TULIPS

Demonstrating lower polluting solutions for sustainable airports across Europe

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WP6 CIRCULAR AIRPORTS

Airport Circularity Baseline Study

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Abstract

This report summarises the TULIPS Work Package 6 Circular Airport project's work from January 2022 to April 2023, which aims to provide a baseline of 2019 operational resource streams of participating airports. Input from Schiphol Amsterdam Airport, Avinor Oslo Airport, and Hermes Larnaca Cyprus Airport was collected through meetings, workshops, and knowledge sharing sessions. The report highlights the results of collaboration with key stakeholders, executing a Waste Safari, performing environmental impact assessments, and ranking priority operational resource streams.

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1 Executive Summary

This report presents a 2019 baseline assessment of waste management practices at participating airports, part of the TULIPS WP6 Circular Airports initiative. The TULIPS consortium aims to reduce airport's operational resource streams by 20% by 2025 (comparing year 2019 with 2024) and maximise the use of secondary materials for constructional resource streams at three participating airports: Schiphol Amsterdam, Avinor Oslo, and Hermes Larnaca. The focus of this report is on operational resource streams solely.

The report emphasises the importance of identifying and managing operational resource streams at airports and highlights the need for collaboration with key stakeholders to move towards a circular economy. It reveals that the waste produced per passenger averages at 218 grams in 2019, with residuals, food waste, and paper being the top three waste streams by volume. All operational resource streams have been ranked by the airports based on the results of the impact assessment, discussions with key stakeholders, insights from the performed Waste Safari, with the top three ranking being Residuals, Food Waste, and Plastic.

The report acknowledges certain limitations, including the exclusion of certain operational streams (such as waste water and cabin waste) and the need to maintain confidentiality, resulting in the averaging of results which may not accurately reflect the actual environmental impact of operational resource streams at each airport.

The report concludes by outlining next steps for reducing operational resource streams at airports, including co-creating nudging strategies and interventions, developing monitoring systems and metrics, and continuing collaboration with key stakeholders. The output of these steps will be covered in future deliverables published under the TULIPS WP6 flag. Overall, this report provides valuable insights into the circular economy approach to waste management at airports and serves as a useful guide for future efforts in this area.

2 Introduction

Are you interested in catching a glimpse of the exciting changes happening in the aviation industry? Applying circular economy principles at airports is definitely one of the changes that the aviation industry is dealing with today. Innovations in this domain are driven by a number of factors such as resource depletion, environmental concerns, economic benefits and regulatory requirements. This chapter dives into how the EU consortium TULIPS Circular Airports aims to implement circular economy principles within operational resource streams and a reading guide for this report.

2.1 Trends and developments at airports

As the global population continues to increase, the demand for air travel is expected to grow (ICAO, 2023). The passengers expect more from airports than ever before (Lee, J., Song, T., & Kim, J. 2007). They want convenient, comfortable, and enjoyable travel experiences, including amenities such as lounges, restaurants, and shopping, as well as innovative design elements that make airports more visually appealing. This means that airports will need to evolve and adapt to meet the needs of more passengers, which presents an exciting challenge for airport designers and operators. The trend of a growing population and an increase in air travel will show a corresponding increase in the consumption of goods, energy, and resources. Amongst a number of additional factors (refer to Figure 1 and Appendix B), airports are driven to explore more sustainable alternatives. Hence, a circular economy is acknowledged as a critical trend that is gaining momentum (NLR, 2019).

Figure 1: Identified factors that drive the circular economy transition for airports

Within this document and the TULIPS consortium, circular economy is defined as follows: "The circular economy is a system solution framework. A circular economy decouples economic activity from the consumption of finite resources to stay within planetary boundaries. It's a model that maintains the highest possible value of raw materials, components and products, either by lengthening their lifetime or by looping them back in the system to be reused. Waste is eliminated or used as a resource, both by smart circular design and value retention processes (R strategies).

Also, a circular economy aims to prioritise the regeneration of nature so that resources can restore, renew or revitalise their own sources of energy and materials."

By embracing circular ambitions and initiatives, airports can demonstrate their commitment to a greener future while reducing their carbon footprint. It is acknowledged that by applying circular economy principles, airports can become more sustainable, resilient, and competitive while reducing their environmental footprint (International Civil Aviation Organization, 2019). This can make them more attractive to passengers, airlines, and other stakeholders, and help to ensure their long-term viability.

2.2 TULIPS Circular Airports

TULIPS is a consortium that will develop innovations that facilitate the transition to low-carbon mobility and enhance sustainability at airports and is supported by the EU with €25 million in funding. The TULIPS project started in January 2022 and will run until December 2025. TULIPS is short for DemonsTrating lower pollUting soLutions for sustaInable airPorts acrosS Europe. Each Work Packages (WP) within TULIPS focuses on a different sustainability aspect and one of these aspects is circularity, which is addressed in WP6. WP6 aims to implement the circular economy principles within both operational and constructional resource streams as visualised in Figure 2.

Figure 2: Overview of activities, demo's and deliverables of TULIPS WP6

The main objectives of WP6 Circular Airports are piloting initiatives, which reduce operational resource streams by 20% by 2025 (comparing 2019 – 2024) and maximise secondary materials for constructional resource streams. As well as, consequently, scaling solutions to develop a circular economy roadmap for airports that will guide them in implementing circular economy solutions and achieving their sustainability goals. By doing so, the TULIPS consortium hopes to contribute to the development of a more sustainable aviation industry. WP6 objectives are divided into various deliverables of which this document, airport circularity baseline report, reflects the first deliverable. This report focuses on operational resource streams solely, excluding energy (which is captured in other WP's) and aims to define a baseline study for the year 2019 for the participating airports.

Within the TULIPS consortium WP6 five partners collaborate, including three airports (Schiphol, Avinor, and Hermes) and two supporting partners (TU Delft and Excess Material Exchange).

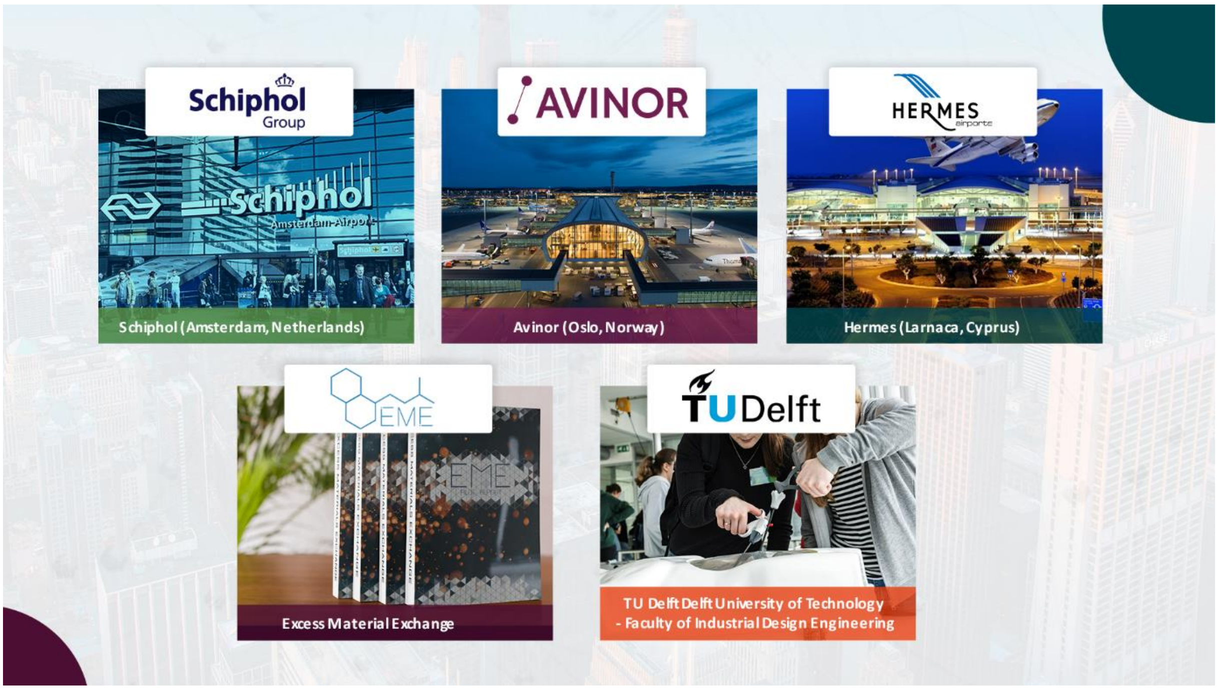

Figure 3: Participating partners in WP6 operational resource streams

The partners will be briefly introduced below and are visualised in Figure 3.

- Royal Schiphol Group (hereafter: RSG or Schiphol) is the Lighthouse Airport in TULIPS and will be coordinating the activities of TULIPS to take care of the overall project coordination, data and IPR issues, and creating an integrated roadmap towards 2030 for different airport categories and configurations.
- Hermes Airports (hereafter: Hermes) is participating in different WP's, validating several of the demonstration projects performed at the lighthouse airport, and demonstrating land carbon sequestration, circular economy solutions, and alternative power production through photovoltaics.
- Avinor is developing sustainable airport operations by focusing on low-carbon ground handling, circular waste management, and renewable energy. They are also involved in testing new sustainable technologies and creating plans for integrating them into other airports.
- The Excess Material Exchange (hereafter: EME) is providing its platform to map waste streams and excess building materials/components, quantify the environmental impact of materials flowing through the airports, and demonstrate how tracking and trace technologies can be applied in an airport environment. ENE also coordinates all work in WP6.
- TU Delft (hereafter: TUD) is providing scientific education, conducting scientific research, transferring knowledge to society, and promoting social responsibility.

Refer to Appendix C for a detailed description of all partners in this process.

2.3 Purpose of this document

The purpose of this report is to provide an in-depth understanding and baseline (2019) of the operational resource streams of airports and its management. The report aims to share knowledge and experiences gained from the TULIPS project and highlights the importance of collaboration with airport's stakeholders, performing a Waste Safari and environmental impact assessment, in order to rank priority operational resource streams. The overall goal of the report is to promote knowledge exchange, scale best practices and all together accelerate the transition towards a circular economy in the aviation industry.

2.4 Reading guide

This report provides a summary of the work performed by TULIPS WP6 from January 2022 to April 2023, based on input from three participating airports: Schiphol Amsterdam Airport, Avinor Oslo Airport, and Hermes Larnaca Cyprus Airport. The input was collected through various meetings, workshops, and knowledge sharing sessions. As this report is public, all input collected is confidential and reported only as an average of the total of the three participating airports. Hence tables, figures, and summarised text are the result of taking an average of waste weights, passengers, costs, etc. Some annexes are only available to participating airports, such as the results of the environmental impact assessment, even though in the text a reference to the annex can be made. Visuals are created by EME based on the collected content from the participating airports, and all other images used are developed by TULIPS or specifically referred to the source.

3 Waste management ambitions of the airports

In this chapter the ambitions of the three participating airports are summarised and an intro is provided to waste management practices in The Netherlands, Norway and Cyprus. As it seems, waste management strategies are just one piece of the puzzle. Will you join our journey in changing the perspective on waste from a problem to a resource to accelerate the transition towards a circular economy?

3.1 The circular approach for dealing with waste at airports

A more traditional and linear approach to waste management is primarily focused on downstream activities, such as collecting, sorting, and disposal. This approach is reactive, with the focus on managing waste once it has been generated, rather than preventing waste from being generated in the first place.

In contrast, a circular economy approach to waste management is focused on preventing waste from being generated in the first place. This approach is proactive, with the focus on designing systems that minimise waste generation and maximise resource utilisation. Airports adopting circular economy principles, usually define and implement waste reduction targets and develop partnerships across the value chain to reach set targets. Whilst the linear approach is still commonly used in waste management at airports, there is a growing recognition of the benefits of adopting circular economy principles. As a result, airports are now seeking new ways to collaborate with waste handlers that involve greater transparency and accountability for waste management beyond the airport premises. This has become a critical evaluation criterion in updating collaboration agreements and selecting new waste handlers through tenders. In addition, the focus is driving towards prevention of waste. The circular economy is the core focus of TULIPS WP6 Circular Airports and participating airports.

3.2 Reporting on environmental impact

As elaborated in Figure 1 (Chapter 2.1 Trends and developments at airports), several factors are driving airports towards taking more responsibility and ownership of its activities. Historically, waste management practices at airports have not been the main priority, due in part to limited reporting requirements. While the Airport Carbon Accreditation (ACA, 2023) has been effective in helping airports reduce their carbon footprint, there is an acknowledged narrow focus on materials and circularity, largely because waste management is typically outsourced to a third party (scope 3). As Christopher Paling, from Manchester Metropolitan University, noted, this presents a challenge.

" Emissions from wastewater and solid waste are mandated in ACA at the highest level (Level 4 and 4+) but not at lower levels. Many would argue that these emissions should be included in any airport operator scope 3 footprint as they are clearly part of the operator's value chain and they are a specific category of emissions required for reporting by the GHG Protocol Corporate Standard and other international reporting standards, such as the CDP and GRI."

Christopher Paling FHEA PIEMA MSc - Manchester Metropolitan University

To address this issue, it is crucial to assess the impact of airports' waste streams and prioritise effective waste management practices, with a particular emphasis on waste prevention. This will ensure that waste management practices are given the attention they deserve and are integrated into the broader strategic agenda of airports.

3.3 Airport’s circular ambitions and national waste management practices

By adopting a circular approach to waste management, airports can help to create a more resilient and sustainable future, while also contributing to the achievement of global sustainability goals such as the United Nations Sustainable Development Goals (UN SDGs). The ambitions of the three participating airports are described and an overview of current waste practices in the local countries are provided. Note that the three airports differ in terms of size as explained in Table 1.

Table 1: Overview 2019 passengers per participating airport

Airport	Passengers (2019)
Schiphol Amsterdam	71.7 million (Schiphol, 2019)
Avinor Oslo Airport	28.5 million (Avinor, 2019)
Hermes Larnaca Cyprus	8.2 million (Hermes, 2019)

Ambitions of Royal Schiphol Group (The Netherlands)

Royal Schiphol Group aims to become the world's most sustainable airport by 2050. The group is focusing on four key themes: circular economy, energy positivity, sustainable aviation, and communities. By 2030, the group aims to make its airports waste and emission-free, reduce CO2 emissions from aviation to 2005 levels, and improve the balance between the airports and local communities. By 2050, the group aims to make its airports circular and energy-positive, achieve CO2 neutrality in the aviation sector, and make it pleasant to live and work in the vicinity of its airports (Schiphol, 2022).

Current waste practices in the Netherlands

Schiphol Airport has introduced a number of recycling bins throughout the airport, which are labelled and colour-coded to enable passengers to recycle different types of materials, such as plastic, paper, and residual streams. The bins are FF3 airport bins from the brand AUWEKO GMBH, see Figure 4. It consists of a compartment for paper (50 Litre), plastic metal and drink cartons (50 Litre) and residual waste (70 Litre). Bins are located across Schiphol premises. Waste at Schiphol airports is managed by waste handler Prezero (up to June 2023) and Renewi & Seenons (as of June 2023) and consequently transported to (post-separation) treatment facilities. The separation rate is provided by waste handlers and also included in the current set of Key Performance Indicators.

Figure 4: FF3 airport bins at Schiphol and separate PET collection

The Dutch waste management system is decentralised, with national, regional, and local authorities sharing responsibilities. The national government sets waste management policy, including a landfill ban, while regional authorities are responsible for waste collection and treatment. The National Waste Management Plan (LAP) outlines waste management policy and is updated every few years.

Ambitions of Avinor Oslo Airport (Norway)

Avinor aims to be a driving force for sustainable aviation, prioritising climate and sustainability goals in decision-making and facilitating the Norwegian aviation industry's goal of being fossil-free by 2050. Avinor also aims to become fossil-free in its own operations by 2030 (Avinor, 2022). Targets, as of 2020 are set to achieve zero waste such as halve the quantity of unsorted waste generated by ordinary operations by 2025 (with 2019 as the base year), with a zero vision for unsorted waste by 2030. Avinor also aims to reduce food waste by 30% by 2025 and 50% per passenger by 2030 (with 2019 as the base year).

Current waste practices in Norway

As shown in Figure 5 below, Oslo Airport terminal uses a multi-stream system for waste collection in the terminal common area. This includes: A bin for bottles and cans, a second one for paper, and a third one for residual waste.

Bins are provided by Røros Products. Plastic bags of different colours are used inside the bins to let both the cleaning crew and the waste collectors keep track of what is recyclable and which central collection container it goes in. Waste at Avinor Oslo Airport is transported from the airport to treatment facilities by Stena Recycling AS (www.stenarecycling.no) who accepts the material according to the type of the collection contract.

Figure 5: Multi-stream waste collection at Avinor Oslo Airport

Norway has an efficient and effective waste management system. Policies and regulations are set on a national level. Thanks to the landfill ban on biodegradable waste introduced in 2009, most of the waste (as is most waste from the Terminal operations) is either recycled or sent to energy recovery. Landfill deposit is almost entirely used by construction and demolition waste, building masses, inert mass, stone, sand and like.

Ambitions of Hermes (Cyprus)

Hermes is committed to addressing sustainability as an integral part of business strategy (Hermes, 2021). The company's sustainability strategy is based on four pillars. These pillars are translated to the operation of a balanced business model with objectives for each items, such as:

- Operational responsibility (such as airport facility management and operational effectiveness).
- Environment (such as climate change, material resources and biodiversity).
- Social (such as employee experience and engagement).
- Economic impact (such as sustainable supply chain and inter-modality).

Current waste practices in Cyprus

Hermes' environmental management system is certified with the voluntary European Eco-Management and Audit Scheme (EMAS). Waste at Cyprus airport is typically collected and exported by specialised waste management companies as stipulated by local regulations. Such (licensed) waste management companies may transport the waste to treatment facilities where it is processed and disposed of using methods such as landfilling, incineration, or recycling. All waste at Larnaca Airport ends up in separate and labelled compactors (21 tons each) that are managed by waste handler Hellenic Tzilalis and consequently transported to licensed facilities. Recycling bins are available throughout the Terminal, which are labelled and colour-coded to enable passengers to recycle different types of materials, such as PMD, paper, and residual streams. The bins of Figure 6 (left) are the FINBIN Bermuda Triple s/s and they consist of three compartments of 100Lt each for paper, PMD and general waste. The bins of Figure 6 (right) are the GLASDON Nexus 140 of durapol plastic and of capacity 140Lt. They are used for the PMD recycling.

Figure 6: Multi-stream waste collection at Hermes

Cyprus has made progress in improving its waste management system, but still faces challenges due to its geography and high population density. The government's policy on waste management aims to protect the environment and human health by promoting reuse, recycling, and environmentally sound management. There is a lack of local waste management infrastructure and coordination between different administrative levels, but the government is working to increase investment in waste management infrastructure and implement policies to reduce landfill and promote waste reduction and recycling (Ministry of Agriculture, Rural Development and Environment, 2022).

3.4 Changing perspectives: From waste to resources

Waste is typically defined as any material or substance that is no longer useful or needed for its intended purpose and is therefore disposed of. The United Nations glossary defines waste as “materials that are not prime products for which the generator has no further use in terms of their own purposes of production, transformation or consumption, and of which they want to dispose” (United Nations Statistics Division, n.d.). However, in a circular economy, waste is no longer seen as something to dispose of, but rather as a resource that can be repurposed and reused to create new products. Keeping resources in use for as long as possible, at the highest possible quality, is one of the core principles of a circular economy (Ellen MacArthur Foundation, n.d.). By viewing waste as a resource, airports can create new economic opportunities, reduce waste, and decrease the demand for virgin materials.

4 Management of operational resource streams at airports

Airports are bustling centres of activity, connecting people and goods across the world. All that traffic comes with a significant amount of waste. These waste streams, or 'resource streams' are typically landfilled or incinerated and hence it's essential to manage such resources efficiently and sustainably to minimise their impact on the environment. This chapter will explore the operational resource streams found at airports, including the volumes generated, and calculations per passenger to monitor waste reduction ambitions in the future. Also an overview is provided on how the participating airports are currently implementing circular initiatives.

4.1 Common operational resource streams at airports

Operational resource streams at airports refer to the various types of waste generated during daily airport operations and activities. A detailed mapping and understanding of these streams can help embed circular principles in airport operations. Since not only passengers, but various stakeholders in and around the airport contribute to these streams, gaining an overview of the streams and identifying significant contributors can assist in reducing or eliminating waste and improving behaviour.

4.1.1 Identification of operational resource streams at airports

For the purpose of ensuring comparability between participating airports (Schiphol Amsterdam, Avinor Oslo, Hermes Larnaca), this report only includes an analysis of common operational resource streams. These streams are those monitored by at least two and up to all three airports. In alphabetical order, the included streams are:

*Table 2: Overview of operational resource streams***

Operational resource streams*	Referring to streams	Examples of items ending up in the stream (non-exhaustive list)
Electronic components, EE	Referring to electronic streams (e-waste) collected at airports.	Computers, printers, phones, chargers, cables, etc.
Food, swill	Referring to food scraps, leftover meals, and packaged food items from airport restaurants, lounges, cafes, and food courts.	Edible and non-edible food waste.
Glass	Referring to glass-based materials that are collected at airports.	Glass bottles, containers from beverages and food products
Hazardous or unspecified	Referring to streams that potentially cause harm to human health or the environment due to its chemical physical or biological properties.	Batteries, fluorescent lamps, medical waste, paint, etc.
LAG	Referring to streams including liquids, aerosols, and gels (LAG) that are not allowed in carry-on luggage on aircrafts.	Liquids over 100 ml (in some airports), such as shampoo or perfume, etc.
Metal	Referring to any metallic material collected at airports. Note that within some airports, drink or food package cans are collected separately (see plastic stream below).	Food or drinking package cans, aluminium foil, etc.
Paper	Referring to paper-based products used by airport staff and passengers.	Tissue, office archive material, cardboard, news-papers, etc.
Plastic	Referring to plastic materials collected at airports. Note that some airports use Plastic Metal and Drinking cartons (PMD) instead of solely Plastic or	Plastic bottles, bags, packaging, material, foils, etc.

	have a separate sub-stream collecting PET and aluminium cans.	
Porcelain	Referring to porcelain products that may be discarded by airport vendors or businesses, as well as any other non-recyclable items collected at airports.	Porcelain dishes, mugs, etc.
Residuals	The presence of residuals in the recycling stream refers to either a problem with source separation, for instance, of commercial waste and waste generated by passengers, or the presence of non-recyclable plastics, food waste, or mixed packaging materials.	Recyclable: Examples can include all items that should have been collected in a different stream. Non-recyclable: Cigarette butts, gum, and other miscellaneous items that cannot be sorted into other categories.
Wood	Referring to wooden items collected at airports.	Wooden crates, pallets, and packaging materials used to transport goods.

** Please note the following: Some of the operational resource streams mentioned, for instance porcelain, wood, metal, and hazardous are also applicable to the construction industry's resource streams. Although only a small fraction of these streams may originate from operational activities, the entire volume of these streams is considered for the baseline assessment.*

*** A reference is made to a confidential appendix for detailed overview of the operational resource streams per airport. Note: This annex is confidential and only accessible to participating airports, not included in the public report. This information is used to further detail KPIs to reduce operational resource streams by 20%, comparing 2019 and 2024 (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.2) and pilot nudging strategies (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.3).*

The streams not mentioned in Table 2, as these are currently collected and monitored by only one of the three airports, are still considered important but could simply not be used for comparable purposes in this report. Examples of such streams are:

- Waste water and sewage sludge: Wastewater and sewage sludge generated by airports refer to the water and solid materials that are collected from the airport's drainage system and wastewater treatment facilities. Sewage sludge is the semi-solid residue that remains after wastewater treatment at a sewage treatment plant. It contains a mix of organic and inorganic materials, including human and animal waste and food scraps.
- International Catering Waste: International Catering Waste (ICW) is regulated by the EU law (Regulation 1069/2009) and considered CAT1. This waste is classified as risk for infection and needs to be handled and disposed of appropriately to prevent the spread of diseases. In practice this indicated that these volumes are incinerated within 24 hours.
- Aircraft cleaning waste: Aircraft cleaning waste refers to any waste generated during the usage and cleaning of aircraft, including both liquid and solid waste. This can include leftover rubbish from items given to passengers on the aircraft such as newspapers, paper towels, plastic bottles, food dropped on the floor, amenity kits and plastic wrapping from blankets, pillows and headsets. Cleaning waste also includes the contents of washroom bins and medical waste such as used syringes (IATA, 2019).

Note that these additional streams will be included in the individual airport's ambition to reduce by 20% in 2025 (year 2019 compared to 2024). These streams are deemed relevant by all airports, but not all airports control or manage the streams themselves, and hence will be included in further activities performed under the TULIPS WP6 flag.

4.2 Introduction to treatment of resource streams

The three participating airports commonly use a combination of recycling, recovery and/or landfill options to treat operational resource streams. As The Netherlands and Cyprus fall within the EU, and Norway not but is implementing many EU regulations, the EU Waste Framework Directive is deemed relevant (European Parliament, & Council of the European Union. 2008). There are three treatments of waste commonly known and reported on, namely landfill, recovery and recycling.

1. Landfill is a method where waste is buried in designated areas and covered with soil. Although it is still commonly practised worldwide, it is generally considered the least sustainable option due to its potential to contribute to soil and water pollution and generate greenhouse gases such as methane.
2. Recovery refers to the extraction of valuable materials, energy, or chemicals from waste. This can be achieved through technologies like incineration, gasification, or mechanical biological treatment (MBT) which involve the mechanical sorting and treatment of waste to recover recyclable materials. Alongside recycling, it is the most predominant waste treatment option available in the Netherlands and Norway.
3. Recycling is a process of converting resource materials into new products through various methods such as mechanical, chemical, or biological processes. A difference can be made with downcycling, the process of converting materials into lower-value products, and upcycling, the process of transforming waste or unwanted materials into higher-value products. Overall, it is considered the most sustainable waste management option because it helps in reducing the need for new raw materials and energy, conserving natural resources, and reducing waste generation.

Even though these three treatments are most commonly known and used, there are other strategies that can be executed to avoid applying treatments in general. This lies into the actual prevention of waste and optimising the re-use potential. A good example of how this can be visualised is within the EU Waste Framework Directive. This directive sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery. In this model, preventing waste is the preferred option, and sending waste to landfill should be the last resort. The focus on prevention aligns with the core principles of transitioning to a circular economy (refer to chapter 3.1 The circular approach for dealing with waste at airports). More specifically, the difference between landfill, recovery, and recycling is in the way waste is managed after it has been generated, this falls into R9 to R7 of the 9R framework (refer to Appendix D). However, there are other strategies for waste management (R0 to R7), which focus on preventing waste generation in the first place. Please refer to Appendix D to see the full R9 strategies and a more detailed explanation on the model. The traditional model of the EU Waste Framework Directive is enriched with the details of the R0-R7 strategies is Figure 7.

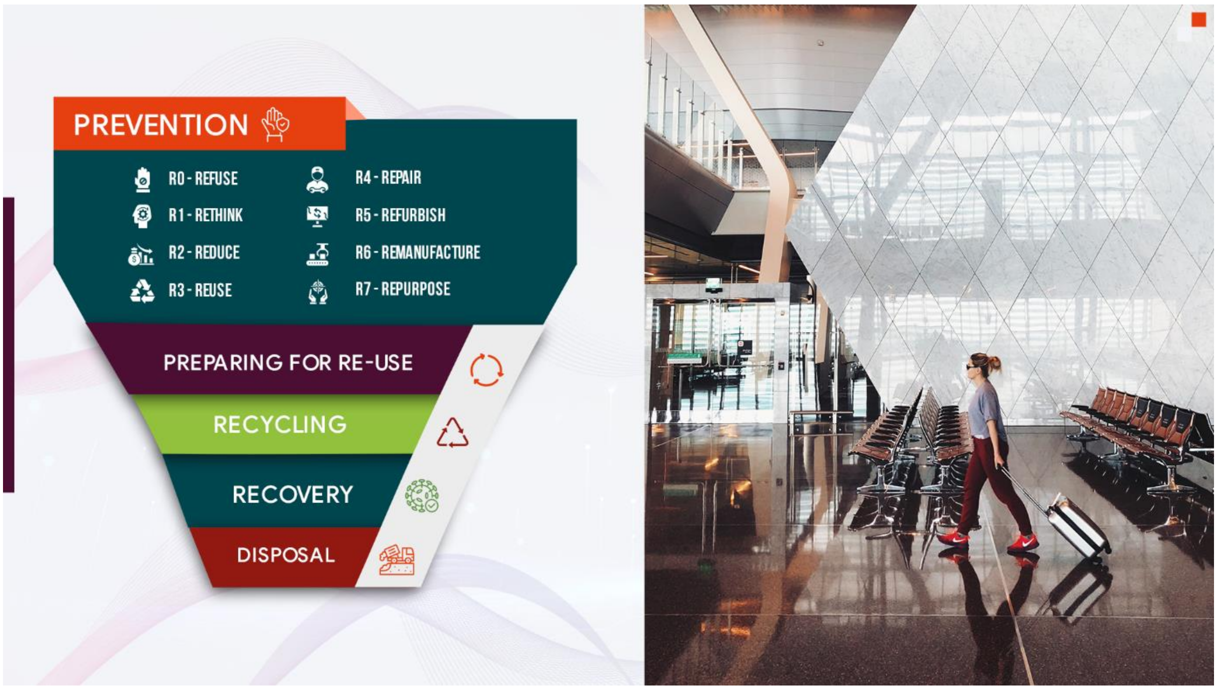

Figure 7: EU waste directive integration with focus on prevention and R-strategies (picture left: Tibbs, C. 2018)

In Chapter 6 Environmental impact assessment, a deep dive is made into how three described treatments are executed in the countries of participating airports. As these are established in the Netherlands, Norway and Cyprus, Eurostat information is available to observe recycling percentages. Please note that this overview includes all resource streams, including for instance construction (which is excluded in this report focusing on operational streams). Refer to Figure 8 for an overview of the countries of participating airports The Netherlands, Norway and Cyprus (Eurostat, 2020). With new waste handling requirements being introduced, airports aim to monitor all R0-R7 waste management strategies in the future.

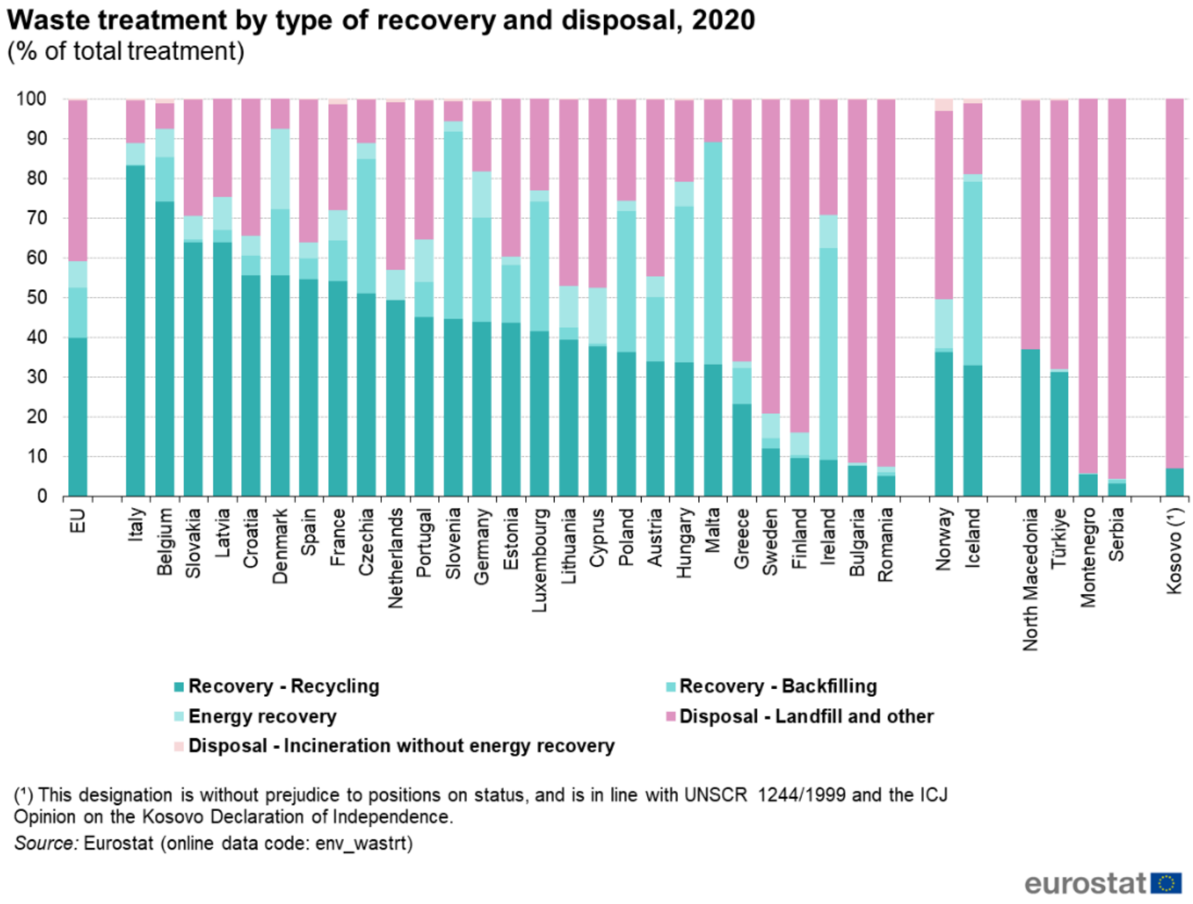

Figure 8: Waste treatment by type of recovery and disposal 2020 (Eurostat, 2020)

The specific percentages of treatment per operational resource streams at participating airports are elaborated in Chapter 6. Environmental impact assessment. In order to prioritise operational resource streams for participating airports, a deep dive assessment is made into the airport's actual bins by means of a Waste Safari (Chapter 5), by performing an environmental impact assessment on operational resource streams (Chapter 6) and understanding the value chain and key stakeholders (Chapter 7).

4.3 Implementing circular initiatives at airports

Airports around the world are recognising the need to accelerate their transition towards a circular economy, as reducing carbon emissions and other environmental impacts becomes a requirement by governments, society, and the industry itself. Implementing such measures may become part of the airport's license to operate and license to grow. To this end, many airports have implemented various initiatives to address this challenge, leading to cost savings and improved sustainability. One of the first activities performed by TUD and EME within TULIPS WP6 was to understand the circular initiatives implemented by participating airports over the past year through various meetings. Figure 9 provides a summary of the activities performed by participating airports, including Schiphol Amsterdam, Avinor Oslo, and Hermes Larnaca. The overview generated in this report covers the current activities executed at airports related to waste prevention, reuse, and better recycling, in alignment with the EU's waste directive plan to include more attention on prevention strategies (R strategies – Refer to Appendix D). Note that this is not an exhaustive overview.

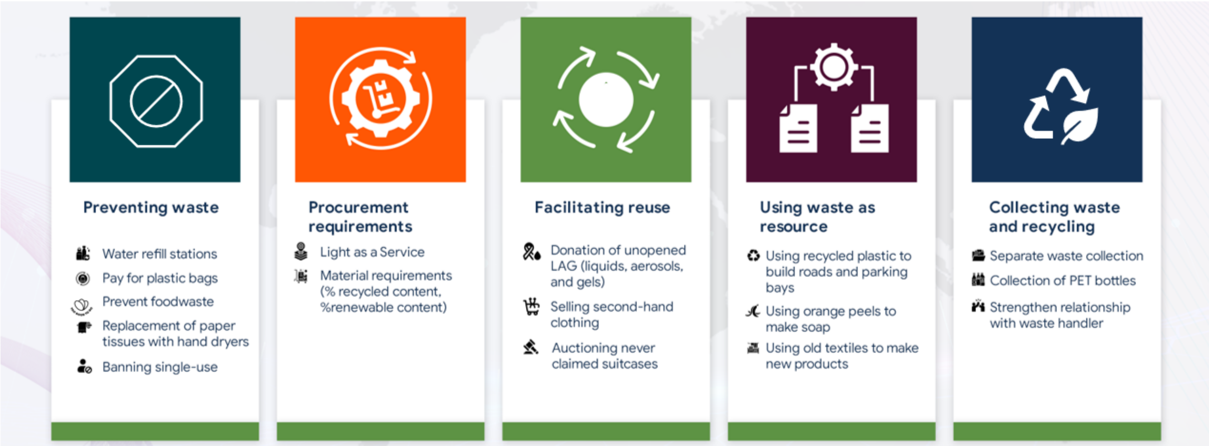

Figure 9: Examples of executed circular initiatives at participating airports

As can be observed in Figure 9, the participating airports are implementing various measures to prevent waste and promote sustainability such as installing refill stations for water bottles, no longer giving out plastics bags for free, partnering with apps like Too Good to Go and donating excess food to local charities, replacing paper tissues with hand dryers to reduce paper streams, and banning single-use plastics. In addition, airports are implementing environmental requirements in procurement, such as paying for services instead of products (e.g. Light as a Service) and requiring suppliers to find products with circular materials. Efforts are made to facilitate reuse by donating unopened LAG (Liquids, Aerosols, and Gels) left by passengers to local charities, selling second-hand clothing, and auctioning unclaimed suitcases. The airports are increasingly using waste as a resource by implementing initiatives such as recycling plastic to build roads and parking bays, using old textiles to create new products, and using organic waste materials, such as orange peels, to make soap. Finally, they are implementing a multi-stream system for waste collection, allowing for more efficient recycling and reducing incinerated or landfill waste. Overall, these initiatives demonstrate the commitment of the participating airports to promote sustainable practices and accelerate the transition to a circular economy.

5 Waste Safari protocol and experiences

Are you ready to spot the big five on your airport Waste Safari? In this chapter, the focus is on the purpose of performing a Waste Safari (waste audit) at airports, and how a Waste Safari protocol developed by TUD can assist other airports in conducting their own Waste Safaris. The procedures executed and findings from the Waste Safaris conducted at Schiphol Amsterdam Airport and Avinor Oslo Airport will be summarised. This chapter aims to provide insights into the importance of waste audits and how they can help airports transition towards a circular economy.

5.1 Motives for executing a Waste Safari

A Waste Safari**,** also known as a waste audit, is a process of evaluating and analysing the waste generated within the airport. It involves collecting, sorting, and measuring the different types of waste produced, as well as identifying the sources and causes of waste. The overview of operational resource streams and volumes (refer to Chapter 4) and talking with key stakeholders (Chapter 7) is informative but some questions remain unanswered about the upstream activities that caused this waste to end up in certain bins. Performing a Waste Safari had several motives, including gaining insights into the airports' waste streams, understanding passenger/tenants source separation and identifying areas where waste reduction or diversion efforts can be implemented to achieve cost savings and environmental benefits. Additionally, the Waste Safari raised awareness about the impact of waste on the environment in order to promote sustainable practices among airport employees, stakeholders, and passengers.

5.2 Protocol Waste Safari at airports

The process of preparing, executing and evaluating a Waste Safari is documented in a process flow and Protocol (refer to Appendix E), ensuring that future assessments can take place in a structured approach and other airports can use this to enlarge their insights. Refer to Figure 10 for a summarised overview of the three steps taken at Schiphol Amsterdam and Avinor Oslo Airport in 2022.

Figure 10: Three-step approach for an airport Waste Safari

Step 1 – Preparation

Planning: To prepare for the Waste Safari several meetings were held with key stakeholders (refer to Chapter 7) to ensure that the objectives and activities for preparation and execution of the Waste Safari were aligned. Consequently, a sample selection took place to ensure bin bags were collected from various locations in the airport. In addition, all equipment required for preparing and executing the Waste Safari were collected.

Picking up bins: The waste handler, in collaboration with cleaning facilities, was responsible for collecting and labelling the bags, and indicated the time of collection and location (e.g. hall number) on a template. In addition, personal information was provided to in-service waste collectors to ensure that they understood the purpose of the study.

Step 2 – Sorting

Open bags – During the waste analysis, the location, time, and type of bag were recorded based on the label on the bag, such as "Gate A4, 13:30, Paper". Consequently a sample from the selected bags were cut open, and the waste is laid out on a sorting table. Materials were grouped according to the general material types, such as plastics, paper, metals, organics, chemicals, and others. The waste bag was then placed on a rolling table and sorted according to pre-defined fractions.

Waste analysis – After the contents of the bags were sorted in its entirety, the boxes with sorted materials were put on a scale and the weight (in grams) was registered in the Excel sheet. In some cases, a specific fraction was taken out and a brief discussion took place within the team about outstanding items, right separation, and types of waste.

Photos - Photos and notes were taken on findings that were considered as significant. Each photo was documented with a number matching the documented data in the Excel sheet.

Documentation - After sorting one bag, the boxes were weighed and the weight was recorded in an Excel sheet.

Step 3 – Evaluation

Analysis: All findings documented in Excel and by means of photos were carefully assessed to understand the main findings and conclusions. Waste that was too contaminated to be identified was also noted in the documentation.

5.3 Experiences executing Waste Safaris in 2022

During 2022, both Avinor Oslo and Schiphol Amsterdam completed a Waste Safari. A summary of the assessment is described below per airport.

Avinor Oslo Airport

During the summer of 2022 a combination of field work, visual waste fraction assessment and detailed weight based analysis of both commercial and passenger waste was done, with focus on residual waste and food waste in the terminal. The study found that commercially generated waste stands for 82% of all residual waste, while passenger waste stands for 18%. Note that commercial waste comes from the businesses operating within the airport (restaurants, shops), while passenger waste comes from the passengers themselves.

During the audit and detailed analysis of the composition of the waste, the fractions have been grouped in passenger streams (Table 3) and streams from commercial tenants (Table 4).

Table 3: Operational resource streams from passengers behind the security checkpoint

Plastics	Paper	Metals	Organics	Other
- Plastic bottles	- Packaging paper (soft paper made without or	- Aluminium packaging (foil/cans)	- Food waste and residues	-Personal care items

- Soft packaging, plastic bags, PE/PP - Plastic cups and hard plastic packaging - Unspecified plastics	with "grease-proofing agents") - Packaging cardboard (hard paper) - Drink packaging box - Paper cups and straw - Newspapers, flyers, books, magazine - Baggage tags - Napkins - Other paper (receipt, printer paper, etc.)	- Other metal (hook, buckle, etc.)	- Organic waste - Liquids - Compostable serving items (bamboo cutleries, etc.)	(plasters, tissues, paper towels, etc.) - Hybrid packaging (mixed paper-plastic) - Glass - Textiles - Unclassified residual waste

Table 4: Operational resource streams from tenants at terminal's biggest staging areas

Plastics	Paper	Metals	Organics	Other
- Plastic bottles - Plastic cups, cup lids, hard plastic - Plastic bags & soft plastic - Other undefined plastics (hard plastic, etc.)	- Packaging paper (made without or with "grease-proofing agents") - Packaging cardboard/hard paper - Drinking box - Paper cups - Napkins and disposable cleaning paper - Other paper (receipt, flyers, magazine, etc.)	- Aluminium packaging (foil/cans) - Other metal	- Food waste - EDIBLE - Organic waste - INEDIBLE - Compostable serving tools (bamboo cutleries, etc.)	- Hybrid packaging (paper-plastic mixed) - Unclassified residual waste

The most interesting findings of the study:

- Food waste from passengers is low: Only 1% of residuals deemed edible.
- Over a third food waste from commercial serving units is edible food waste.
- Paper containers in the passenger areas contain mostly paper, but half of that is not recyclable paper due to contamination or mixed materials.
- Good cans and bottles source separation in public areas: 92% of the cans and bottles bins were recyclable cans and bottles
- Most single use items are used and thrown within the serving units' locale.

Oslo Airport is continuously working on developing measures to increase circularity both aimed towards passengers and commercial units.

Schiphol Amsterdam Airport

Schiphol performed a shorter, more compact version of the Waste Safari, compared to the detailed assessment of Avinor. The study's findings indicated that the top five waste items generated at Schiphol Airport were cups, PET bottles, food bags, food boxes, and cans, all of which were related to food and beverage consumption (refer to Figure 11).

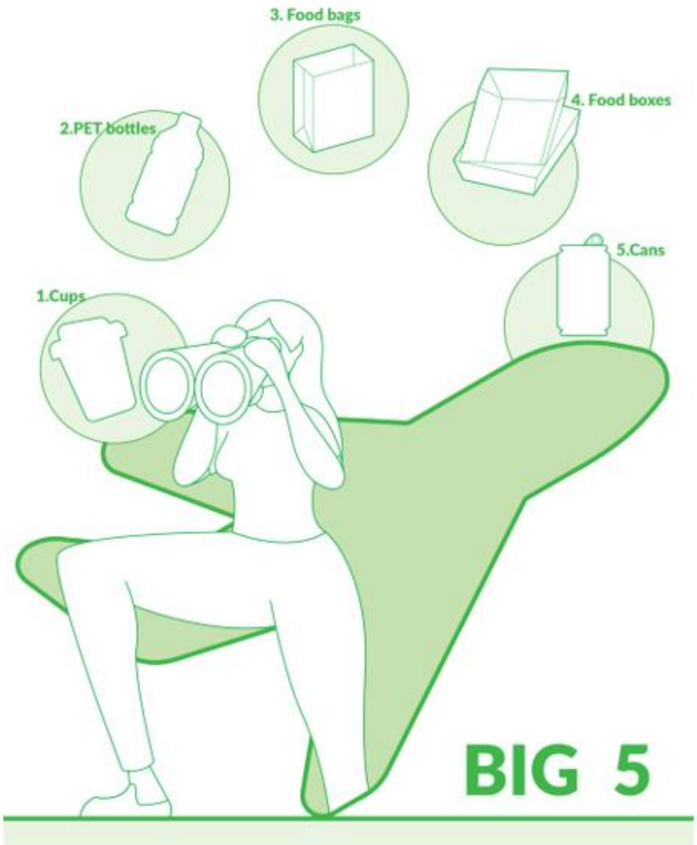

Figure 11: Big 5 spotted at Schiphol Airport

Some other interesting finding resulted from the study such as:

- Bags are contaminated due to passengers not separating their items properly, leading to an increased need for post-separation.
- PET bottles are not ending up in the bags as frequently as expected based on the number of bottles sold, according to information from a food and beverage partner.
- The bin bags are most of the time not full which results in more plastic waste (currently virgin plastic used), which shows the urgency of using alternative materials.
- The paper bins always contain paper waste contaminated with other materials like glass, PET, coffee cups and cans.
- The heavy bags found contain food waste (solid or liquid).
- In most bags the following 3 items can be found: PET/cans/coffee cups.
- People bring private food including packaging from home (e.g. aluminium foil).

TULIPS responds to the identified points of sustainable improvement by accelerating the adoption of innovative and sustainable solutions aimed at reducing waste at airports and accelerating circularity. Meaning that demonstrations of green innovations will be carried out at Schiphol to reduce passenger waste. Developing and showcasing these demonstrations falls within the TULIPS partner TUD and the graduation students involved at Schiphol Amsterdam. Resulting in the following graduation projects:

- Increasing return of deposit PET bottles and aluminium cans.
- Improving waste separation by passengers through the bin system.
- Developing an innovative coffee cup system.

6 Environmental impact assessment

This chapter will guide you through the six-step process of conducting an impact assessment, which includes collecting baseline data from 2019, defining processing pathways, validating processing pathways, performing impact assessment, analysing and interpreting results, and monitoring and improving. The focus of this chapter will be on the results of impact assessments and how they can be used to identify areas for improvement and promote sustainable practices.

6.1 Objectives and boundaries

The scope is to assess environmental impacts and circularity of 2019 operational resource streams at participating airports (Schiphol Amsterdam, Avinor Oslo, Hermes Larnaca) and identify which streams should be prioritised based on the assessment. By doing so, solutions for a better afterlife for the priority flows can be defined which will be the core focus for next TULIPS deliverables to be published in 2023 up to 2025, refer to TULIPS WP6 deliverable 6.2 and 6.3.

There are two main boundaries in this assessment:

1. Technical boundary: The assessment is based on data from existing databases that provide information on the waste processing pathways, which are landfill, incineration and recycling (as the best-case scenario). However, it is important to note that other waste management strategies, referred to as R-strategies (repair, reuse, etc.), these strategies are not included in these databases. Refer to Appendix D for more information on these R-strategies.
2. The stakeholder boundary: Waste management is operated in different ways in the Netherlands, Oslo, and Cyprus, and national-specific procedures take place. To address this limitation, the waste processing pathways are nation specific (and hence uses different databases and percentages), ensuring that results are useful for the airport but making it challenging to compare results across regions.

6.2 Methodology

The methodology of the environmental impact assessment follows a process-step approach which is visualised in Figure 12.

Figure 12: Methodology for executing the environmental impact assessment

** Step6: An analysis of the impact assessment is part of this report, however further interpretation and monitoring and improving is an ongoing activity for the participating airports.*

1. Data collection 2019 baseline

The first step in executing the environmental impact assessment was to collect baseline data from the participating airport's waste management system for the baseline year 2019. This includes primarily the collection of data on the types and quantities of waste generated. In addition, conversations with waste handlers took place to understand the separation rates, 'potential' waste processing pathways, waste treatment and disposal methods. All collected data was consequently organised and analysed to identify trends and patterns.

2. Define processing pathways

The second step in executing the environmental impact assessment was to define the 'actual' waste processing pathways at the airports (as explained in Chapter 4.2 Introduction to treatment of operational resource streams). Note that 'potential' waste processing pathways refer to all possible ways that waste generated at an airport could be processed and managed, while 'actual' waste processing pathways refer to the methods and processes that are currently being used to manage the waste generated at the airport. An example of the difference between 'potential' and 'actual' waste processing pathways is that while wood can 'potentially' be recycled into pallets, the 'actual' processing pathway may be incineration for energy if this is more cost-effective.

3. Validate processing pathways

The third step in executing the environmental impact assessment was to validate the identified waste processing pathways through meetings with airport stakeholders, including waste management personnel and service providers.

4. Perform impact assessment

The fourth step is conducting the impact assessment to evaluate the baseline 2019 airport streams. Each waste treatment process, landfill, incineration, and recycling, will be assigned to a separate reference from databases. With these references, the environmental impact of 1 ton of waste can be calculated using the Product Environmental Footprint (PEF) impact assessment method. With this method, the environmental impact of the waste streams are calculated for sixteen impact categories; climate change, ozone depletion, ionising radiation, photochemical ozone formation, particulate matter, human toxicity (non-cancer), human toxicity (cancer), acidification, eutrophication in freshwater, marine and terrestrial, eco-toxicity freshwater, land use, water use, resource use – fossils and resource use – minerals and metals. An explanation for each category can be found in Appendix F (Hedgehog Company, 2022).

5. Analyse and interpret results

The next step in executing the environmental impact assessment was to analyse and interpret the results. The insights of the assessment assist in identifying the most impactful operational resource streams as the basis for defining strategies to reduce or prevent such streams in line with TULIPS WP6 objectives set (refer to Chapter 2.2. TULIPS Circular Airports). Further interpretation of the results will be done during the course of TULIPS, by means of various deep dive sessions towards formulation of Key Performance Indicators (see also Monitor and Improve section below).

6. Monitor and improve*

From now up to December 2023, the final and last step of the environmental impact assessment will be conducted. The purpose of this final step is to monitor the effectiveness of the mitigation measures and to implement any necessary improvements to ensure that the environmental impacts are minimised. The actions undertaken in these steps are included in the monitoring framework with KPIs, delivered in December 2023 (refer to TULIPS WP6 deliverable 6.2). ** An analysis of the impact assessment is part of this report, however further interpretation and monitoring and improving is an ongoing activity for the participating airports.*

6.3 Results environmental impact assessment

Results of the environmental impact assessment are described per methodology step.

1. Data Collection 2019 Baseline

Several meetings took place to gain an understanding of all operational resource streams. To compare the data of different airports, the datasets were cleaned up to ensure comparability. An important learning of this work has been that most airports have their own ways in how they stored data. In the future, standards on storing data may be beneficial. For example, the data collected was not always from one handler, and the documented volumes differed due to various units. An overview of all operational resource streams per airport is provided. A reference is made to a confidential appendix (Note: This annex is confidential and only accessible to participating airports, not included in the public report).

The comparable operational resource streams and their average volume presented in percentages of the total is visualised in Figure 13. The average volume of comparable operational resource streams at the participating airports is visualised in a bar chart to represent how these streams add up to the total waste generation. The biggest streams include residuals, paper and food waste.

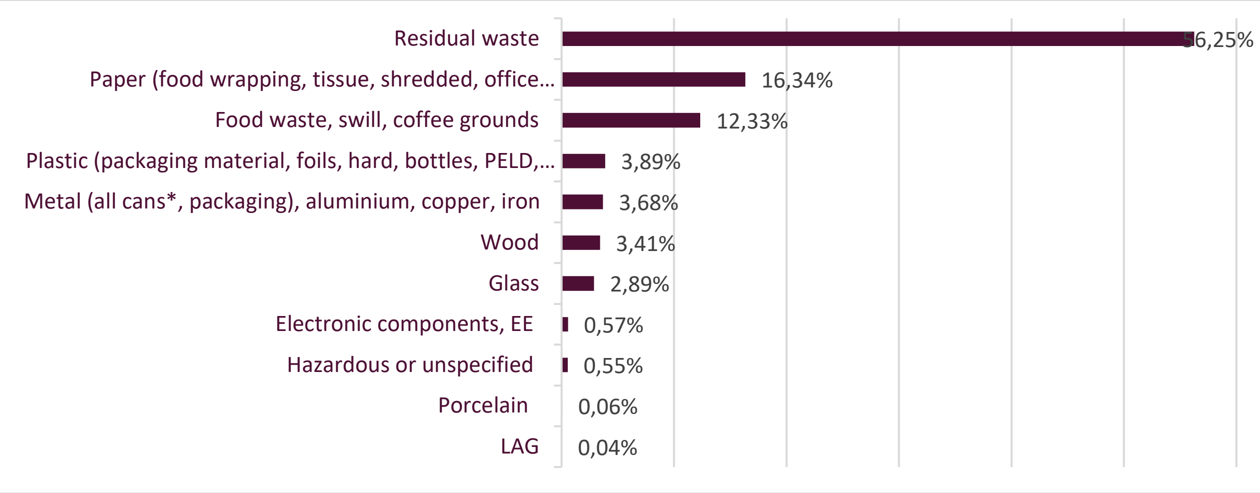

Figure 13: Average volumes of operational resource streams at participating airports

As explained in Chapter 4.1.1 Identification of operational resource streams, some operational streams managed by the airport are not included in this overview but deemed relevant such as waste water and sewage sludge, International Catering Waste (CAT1) and aircraft cleaning waste.

The calculated waste per passenger is an important KPI in the baseline assessment in order to monitor waste reduction activities (between 2019 to 2024). The average waste per passenger for participating airports (Schiphol Amsterdam, Avinor Oslo, Hermes Larnaca) for 2019 is: 218 gram per passenger. A reference is made to a confidential appendix for a calculation of the waste per passenger based on the operational resource volumes of per airport. Note: This annex is confidential and only accessible to participating airports, not included in the public report. This information is used to understand if objectives are reached at the end of 2025, refer to TULIPS deliverable 6.6).

2. **Define processing pathways**

Understanding the difference between 'potential' and 'actual' waste processing pathways is important for identifying opportunities to improve waste management practices and move towards a more sustainable approach. By analysing the potential processing pathways and comparing them to the actual pathways being used, an airport can identify areas for improvement and take actions to reduce waste, increase recycling, and minimise the environmental impact of its operations.

The 'actual' processing pathway per stream is data that should be provided by the waste handler (including location and treatment) and is considered primary data. The primary data was often not available from waste handlers and hence the following references were used and applied, refer to Table 5.

Table 5: Sources used for waste processing pathways

Schiphol Group	AVINOR	HERMES airports
Nationale Milieu Database (Milieudatabase, 2022)	Statistisk SentralByrå' (Statistics Norway, 2022)	European Commission's Eurostat database (Eurostat, 2022)
European Commission's Eurostat database (Eurostat, 2022)	European Commission's Eurostat database (Eurostat, 2022)	For the waste streams processed outside of the EU,

		assumptions were made based on the literature

Some assumptions had to be made for the treatment of some waste streams that were not available in the databases. The actual processing pathways per operational resource streams are averaged and visualised in Figure 14.

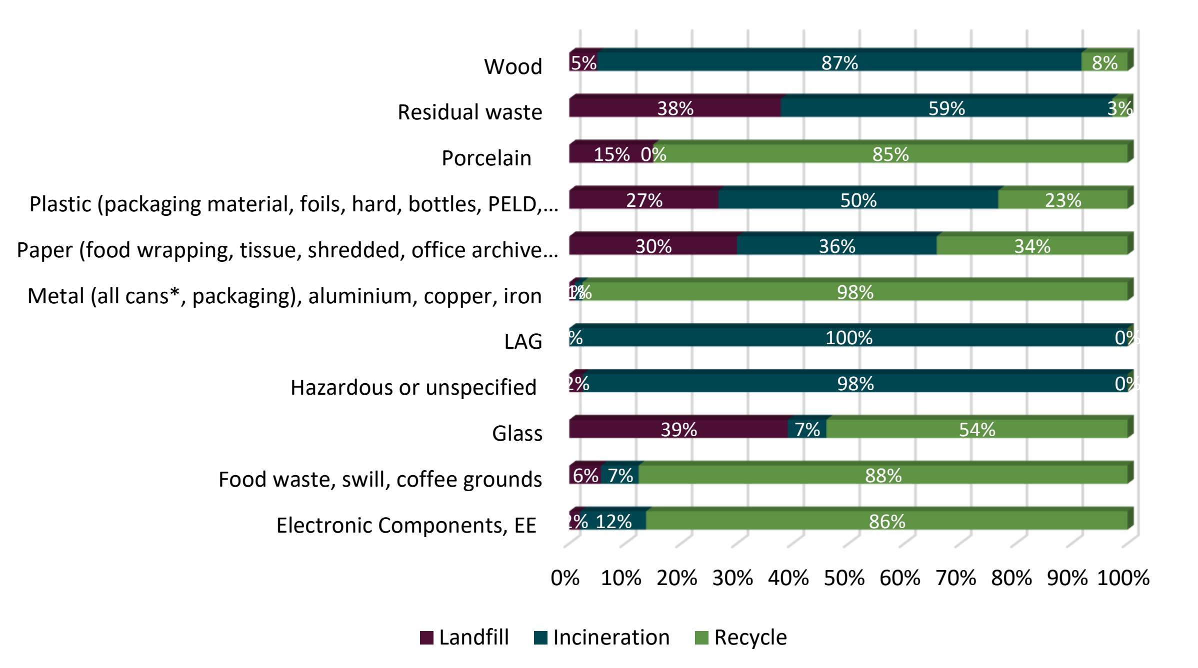

Figure 14: Average actual treatments for operational resource streams

As explained in Chapter 4.1.1 Identification of operational resource streams, some operational streams managed by the airport are not included in this overview but deemed relevant such as waste water and sewage sludge, International Catering Waste (CAT1) and aircraft cleaning waste.

A reference is made to a confidential appendix for the waste processing pathways per airport - Note: This annex is confidential and only accessible to participating airports, not included in the public report. This information is used to further detail KPIs to reduce operational resource streams by 20% in 2025, by comparing year 2019 and 2024 (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.2) and pilot nudging strategies (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.3).

The average costs associated with the treatments per operational resource streams are shown in Table 6. The costs of treating operational resources can vary widely depending on the type of waste, the method of treatment and required transportation costs (referring to limited local recycling options within Cyprus). Some forms of waste, such as hazardous waste, may require expensive and specialised treatment methods, such as incineration or chemical treatment, which can be costly. On the other hand, some forms of waste, such as recyclable metals, can generate revenue for the airport if sold to scrap metal dealers.

Table 6: Average treatment costs of operational resource streams

Operational resource streams	Average treatment costs (based on total costs per total waste volume per airport)*	
Electronic components, EE	€	(7,889.21)
Food waste, swill, coffee grounds	€	147,284.45
Glass	€	31,232.78
Hazardous or unspecified	€	80,270.41
LAG	€	1,700.00
Metal (all cans*, packaging), aluminum, copper, iron	€	(119,750.62)
Paper (food wrapping, tissue, shredded, office archive material), and cardboard	€	(87,699.23)
Plastic (packaging material, foils, hard, bottles, PELD, PET*),	€	31,047.65
Porcelain	€	1,518.69
Residual waste	€	896,940.91
Wood	€	56,606.03
Total	**€**	**1,031,261.85**

** The values enclosed within brackets denote refundable fractions, while the ones outside of the brackets represent the costs paid by the airport.*

3. Validate processing pathways

Results of validating the waste processing pathways with airports revealed several challenges:

1. There is uncertainty about 'potential' and 'actual' waste processing pathways. Note that the waste handlers often provide a positive perspective to airports on the treatment of resource streams, which are considered as 'potential' processing pathways. The 'actual' treatment is showing less positive numbers which was surprising to participating airports. It's acknowledged by participating airports that there is limited transparency after the waste leaves the airport premises, making it difficult to track the waste processing pathway. This can lead to uncertainty regarding whether the waste is being treated in an environmentally sustainable manner. This is one of the reasons why airports are now seeking new ways to collaborate with waste handlers that involve greater transparency and accountability for waste management beyond the airport premises.
2. The actual treatment of the waste differs due to various factors such as cost-effective measures, national regulation, and other partners involved in the waste management process. This can lead to inconsistencies in waste processing, which can be a challenge when trying to assess the impact of airport waste.

Overall, validating waste processing pathways revealed that there are opportunities to improve waste management practices at airports. The results suggest that greater transparency, accountability, and monitoring of waste streams are essential steps towards more sustainable airport waste management practices.

4. Perform impact assessment

Different waste processing methods result in different environmental impacts. In the case of incineration, the main environmental burden lies in the direct emissions to the air from burning waste, such as toxic chemicals and pollutants, as well as the energy required to run the incineration facility. When it comes to landfill, the negative impact on the environment comes from the release of greenhouse gases, such as carbon dioxide and methane, and the contamination of surrounding soil and water. Recycling is the most sustainable waste processing method in this assessment*, although it still involves energy for operating the recycling facility, resulting in indirect emissions.

** Even though these three treatments are most commonly known and used, there are other strategies that can be executed to avoid applying treatments in general. This lies into the actual prevention of waste and optimising the re-use potential (refer to Appendix D).*

The impact assessment is using the Ecoinvent v3.6 (Ecoinvent, 2021) database to assess operational resource streams per participating airport. Some assumptions were made because the Ecoinvent database does not contain references for every single waste process. When an assumption had to be made, the worst-case reference was used to not underestimate the total environmental impact.

Note: The environmental impact assessments are performed and delivered in Excel format to participating airports and not made public.

5. Analyse and interpret results

Observing resource streams by weight alone can overlook the potential harm caused to the environment. Hence, the executed impact assessments provide great insights into criteria relevant other than weight (refer to Appendix F). However, due to the fact that impact categories have different units, such as water use (m3 deprived) and climate change (kg CO2 eq), comparing the results can be difficult. To address this issue, an eco-cost calculation is performed, which measures the environmental burden of an operational resource stream based on the cost of preventing that burden. This calculation represents the cost required to reduce environmental pollution and material depletion to a level in line with the carrying capacity of the earth. Eco-cost allows for the comparison of all waste streams, taking into account various environmental impacts such as climate change, human toxicity, ecotoxicity, and resource scarcity. Based on the performed impact assessment including eco cost calculation and various discussions with airports the top 3 most impactful waste streams per airport are summarised in Table 7.

Table 7: Top 3 impactful operational resource streams per airport

Avinor Oslo Airport	Schiphol Amsterdam Airport	Hermes Larnaca Airport
Residual	Residual	Residual
Food waste	Plastic	Plastic
Plastic	Food waste	Paper

6. Monitor and improve

In the coming period, the results of the impact assessment are to be reviewed in much more detail, to pinpoint areas where improvements can be made and opportunities for implementing circular economy principles can be explored. To track the impact of these initiatives, a monitoring framework is being developed under TULIPS WP6. This framework will incorporate smart KPIs and strategies (aimed at achieving those KPIs). The framework is designed for release in June 2023, followed by a demonstration report showcasing the piloting of these KPIs and strategies at participating airports in December 2023. Refer to TULIPS WP6 deliverable 6.2.

7 Airport Value Chain and stakeholders

This chapter dives into the importance of collaboration within the entire airport value chain. The focus will be on analysing the stakeholders who have an impact on operational material streams at airports and current experiences in teaming up with stakeholders to co-create innovative solutions and achieve circular economy ambitions.

"We can't solve problems by using the same kind of thinking we use when we created them"

- Albert Einstein

7.1 Moving to a circular economy with airport value chain

The aviation industry is made up of various sectors that are interdependent and therefore collaboration and cooperation are essential for the success of the industry as a whole. This can lead to enhanced performance across the value chain, which in turn can generate a return to investors beyond the minimum based on their risk profile. McKinsey and IATA (International Air Transport Association, 2021) have jointly analysed the aviation value chain since 2005 to understand what drives performance and to enhance value creation and efficiency across the entire chain. Recognised benefits of collaborating between value chain actors includes improving service and reliability to attract customers, sharing data and insights across the value chain, removing inefficiencies, working together on decarbonization, meeting ever-changing demand and customer requirements, and enhancing resilience and robustness.

7.2 Identification of stakeholders in operational material streams

In order to achieve the objectives of reducing operational resource streams (refer to chapter 2.2. TULIPS Circular Airports), participating airports recognize the significance of stakeholders in this process. It's not the passenger solely that generates waste, it flows from all touch points in and around the airport, including shops, restaurants. Hence, in order to effectively achieve the objectives, airports must take into account their stakeholders. In this context, stakeholders are defined as individuals, groups, or organisations that are impacted by, or have an impact on, the activities of the airport. They can be classified as internal, such as employees and management, or external, including suppliers, customers, government entities, and non-governmental organisations (You, L., Du, J., Zhang, L., & Yan, X. 2022). For the purpose of TULIPS WP6, the stakeholder identification process is narrowed down to those directly influencing the airport's operational resource streams, which are referred to as 'key stakeholders' in the following report sections. This stakeholder identification process is illustrated in Figure 15.

Figure 15: Airport's key stakeholders influencing the operational resource streams

The key stakeholder influence airport's operational resource streams by means of the following:

- Food & Beverage partners: These partners include restaurants, cafes, and other food vendors operating within the airport. They contribute to the waste stream through food packaging, leftover food, and other disposables.
- Retail partners: Retail partners include shops and stores within the airport, which generate waste through packaging, shopping bags, and other disposable items.
- Facilities partners: Facilities partners include those responsible for maintaining the cleanliness of the airport, including waste management. They contribute to the waste stream through cleaning products, disposable items such as paper towels, and other materials used in their operations.
- Airport employees: Airport employees, including security personnel, maintenance staff, and administrative personnel, generate waste through their daily operations.
- Airline operators: Airline operators generate waste through in-flight services, such as food and beverage service, handing out products to passengers during flights (e.g. headphones or blankets), as well as through ground operations, such as baggage handling.
- Passengers: Passengers play a critical role in achieving the objectives of TULIPS WP6, as they are the primary users and a significant presence at airports. To effectively reduce operational resource streams, it is important for airports to understand the "passenger journey" and how it impacts waste management. Passengers have a direct influence on streams related to paper, plastic, residual waste, and Liquids, Aerosols, and Gels (LAG) as they can easily dispose of these items in dedicated bins. However, their influence on other streams such as food waste is indirect.

Detailed stakeholder mapping per airport took place to understand if and how each stakeholder is contributing to the operational resource streams (refer to Chapter 4.1.1 Identification of operational resource streams). A reference is made to a confidential Appendix. Note: This annex is confidential and only accessible to participating airports, not included in the public report. This information is used to further detail KPIs to reduce operational resource streams by 20% in 2025, comparing year 2019 and 2024 (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.2) and pilot nudging strategies (expected to deliver December 2023, refer to TULIPS WP6 deliverable 6.3).

7.3 Collaborating with stakeholders

Circular solutions with a high circularity impact are usually embedded in a complex network of stakeholders (Eisenreich, S., & Fuller, D. A., 2023), hence collaboration with key stakeholders is considered a key priority in reaching the TULIPS WP6 objectives set. Extensive collaboration with stakeholders is currently piloted at Schiphol Amsterdam airport, Lighthouse of TULIPS. A summary of the activities performed are described below.

- Identification of specific stakeholders influencing the operational resource streams: During the stakeholder identification process, the most important stakeholders were selected. This process resulted in selecting two Food & Beverage partners, the Schiphol commercial department (to dive into retailers), three facilities partners, various conversations with airport employees and airline operators and passenger insights department.
- Periodical meeting structure: With all individual partners/departments, periodical meetings (at least quarterly) were set-up with TULIPS WP6 work package lead (EME), TUD partner and Schiphol liaison. These meetings were executed in the period September 2022 up to April 2023 and expected to continue over the course of TULIPS timeline. The meetings are scheduled for approximately one hour, with the exception of site visits in the terminal.
- Topics to align and collaborate on: The various topics deemed relevant to discuss with the identified partners in achieving a circular economy and airport's sustainable ambitions are visualised in Figure 16 and described below.

Figure 16: Summary of initiatives with Schiphol's key stakeholders to reduce waste

Note that the initiatives 1, 2 and 3 were pursued by the TULIPS WP6 team (EME, TUD and Schiphol Liaison) with key stakeholders as identified by Schiphol. Initiatives 4 to 8 are ongoing and will be included in other deliverables provided under the TULIPS WP6 flag. Overall, the initiatives mentioned are also started with key stakeholders as identified by Avinor Oslo Airport and Hermes.

1. Increasing awareness and knowledge: During the initial meetings with key stakeholders, it became apparent that there was a variation in the level of expertise on circular economy

topics. In order to facilitate effective communication and collaboration among all parties, the TULIPS WP6 team provided knowledge and insights on circular economy topics to bridge any gaps in understanding and ensure a shared understanding.

2. Conducting research and assessments: As observed during the executed meetings, the key stakeholders acknowledged that they are part of a wide value chain. For some parts, they had information and control while for other parts not. Various insights were provided during periodical meetings or site visits. Examples are provided in Table 8.

Table 8: Examples of insights per key stakeholder

Key Stakeholders	Examples (note: these are examples and not an exhaustive overview)
Food & Beverage	Insights around the coffee cup challenge, deposit systems of PET, limited operating space, procurement options, incentives for passengers, etc.
Retail	Insights around reducing (plastic) packaging materials, external warehouses used by retailers, current initiatives performed to increase sustainable behaviour, etc.
Facilities	Insights around sensors in bins and optimal routes, changing to alternative cleaning products (or reusable packaging materials), alternatives for paper tissues, switching to recycled bin bags, etc.
Airport employees	Insights around current behaviour and initiatives set-up within Schiphol premises, etc.
Airline operators	Insights around current practices, various waste management strategies of employers (for instance airlines), etc.
Passengers	Insights around the passenger journey, changing demands, etc.

All key stakeholders were interested in the research and assessments taking place within TULIPS - such as the Waste Safari (refer to Chapter 5), research into behaviour by TUD, executing impact assessment (refer to Chapter 6) and ongoing assessments of best practices within participating airports and other airports.

3. Aligning circular objectives: When the first 2 initiatives were performed, the conversations continued to focus on circular objectives and metrics to achieve those. Alignment of circular objectives was a key focus of the TULIPS project, as Schiphol's ambition of zero waste could not be achieved without collaboration with key stakeholders. Through discussions, it was discovered that all key stakeholders shared a similar objective towards zero waste or circular economy, providing a foundation for effective collaboration and a common goal towards the transition to a circular economy.
4. Providing incentives: – *ongoing, not yet completed* – This includes brainstorming on how to encourage stakeholders to reduce operational resource streams, such as discounts or rewards for returning used products or materials.
5. Monitoring progress: – *ongoing, not yet completed* - This includes teaming up in achieving Key Performance Indicators (KPIs) currently developed under TULIPS WP6 flag (expected to deliver December 2023, refer to *TULIPS WP6 deliverable 6.2*) and track progress towards circularity.
6. Teaming up in pilots to improve: – *ongoing, not yet completed* - This includes the involvement of stakeholders in the design and implementation of circular initiatives to ensure that their needs and perspectives are taken into account. Pilots can be executed to test new circular initiatives and identify areas for improvement.
7. Sharing data and experiences: – *ongoing, not yet completed* - This includes sharing data and experiences to learn from each other and monitor progress towards circularity.

8. Facilitating communication: – *ongoing, not yet completed* – This includes the creation of platforms and channels for stakeholders to communicate with each other and with the airport organisation, to facilitate dialogue and collaboration.

By undertaking the eight defined steps, it's acknowledged by the participating airports that they can build stronger relationships with their stakeholders, and create a more inclusive and effective transition to a circular economy.

8 Ranking operational resource streams baseline 2019

Based on the extensive research performed, which includes the Waste Safari (Chapter 5), the execution of an environmental impact assessment (Chapter 6) and periodical conversations with key stakeholders (Chapter 7), a deep understanding of the 2019 baseline situation of participating airports is developed. By ranking the operational resource streams, the most pressing issues were identified and prioritised for action and allowed the airports to focus on specific sub-streams (within the operational resource streams). Which are directly feeding into the design of a monitoring framework currently developed under the TULIPS WP6 flag, ensuring that efforts are both effective and sustainable.

8.1 Ranking operational resource streams

The priority streams are ranked in the list below, resulting from the extensive research performed at participating airports. For each stream, the most important elements from the Waste Safari (Chapter 5), the environmental impact assessment (Chapter 6 and Appendix F) and stakeholder insights are provided.

1. Residuals - Residuals are prioritised mainly due to their large volume at airports. Due to the contamination of all the bin bags as observed during the Waste Safari, an assumption is made that relatively large chunks still end up in the residual stream. Residuals significantly contribute to climate change (CO2 and other greenhouse gas emissions) and resource scarcity. Acknowledged by key stakeholders, preventing and reducing the total residual stream should be a priority. Airports can encourage better waste separation at the airport and invest in post-separation methods after it leaves the airport premises for treatment.
2. Food/swill big volume - Food waste is a global problem that contributes to hunger and food insecurity. By reducing food waste, airports can demonstrate social responsibility and contribute to global efforts to address food waste and hunger. While tenants can, passengers cannot separate food waste at the airports, and this ends up in the other bin bags on site (plastic, paper, or residuals). Hence post-separation is vital for this stream as food and swill waste comes in large volumes, and reducing this stream is vital to limit the impact on ecotoxicity and resource scarcity. To achieve this, airports experiment with technologies to predict consumption patterns better and, for instance, collaborate with food and beverage outlets to separate waste for other products in the kitchens.
3. Plastic (and PMD or PET/cans) – Similar to residuals, food, and paper, plastics are found in most of the airport bins and contaminate the bags drastically, as observed during the Waste Safari. Plastic waste is a major contributor to ocean pollution and harms wildlife and has a significant impact on climate change as it takes hundreds of years to decompose, releasing harmful chemicals into the environment over time. Reducing plastic waste requires working with airport key stakeholders (such as retailers and F&B partners) to reduce single-use plastics via, for instance, circular procurement requirements and encouraging better waste separation for passengers (for instance, separate PET/cans collection if not already present).
4. Paper/cardboard - Similar to residuals, food, and plastics, paper is found in most of the airport bins and contaminates the bags drastically, as observed during the Waste Safari. It seems different for passengers to separate their coffee cups, assuming it’s paper and potentially not knowing that it’s also plastic. Also, for instance, used napkins or other products arise. Clean cardboard is coming mainly from key stakeholders F&B and retailers. Paper and cardboard waste contribute to deforestation and greenhouse gas emissions.

Other important streams, not included in the environmental impact assessment are:

1. International Catering Waste – This stream is regulated by EU law (Regulation 1069/2009) and hence needs to be incinerated within 24 hours. From an airport's perspective, its influence on International Catering Waste (ICW) may be limited as it depends on a variety of factors such as airline practices and their respective agreements with waste handlers. ICW significantly contributes to impact criteria such as acidification, eutrophication, and ecotoxicity. To address this issue, a collaboration between airlines, catering companies, airports, and legislative bodies is required. Although the adoption of individual actions will yield tangible business and environmental benefits, a structured coordinated approach will have a synergistic effect and result in long term change. Airports can play a key role in facilitating this collaboration and, for instance, explore how the (local interpretation of) legislation can find room for recycling (instead of incineration), and potentially producing biokerosene from ICW waste.
2. Aircraft cleaning waste – Similar to the ICW, the airport's influence on aircraft cleaning waste may be limited. However, IATA highlights that in the absence of smarter regulation, cabin waste volumes could double in the next 10 years(IATA, 2019). To address this issue, a collaboration between airlines, catering companies, airports is required. Although the adoption of individual actions will yield tangible business and environmental benefits, a structured coordinated approach will have a synergistic effect and result in long term change. Airports can play a key role in preventing such waste to exist or ensuring the best treatment for operational resource streams arising from aircraft cleaning waste.
3. Waste water and sewage sludge – Water is an essential resource for life, but unfortunately, almost all water on Earth is not readily available for human consumption (National Geographic Society. (n.d.). Additionally, the distribution of usable water is not equal globally, and water scarcity in some areas can lead to social unrest and conflict. Climate change and pollution further exacerbate the issue by affecting water quality and availability, emphasising the importance of conservation and proper management of this precious resource. Given the limited availability of water, it is critical for airports to reduce water usage and ensure proper treatment of wastewater in order to meet the current and future needs of humans, ecosystems, and the planet.

8.2 Next steps in reducing operational resource streams

Now that resource streams are prioritised per airport, the next steps in reducing these streams (i.e. the core objective of TULIPS for operational streams) involves selecting sub-streams to focus on, such as PET in plastic bins, orange peels in food streams, and phones in electronic streams. These efforts will be tracked through a monitoring system that is currently being developed. The system will measure the effectiveness of interventions executed under TULIPS WP6 and allow for necessary adjustments. Development and testing of the monitoring system will take place throughout 2023, with a summary report of testing presented in December 2023 as "Deliverable 6.2 Circularity performance management system".

The TULIPS WP6 partners are engaging in ongoing knowledge exchange sessions to interpret the baseline report results and develop solutions for reducing operational resource streams. So far, airports have identified several potential opportunities for reducing these streams, for example*:

- Prevent (linked with R0-R2 strategies – Appendix D)
    - Setting stricter procurement requirements for tenants: Ongoing conversations with F&B partners and retailers show that similar objectives around zero waste and circularity already exist. This provides room to explore how tenants' respective

offerings at airports can be adjusted, such as predicting food consumption with technologies or offering food with less or circular packaging, etc.
    - Bins, bags, and sensors: Various airports try out different techniques to cope with the observation that bins are often cleaned without being full, resulting in excess plastic bags ending up in the waste stream. Cleaning companies are trying out sensors in bins and are optimising their routes through the airports and the selection of bin bags. In addition, decisions are made in moving from virgin plastic bin bags to non-virgin bin bags or biodegradable bin bags.
    - Passenger communications: Airports are increasingly putting effort in informing passengers about the airport's facilities, such as water bottle fill stations. For instance at Schiphol Amsterdam Airport, there is no more need for plastic bags for LAG during security in Departures 1 since their switch to CT scanners instead of x-ray scanners.
- Ensure reuse (linked with R3-R7 strategies – Appendix D)
    - Reusing products: From furniture, electronics, and textiles, many functioning materials end up in waste collection locations at airports. Various initiatives are explored to avoid such articles from going to waste, such as donating them to charity or second-hand shops.
    - Using waste as a resource: Successful examples of using orange peels for soap or repurposing textiles and furniture are used to inspire action for other sub-streams within the operational resource streams. For instance, within the Food stream, discussions take place to examine using food fractions for biochar (linked to TULIPS WP7) and other innovative pilot projects.
- Increase recycling (linked with R8 strategy – Appendix D)
    - Separate PET collection: If not already present at airports, discussions are being held to ensure that PET bottles are collected separately, to determine the applicability of deposit systems, and to ensure that PET bottles are emptied prior to transportation for treatment.
- Avoid incineration (linked with R9 strategy – Appendix D)
    - ICW: Currently, ICW (referred to as CAT1) must be incinerated within 24 hours due to EU legislation 1069/2009 (European Union, 2009). Currently, discussions are underway to interpret this legislation locally and explore alternative treatments such as recycling (for biogas or biokerosene).
- Overarching initiatives
    - Increase transparency: Airports are collaborating with (new) waste management handlers to increase transparency after streams are leaving the airport premises. This includes using technologies to tag bin bags and track their movements to determine reuse or treatments.
    - Reporting: Conversations are ongoing to increase the importance of the impact of treating operational resource streams within ACA reporting standards.
    - Explore similar complex systems: Conversations are also underway with partners in other complex systems environments, such as the NS Dutch railroad and municipalities in the surrounding areas, to increase understanding of successful nudging strategies. These conversations are made possible by the TULIPS External Advisory Board.

** This list includes examples and is not a complete overview. The complete overview will be part of the deliverable D6.3 Demo report for pilots in the terminal.*

The examples mentioned, as well as future knowledge exchange sessions, will lead to an overview of important sub-streams per airport. Interventions and nudging strategies will be co-created with

TUD and piloted at participating airports to determine their effectiveness. Key stakeholders, such as F&B partners and waste management companies, will collaborate to execute pilots and share data to gain insights into waste management practices. The next deliverable, D6.3 Demo report for pilot in terminal, will include the design and testing of these nudging strategies in 2023 and 2024, with a summary report of the pilots delivered in December 2024.

In summary, this report serves as the basis for other TULIPS WP6 deliverables. These deliverables include the development of a monitoring system, which will be outlined in "Deliverable 6.2 Circularity performance management system" to be delivered in December 2023, as well as the design and testing of nudging strategies. The nudging strategies will be developed and tested from 2023 to 2024, with a summary report of the pilots delivered in December 2024 as "Deliverable 6.3 Demo report for pilot in terminal."

The TULIPS project has generated a great momentum towards achieving a circular economy in the airport industry. With the collaborative efforts of all partners, including those involved in WP6, small steps are being taken towards the larger systemic change of sustainable airport operations.

"It is great to see that our work is showing that a shift towards circular economy principles at airports has the potential to significantly reduce Scope 3 CO2 emissions by optimising resource use, minimising waste, and enabling a more sustainable and efficient operation."."

Christian van Maaren – Excess Materials Exchange

As the TULIPS project progresses, the WP6 partners are excited to bring their contributions further and work towards achieving the project's objectives. By implementing sustainable practices and promoting circularity, the airport industry can reduce its environmental impact and contribute to a more sustainable future. With the support and collaboration of all partners, the TULIPS project is poised to continue driving positive change towards a circular economy in the airport industry.

9 Conclusion

By considering waste as a resource, airports can create new economic opportunities and reduce the demand for virgin materials. Waste management processes at airports are designed to promote sustainability and decrease the environmental impact of airport operations. However, uncertainties still exist regarding the fate of materials once they leave the airport premises and are transported to treatment facilities. These uncertainties include potential resource loss during processing, environmental contamination, and the fate of residuals that cannot be recycled. Therefore, the core focus of TULIPS WP6 is to prevent the generation of such resource streams in the first place.

Within the TULIPS consortium, the objective of this deliverable of WP6 Circular Airports is to reduce passenger operational resource streams by 20% in 2025 (comparing year 2019 and 2024). Reduction initiatives are focusing on prevention (R0-R2 strategies), extending the lifespan (R3-R7) and increasing high-quality recycling (R8). This the foundation used in following TULIPS deliverables, namely monitoring framework D6.2 (delivered December 2023) and piloting nudging strategies D6.3 (delivered December 2024). This report provides an introduction to the circular economy approach to waste management and a baseline assessment for the year 2019 at three participating airports: Schiphol Amsterdam, Avinor Oslo, and Hermes Larnaca.

Since the start of TULIPS in January 2022, all WP6 partners have been expanding their understanding of the circular ambitions and initiatives of the participating airports. The activities carried out have highlighted the importance of identifying and managing operational resource streams at airports, as well as the need to collaborate with key stakeholders in the airport value chain to move towards a circular economy. The executed Waste Safaris has proven to be a useful tool in understanding how passengers or tenants handle their waste. In addition, the environmental impact assessment demonstrated that factors beyond volume, such as impact categories related to climate change, resource use, and toxicity, also play a role in prioritising and ranking operational resource streams.

Due to confidentiality reasons, the 2019 baseline results in this report have been averaged, resulting in less detailed information. Nonetheless, the report reveals that waste produced per passenger averages at 218 grams, with residuals, food waste, and paper being the biggest waste streams by volume. The operational resource streams have been ranked based on the results of the impact assessment, stakeholder sessions, Waste Safaris, and airport conversations, with the top three being Residuals, Food Waste, and Plastic. Please note that while the detailed information per airport available for the baseline assessment, such as impact assessments for all individual operational streams, detailed stakeholder mapping, and full Waste Safari reports, is not made public, all participating airports have access to this information. Going forward, each airport will aim to achieve the set objectives of reducing operational resource streams by 20% by 2025 (comparing year 2019 and 2024), building upon the insights gained in these personal reports/insights and ongoing knowledge exchange sessions between the participating airports.

A few limitations are highlighted: The report only takes into consideration the operational resource streams that were mentioned by at least two out of three participating airports. This means that other large or impactful resource streams, such as waste water/sewage sludge, CAT1 waste, and aircraft cleaning waste, were not included in the public report. They are taking into consideration the next steps by responsible airports. Next, due to confidentiality reasons, the report cannot include airport-specific information. This has resulted in the averaging of results, which may not accurately reflect the real impact of waste management practices at each airport. In addition, the detailed information created for the baseline assessment, such as impact assessments for all individual airport's operational streams, stakeholder mapping, and full Waste Safari reports, are not made public. Last but not least, the circular economy is a field that is continuously evolving, with new innovations and best practices emerging all the time. As such, the findings and next steps of this report may become outdated as the circular economy evolves. Therefore, it is important to continually monitor and update waste management practices at airports to stay current with the latest developments in the field.

The report concludes by outlining the next steps for reducing operational resource streams at airports. This will enable scaling of circular solutions and development of a roadmap for airports to implement circular economy solutions and achieve their sustainability goals. These steps include co-creating interventions and nudging strategies, developing monitoring systems to track progress, and continuing to collaborate with key stakeholders. The output of these steps will be covered in future deliverables published under the TULIPS WP6 flag. Overall, this report provides valuable insights into the circular economy approach to waste management at airports and serves as a useful guide for future efforts in this area.

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Appendix B: FACTORS THAT DRIVE THE CIRCULAR ECONOMY TRANSITION FOR AIRPORTS

Regulatory requirements - Airports are subject to various regulatory requirements may impact their transition towards a circular economy. An example is the EU Circular Economy Action Plan and Waste Framework Directive which set guidelines for waste management and reduction. Other examples include Extended Producer Responsibility (EPR), emissions reduction targets (carbon taxation, Emissions Trading System) and Sustainable procurement practices and Environmental, Social, and Governance (ESG) performance requirements. Compliance with these regulations is critical for airports to operate sustainably and make a positive impact on the environment.

License to grow - The transition towards a circular economy in airports is driven by the expectations and demands of various stakeholders. Airports need to engage with their stakeholders to understand their expectations and incorporate these into their circular economy strategies. "License to grow" offers an approach to take the demands of passengers, employees, airlines, regulatory bodies, suppliers, contractors, and the local community into account. In practice, there may be tensions and conflicts between the concept of a license to grow and regulatory restrictions to grow. For example, an airport may be granted a license to expand its operations, but it may face opposition from local residents or environmental groups who are concerned about the impact on noise levels or air quality.

Airports' strategic sustainable ambitions - Airports' strategic sustainable ambitions aim to minimize their environmental impact, reduce waste, and promote a circular economy. Airports that successfully implement these sustainable ambitions can create a competitive advantage by differentiating themselves from other airports and meeting the expectations of passengers, airlines, and regulatory bodies. In turn, this can lead to improved financial performance (for example by cost savings, reputation, compliance with regulators and attracting investments) and a more positive reputation in the aviation industry.

Resource scarcity - With the global population increasing, the demand for resources such as water, energy, and raw materials is also rising. This creates a challenge for airports to manage their resources effectively and efficiently. By transitioning towards a circular economy, airports can reduce their reliance on finite resources, and instead focus on the sustainable use of renewable and recycled resources. This not only benefits the environment, but can also lead to cost savings and a competitive advantage for airports that are able to manage their resources effectively.

Environmental concerns - Environmental concerns have become increasingly important for airports as they try to transition towards a circular economy. Reasons include the awareness of airport's greenhouse gas emissions, stricter environmental regulations and the increased awareness of stakeholders (such as the passengers) These concerns include greenhouse gas (GHG) emissions, noise pollution, water pollution, and energy consumption.

Technological opportunities - Technological advancements are creating new business opportunities for airports and helping them to reduce waste. Examples include smart bins equipped with sensors and internet of things (IoT) technology that can optimize waste collection and provide real-time data on waste generation patterns. Circular design technologies such as 3D printing and digital material passports can promote the reuse and recycling of materials. Predictive algorithms powered by artificial intelligence (AI) can help prevent waste by forecasting maintenance needs and improving operational efficiency. These technological opportunities offer potential approaches to make implementation of circular solutions in the airport environment feasible.

Appendix C: WP6 INVOLVED AIRPORTS AND PARTNERS

About Avinor

Avinor is a 100% state owned limited company under the Norwegian Ministry of Transport and Communications and is responsible for 43 airports. Avinor has taken a leading role in reducing greenhouse gas emissions from the aviation industry, including the development of electric aircraft and supplying sustainable aviation fuel (SAF). Avinor provides safe and efficient travels for around 50 million passengers annually, half of which travel to and from Oslo Airport. Avinor is financed via airport charges and commercial sales. The air navigation services are organised as subsidiary completely owned by Avinor. Avinor's headquarter is in Oslo.

About Excess Materials Exchange (EME)

Excess Materials Exchange is a software as a service (SaaS) platform that functions as a “dating site" for secondary materials and waste. With that, the platform unlocks the maximum potential of the world’s excess materials and products by matching them to their highest value uses. EMEs approach is to provide an identity to materials and (waste) products, add intelligence to them by using Collective Intelligence and use an integral approach by identifying high-value reuse opportunities across sectors.

The vision of EME is to create a world without waste by reinstating waste or the valuable resource that it is. Their mission is to fundamentally change the waste game - by introducing innovative ways of doing business that become the industry standard on how to deal with excess materials. That way, they will speed-up the world’s transition to a circular economy and create a clean planet for everyone.

EME is contributing to the Project by demonstrating the use of their platform in the airport environment, mapping waste streams and excess building materials/components through their resources passports approach, quantifying the environmental impact of materials flowing through the airports part of this consortium and demonstrating how tracking and trace technologies can be applied in an airport environment.

About Hermes Airports Ltd

Hermes Airports, a Cyprus registered company comprises an international consortium of 9 shareholders, representing a mix of Cypriot and international partners. Hermes Airports operates the two international airports of Cyprus in Larnaka and Pafos, since 12th May 2006 under a BOT agreement with the Government of Cyprus. The fellow airport Larnaka is located on the south east coast of the island and it is built on a total area of 603 hectares. Since January 2010, the airport has served more than 69 million passengers reaching a record high of 8m total passengers in 2019 and has an annual contribution of around 3% on the island’s GDP. Hermes airports is serving the needs of a primarily leisure destination and as such is committed to improve the island’s connectivity to maintain high levels of passenger experience and to support the creation of touristic demand for Cyprus.

About Royal Schiphol Group

Connecting your world embodies the 'Why' of Royal Schiphol Group. Amsterdam Airport Schiphol is one of the world’s best-connected airports, offering direct links to 296 international destinations. This reach is expanded by our regional airports. In a world where demand for connectivity continues to grow, we want to ensure air travel develops responsibly by balancing the needs of air passengers and cargo with those of society at large. Our ambition is to operate the world's most #sustainable, high-quality airports. We want our airports to be zero-emission and zero-waste by 2030 on route to becoming energy-positive and circular in the long run. We're taking steps, being already CO2-

neutral when it comes to our own activities since 2012. All the while, we will continue to play a leadership role in making the aviation sector more sustainable to achieve net-zero emission aviation by 2050. To achieve this, collaboration is key. That's why we're proud to lead the TULIPS consortium.

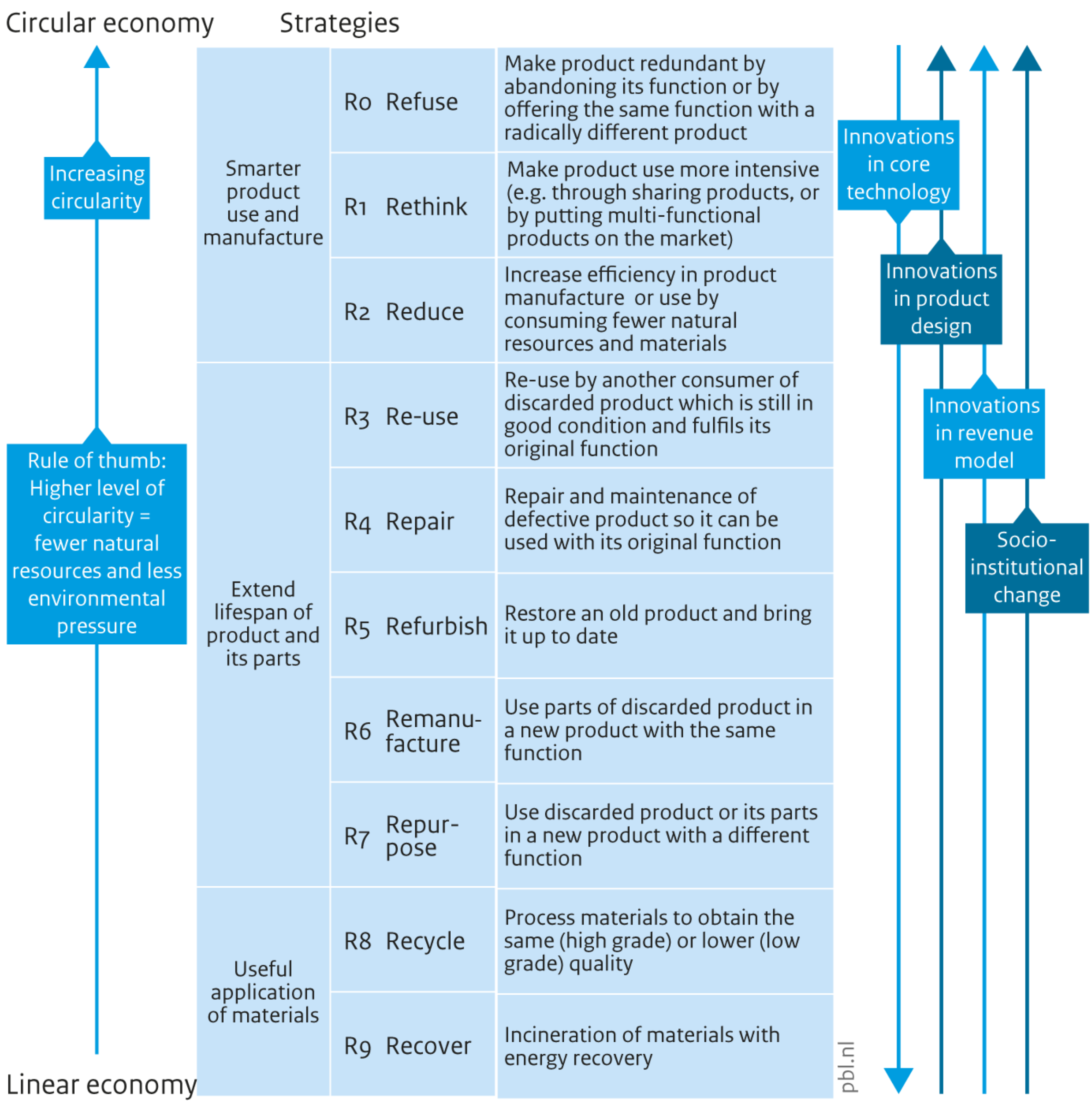
About TUD

Delft University of Technology, founded in 1842, is one of the world's top Universities of Technology with excellent international rankings. The University has 25.000 students, 5.000 staff members and 8 Faculties: Mechanical, Maritime and Materials Engineering; Architecture and the Built Environment; Civil Engineering and Geosciences; Electrical Engineering, Mathematics and Computer Science; Industrial Design Engineering; Aerospace Engineering; Technology, Policy and Management; Applied Sciences. TU Delft offers 16 Bachelor's programs and 35 English taught Master's programs in science, engineering and design, but you can also work on your doctorate there. Delft University of Technology is the oldest and largest Dutch public technical university. TU Delft works together with many other educational and research institutions at home and abroad. The main tasks include providing scientific education, conducting scientific research, transferring knowledge to society and promoting social responsibility. The university has been designated as a 'public benefit institution'. Besides, TU Delft offers one of the largest university campuses in the world, stretching over 161 hectares, with a library, an aula and a cultural and sports centre. Additionally, three museums are associated with the university and they operate a botanical garden.

Appendix D: R STRATEGIES

An important question is how to measure the progress of the transition towards a circular economy (CE transition). Together PBL and Utrecht University (PBL, 2016) a framework is developed that dives into the role of innovation in CE-transitions in product chains. The model provides a framework to analyse and design circular economy strategies for businesses, organisations, and governments.

Circularity strategies within the production chain, in order of priority



Source: RLI 2015; edited by PBL www.pbl.nl

The 9R model consists of nine steps, each representing a key aspect of the circular economy, as follows:

1. Rethink: This step encourages stakeholders to rethink their approach to resource use and consider circular alternatives.
2. Refuse: This step focuses on reducing the use of virgin resources and encouraging the refusal of single-use products.
3. Reduce: This step focuses on reducing the use of materials and resources throughout the value chain.
4. Reuse: This step encourages the reuse of products and components, either through repair or refurbishment.
5. Repair: This step focuses on extending the life of products through repair and maintenance.
6. Refurbish: This step involves bringing used products back to a near-original condition.
7. Remanufacture: This step involves disassembling used products and using the components to create new products.
8. Recycle: This step involves processing used products to recover valuable materials and turn them into new products.
9. Recover: This step involves recovering energy from waste that cannot be recycled.

Appendix E: WASTE SAFARI TEST PROTOCOL

TULIPS

Test protocol Waste Safari

Are you ready to spot the big five on your airport Waste Safari?

What is a Waste Safari?
A waste safari, also known as a waste audit, is a process of systematically evaluating and analysing the waste generated within the airport. It involves collecting, sorting, and measuring the different types of waste produced, as well as identifying the sources and causes of waste.

Why perform a waste safari?
- ✓ Gaining insights into the airports' waste streams,
- ✓ Identifying areas where waste reduction or diversion efforts can be implemented, potentially leading to cost savings and environmental benefits.
- ✓ Raising awareness about the impact of waste on the environment and promote sustainable practices among airport employees, stakeholders, and passengers.

What is important prior starting a Waste Safari?
Aligning with key stakeholders such as waste management partner and cleaning companies

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Equipment needed for a Waste Safari

The equipment needed to prepare the Waste Safari includes:

- Approx 10 tables
- Big buckets for pre-sorted waste (such as 12x50 Liter)
- Small buckets for sorted waste (such as 40x20 Liter)
- Large container for analyzed waste
- Labels for buckets (A4/A5 paper, marker, and tape)
- Personal protection gear (such as long gloves and masks)
- Cleaning materials (such as towels, cloths, all-purpose cleaner, hand soap, paper towels)
- Protective tablecloths
- Scales
- Large and small tongs
- If possible, a material scanner
- Laptop(s)
- Photo camera

The equipment needed to collect and transport the samples includes:

- A warehouse trolley
- Pre-printed information signs to notify the collector crew of the sample bin and ongoing work,
- Tape to fix information signs
- Protective gloves
- Blank etiquettes and a pen for marking the location and collection time of the sample bags.

The equipment needed to analyze the samples include:

- Long tables were used (1 for measuring and registering items, 1 for paper fractions, 1 for plastics, and 1 for others)
- Standard-sized (24.5 x 28 x 34 cm) corrugated waste boxes for each fraction of waste
- Bin liners (plastic bags) to protect the boxes
- Labels for boxes (stickers)
- A scale with 3 decimal precision and a flat surface sufficient to place corrugated trash boxes
- A laptop, camera, and chargers,
- A bucket for collecting liquids,
- HSE tools (gloves, masks, protective clothes)
- Cleaning materials (antibacterial surface disinfectant, paper towels)
- Good shoes (preferably cushioned shoe) due to the long hours of standing,
- Good mood and sense of observation

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Sample selection requirements

Samples' locations of bin bags were selected based on various criteria, including the activities near the collection bins, observation time within a 24-hour interval, the nearest gate and flight destinations, the number of passengers at the nearby gate, and the season. Additionally, locations close to restaurants or retailers were given priority. These criteria were used to ensure that the sample size would be representative and could be generalized.

Picking up bins

The waste handler, in collaboration with cleaning facilities, was responsible for collecting and labelling the bags, and indicating the time of collection and location (e.g. gall number) on a template.

Waste Safari <airportname>				
Location				
Date				
Time				
Waste stream	<general>	<paper>	<plastic>	Waste handler logo
KG				

To avoid empty or nearly empty bags, pre-printed signs could be placed inside the bins describing the Waste Safari process and notifying the collector crew not to empty or take away marked bags.

Bag opning - pre-sorting

- All collected bags are weighed and recorded.
- Bags are opened
- Materials from the bags are sorted into labeled big buckets based on their general material types, such as plastics, paper, metals, organics, chemicals, and others
- The location and time of the bag are labeled on the big buckets.
- The big buckets are moved to sorting tables.
- Pre-sorting is performed on the materials.

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Sorting and weighting

Large buckets are further sorted into more specific items. For example, metals are separated into small buckets based on the type of metal such as ferro or non-ferrous metals. For the bucket with 'other' materials or unknown materials, a rough determination by sight takes place (and if available, a detailed material determination can take place with a scanner)

The buckets are labeled again with the specific information such as "Metals, non-ferrous, Hall 2, 3 pm". Sorting is then carried out. After bags are entirely sorted, the boxes are put on a scale and the weight (in grams) is registered in the Excel sheet. For weighing, the process involves putting a fully sorted bucket on a scale and registering the weight in grams on the Excel sheet. Photos and notes were taken on findings that were considered as significant. Each photo is documented with a number matching the documented data in the Excel sheet. Note that photos should be documented with the time, location, and material of the bucket's content in the title.

	Commercial area												
Material/product	Waste bag — Hall 2 — 3 PM	Notable item	Weight (grams)	Remarks	Waste bag — Hall 2 — 3 PM	Notable item	Weight (grams)	Remarks	Waste bag — Hall 2 — 5 PM	Notable item	Weight (grams)	Remarks	Total commercial area
Plastics													0
- PET bottles													0
- EPS packaging													0
- Plastic cups													
- Plastic cup lids													0
- Plastic bags (PE/PP/Flexibles)													0
- Plastic packaging													0
- Multilayer bags (Chips)													0
- Cup, cup holders and lids													0
- Unspecified plastics													0
													0
Paper													0
- Packaging paper													0
- Packaging cardboard													0
- Cup holders													
- Carboard cups													0
- Newspapers (flyers, books, magazine)													0
- Baggage tags													0
- Paper bags													
- Napkins													0
- Other (receipt, printer paper, etc.)													0

Assessment and reporting

Reporting is recommended and could contain the following information:

- Introduction and problem description
- Research questions
- Procedure and test methodology
- Context description
  - Time, location, flight schedule, sample etc.
- Results
  - A complete description of the sorted materials (see appendix A)
  - Any specific comments (remarkable finds, deviations from the test method, etc)
- Interpretation and discussion
- Conclusion and recommendations

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Appendix F: EXPLANATION ENVIRONMENTAL IMPACT CATEGORIES

Operational resource streams*	Referring to streams
Climate change (kg CO2 eq)	Increase in the average global temperature resulting from greenhouse gas emissions (GHG)
Ozone depletion (kg CFC11 eq)	Depletion of the stratospheric ozone layer protecting from hazardous ultraviolet radiation
Ionising radiation (kBq U-235 eq)	Impact of exposure to ionising radiations on human health
Photochemical ozone formation (kg NMVOC eq)	Potential of harmful tropospheric ozone formation ("summer smog") from air emissions
Particulate matter (disease inc.)	Impact on human health caused by particulate matter emissions and its precursors (e.g. sulfur and nitrogen oxides)
Human toxicity, non-cancer (CTUh)	Impact on human health caused by absorbing substances through the air, water, and soil. Direct effects of products on humans are not measured
Human toxicity, cancer (CTUh)	
Acidification (mol H+ eq)	Acidification from air, water, and soil emissions (primarily sulfur compounds) mainly due to combustion processes in electricity generation, heating, and transport
Eutrophication, freshwater (kg P eq)	Eutrophication and potential impact on ecosystems caused by nitrogen and phosphorous emissions mainly due to fertilizers, combustion, sewage systems
Eutrophication, marine (kg N eq)	
Eutrophication, terrestrial (mol N eq)	
Ecotoxicity, freshwater (CTUe)	Impact of toxic substances on freshwater ecosystems
Land use (Pt)	Transformation and use of land for agriculture, roads, housing, mining or other purposes. The impact can include loss of species, organic matter, soil, filtration capacity, permeability
Water use (m3 depriv.)	Depletion of available water depending on local water scarcity and water needs for human activities and ecosystem integrity
Resource use, fossils (MJ)	Depletion of non-renewable resources and deprivation for future generations
Resource use, minerals and metals (kg Sb eq)	

Source: Hedgehoc Company, 2022