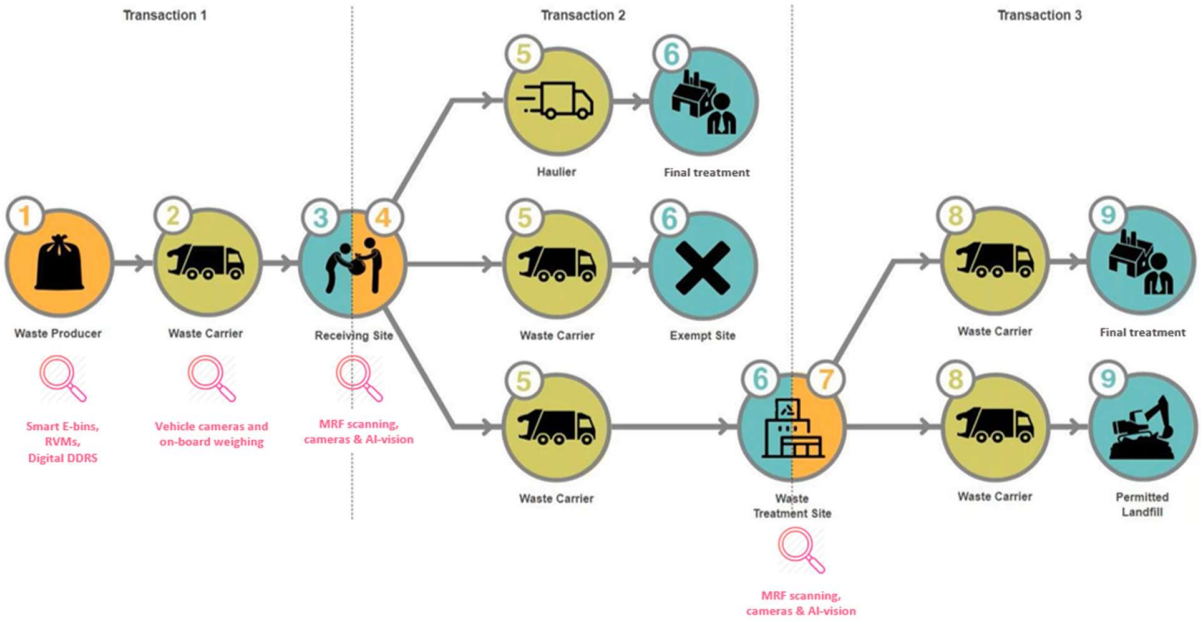
The following recommendations are provided to support waste data collection and reporting in the medium-term:

- **Introduce electronic waste transfer notes** to collect transactional data on the full waste value chain, as described above.
- **Increase and automate granular waste data collection and submission to KOTKAS.** Review EU Directives and National strategy to foresee future data needs, e.g. introduction of EPR for new waste streams such as fishing gear, textiles, certain C&D wastes, etc. or eco-modulation of producer fees under EPR reform, which may be based on 'recyclability' of packaging and other factors. When new legislation is drafted, start to adapt KOTKAS to incorporate new datasets and fields to maintain a single dataset for waste legislation compliance and reporting needs.
- **Benchmark municipalities for performance**, identify outliers, and investigate reasons for high and low performance. Address issues identified and share best practice.

4.3 Long-term

In the long-term, new technology can be introduced to gather data on the waste producer and to provide greater granularity, frequency and automation of data collection at other points in the value chain. Figure 28 illustrates how some of the data collection technologies described in Section 3.1 can be integrated into the data collection action plan to supplement transactional data outlined above.

Figure 28: Full waste value chain transparency with additional granularity denoted in pink



The following recommendations are provided to support waste data collection and reporting in the long-term:

- **Take advantage of new technologies available** for waste data collection, waste monitoring, tracking, and reporting. Carefully design roll-out of such technologies to avoid duplication of data (and potential disparities) and ensure successful integration with national systems. Focus on key areas of data gaps or data quality issues, such as greater granularity on source of data (waste generator type and location, aligning with EU and national waste categorisation schemes such as Waste Framework Directive methods for categorising MSW).
- **Use near real-time data feeds from new technologies to create dashboards and monitoring systems** that can remotely identify and respond to waste crime. For example, compare waste permits to live operations and notify operators if they are reporting waste types they are not licensed for, or are approaching their permit limits on quantities of waste. Automate mass-balance checks on individual operators to identify potential criminal activity, such as fly tipping or illegal waste treatment.
- **Create a centralised data centre for national material flows** – raw materials, finished and semi-finished products and waste, taking account of import, exports and national production, as well

as consumables and process losses (such as evaporation of wet waste, and incineration of waste). Aim to produce a comprehensive view of material flows through the economy and through the geography, from which national circular economy strategies can be targeted and performance measured.

- **Aim to align data categories** where possible, e.g. align EWC codes with industrial categories (such as NACE codes) used to record non-waste material flows, to allow a direct comparison and unification of data. This may require additional data requirements at waste data collection, e.g. NACE code of waste generator, but this would not be onerous if new waste technology were utilised – as described elsewhere in this report.

Appendix A Waste Act reporting procedures

Key sections of the Waste Act[28] which define legislation for reporting of waste.

§ 116.	*Maintenance of records on waste*
	(1) [Repealed - RT I 2007, 19, 94 - entry into force 11.03.2007] *(2) **Persons holding an environmental protection permit** and producers of hazardous waste, except households, are required to keep, taking account of the provisions of subsection 28 (11) of this Act, regular records of the type, quantity, properties and origin of the waste generated, collected, stored or temporarily stored, transported, treated, recovered or disposed of in the course of their activities. If waste is transferred to other waste handlers, records must also be kept of the destination, frequency of collection, modes of transport of and recovery and disposal operations regarding the waste.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]* *(3) The source documents for the records specified in subsection (2) of this section and the consolidated data produced on the basis thereof shall be stored for at least five years.* *(4) Environmental supervision agencies and the controller and processor of the environmental decisions information system have the right to have access to source documents for records and to consolidated data.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]*
§ 117.	*Reporting on waste*
	(1) The person specified in subsection 116 (2) of this Act shall submit an annual report on waste to the Environmental Board. The dataset for the report on waste and the procedure for the submission thereof shall be established by a regulation of the minister responsible for the area. *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]* *(1[1]) The obligation to submit reports on waste does not extend to the following persons:* *1) persons generating hazardous waste, for whose operation no environmental protection permit is required;* *2) brokers registered on the basis of clause 987 (2) 4) of this Act;* *3) dealers registered on the basis of clause 987 (2) 5) of this Act.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]*

[28] https://www.riigiteataja.ee/en/eli/521122020002/consolide

	*(2) The Environmental Board has the right to require submission of a report on waste also from waste producers whose activities do not require an environmental protection permit, but who produce more than **10 tons** of non-hazardous waste per year or more than **100 kilograms** of hazardous waste per year.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]* *(2^1) Persons other than the producer who receive from waste holders waste resulting from products of concern and recover or dispose of them are required to submit to the register of products of concern data on the handling of waste resulting from products of concern in accordance with the requirements provided for under subsection 26^1 (2) of this Act.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]* *(22) If the person specified in subsection (2^1) of this section offers services to a producer of products of concern and submits data to the register of products of concern on their behalf, the obligation of the producer of products of concern to submit data on the handling of waste resulting from products of concern is deemed to be met.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]* *(3) The minister responsible for the area and environmental supervision agencies have the right to obtain information concerning products produced in or imported into Estonia, the substances used in manufacturing the products, the waste resulting from the products and concerning the handling of the waste from the producers and importers of the products and from governmental authorities and rural municipality and city governments.* *(4) Statistical works relating to waste shall be organised pursuant to the procedure provided by the Official Statistics Act.* *[RT I 2010, 41, 241 - entry into force 01.08.2010]* *(5) A report on waste is intended for internal use.* *[RT I, 21.12.2019, 1 - entry into force 01.01.2020]*

Appendix B Key institutions and roles in waste management

Roles and responsibilities in waste management system

Activity/Role	Responsible institutions	Description
MSW Collection and treatment	Municipality, private companies	Municipality has to establish a 'register of the waste holders', set the practical requirements for waste sorting and collection and pick up the collection company by tender. The collection company is obliged to collect waste in a given area based on their contract with the municipality. In most cases municipalities do not regulate the destination of the waste, hence it has become practice for the collection company to decide.
Registration and permitting - **Landfill sites** - **Transport operators**	Environmental Board, Municipalities	Landfill sites are to be selected based on the Planning Act (public hearing etc.), but the permit for landfill operations, as any other waste management operation, is issued by the Environmental Board. On some limited cases, where a waste permit is not required, but registration of waste management entities is, it could be done by the municipality.
Enforcement and compliance monitoring - **Local activities** - **National level activities** - **Transboundary movement**	Environmental Inspectorate (from 2021 as part of the Environmental Board), Local municipality or co-operation structure of the municipalities.	Environmental Inspectorate is the basic entity for supervision and enforcement, working together, if needed with the police, customs, tax department, etc. Municipalities are generally responsible for implementation and supervision of the local Council waste regulations.

Data collection and reporting	Environmental Board Environmental Agency	Until recently the Environmental Board had the obligation to provide 'first tier control' on waste reports (compliance with permits etc.), but this is now being migrated to under the Environmental Agency.
Infrastructure investment funding	EIC Municipalities Private companies	State is offering investment support, both based on Estonia's Environmental Charges, but also on EU finances (and other EFTA Counties contributions). Municipalities and private WM companies are expected to apply for those grants and develop projects, first of all for recycling.
Waste Prevention (Communication, etc.)	State authorities, NGOs, PROs, private companies	All stakeholders have some role to play, but only limited amounts of funds are set aside for this purpose and there is no nationally coordinated effort in this regard.