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# **Circularity Performance Management System – Part 2**

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### Abstract

This report marks the second phase in exploring the circularity performance management system introduced in June 2023 (D6.2). It focuses on the practical application of Key Performance Indicators (KPIs), integrating a database housing reduction initiative categorised across priority waste streams: plastic, residual, paper, and food. The examination extends to an analysis of Capital Expenditures (CAPEX) and Operating Expenditures (OPEX) in waste management, correlating investments with initiatives in the database.

In tandem, to address the inherent uncertainty in waste treatments and destinations, tags were released in streams disposed at three major airports. Insights from previous research related to the baseline assessment (D6.1) were combined in a monitoring dashboard so that airports can connect data from waste handlers with environmental impact calculations and potential environmental and/or financial savings from the initiatives pursued to reduce waste.



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**Public:**

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# 1 Executive summary

Building upon the foundation laid in the previous report, D6.2 Circularity performance measurement system – Part 1, the focus of this report delves into a more comprehensive examination of its practical implementation. Key activities outlined in this report are:

- **Initiative database launch:** Introduction of an initiative database ([www.zerowasteairport.com](http://www.zerowasteairport.com)) categorising activities under three waste management strategies — prevention, reuse, and recycling — across priority resource streams residuals, plastics, food, and paper.
- **CAPEX and OPEX assessment:** An evaluation of Capital Expenditures (CAPEX) and Operating Expenditures (OPEX) in the context of waste management which reveals anticipated increased expenses in the upcoming years. Current investment levels — classified as low, medium, or high — are correlated with all initiatives catalogued in the database.
- **Operational resource stream tagging:** Deployment of tags within operational resource streams to trace the destination and fate of resources leaving the airport premises. This initiative aimed to enhance visibility and accountability throughout the entire resource lifecycle.
- **Integration of monitoring tools:** The report concludes by emphasising the implementation of monitoring tools which can seamlessly connect data from waste handlers, environmental impact information from performed baseline (D6.1), and real data or assumptions per database initiative. The integrated system enables continuous monitoring of performance and facilitates scenario analysis to refine waste reduction efforts.



## 2 Introduction

This chapter provides an introduction and background of the report and outlines a reading guide to enhance clarity on what activities are performed within TULIPS Work Package 6 Circular Airports and specifically this deliverable.

### 2.1 Background to the report

The environmental impact assessment conducted in 2022 specifically addressed operational resource streams prioritised by airports, including residuals, plastic, paper, and food (please refer to deliverable 6.1 Circularity Baseline Assessment). This assessment, utilising 2019 data from three airports, serves as a baseline to monitor progress towards reducing waste in 2025 - which is one of the core objectives – and ultimately achieve circularity. Within TULIPS Work Package 6 (refer to section 2.3), progress towards circularity is guided by three horizons (refer to section 3.2). For the first horizon, the primary Key Performance Indicator (KPI) and objective until 2025 is to reduce residuals produced per passenger by 20%, based on weight and the 2019 level, excluding CAT1, which is handled by the contracted waste partner at the airport. The conceptual model supporting the horizons, along with detailed key performance indicators and strategies, is outlined in deliverable 6.2 Circularity Performance Management System – Part 1<sup>1</sup>.

This report, constituting the second part of the performance management system, specifically elaborates on initiatives to take for each priority resource stream to achieve the KPIs. In addition, it details the necessary capital (CAPEX) and operational (OPEX) expenses required to elevate waste management to the next level. Additionally, the report outlines effective approaches for using technology and tagging in operational resource streams and explains how to monitor overall progress.

### 2.2 Urgency to transition to a circular economy for airports

There is an urgent need for airports to transition towards a circular economy. The increasing global population and growing air travel trend will inevitably lead to a surge in goods, energy, and resource consumption<sup>2</sup>. By embracing circular ambitions and initiatives, airports can showcase their dedication to a more environmentally friendly future while mitigating their carbon footprint.<sup>3</sup>

Adding to this urgency there are some recent developments in the arena of sustainability certifications, such as the introduction of a new level of accreditation by the Airport Carbon Accreditation (hereafter ACI).<sup>4</sup> This Level 5 signifies the highest achievement and maturity in airport carbon management, with one of its requirements directly related to third parties managing resources in and around airports, namely Extended Carbon Footprint. In compliance with this requirement, airports must submit a verified carbon footprint for Scope 1 and 2 (direct and indirect emissions under the airport's control) and all relevant categories of Scope 3 (indirect emissions outside of the airport's control). This information is also needed by airports if they want to comply with Corporate Sustainability Reporting Directive and the approved Digital Product Passports in the Eco-design for Sustainable Products Regulations (refer to section 5.1).

<sup>1</sup> TULIPS. (2023). Circularity performance measurement system – Part 1.

<sup>2</sup> International Civil Aviation Organization. (2022). ICAO forecasts complete and sustainable recovery and growth of air passenger demand.

<sup>3</sup> International Civil Aviation Organization. (2019). Circular Economy.

<sup>4</sup> Airport carbon accreditation. (2023). Global carbon standard launches its new pinnacle at COP28, certifying airports for achieving net zero carbon balance.



## 2.3 TULIPS Circular Airports

TULIPS is a consortium that develops innovations that facilitate the transition to low-carbon mobility and enhance sustainability at airports. The TULIPS project is supported by the EU with €25 million in funding and started in January 2022 up to December 2025. TULIPS is short for DemonsTrating lower pollUting soLutions for sustaInable airPorts across Europe. Each Work Package (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 1.



Figure 1 - Overview of activities, demos, and deliverables of TULIPS WP6

The main objectives of WP6 Circular Airports are piloting initiatives, which reduce operational resource streams by 20% in 2025 (comparing baseline year 2019 with year 2024) and maximise secondary materials for constructional resource streams. Additionally, the project aims to scale solutions and develop a circular economy roadmap for airports, guiding them in implementing circular economy practices and achieving their sustainability goals. By doing so, the TULIPS consortium hopes to contribute to the development of a more sustainable aviation industry.

## 2.4 Reading guide

This report summarises the work around the circularity performance measurement system carried out by TULIPS WP6 across 2022 and 2023 and highlights the next steps taken. Overall, this report aims to promote knowledge exchange, scale best practices, and accelerate the transition towards a circular economy in the aviation industry.

The process of 'setting up' a circularity performance measurement system is described in Deliverable 6.2<sup>5</sup>. The process of 'implementing' it is outlined in Figure 2 and is subsequently detailed in the following chapters of this report.

<sup>5</sup> TULIPS. (2023). Circularity performance measurement system – Part 1.



Figure 2 - Overview of process steps

*\*The progress of the KPIs, as defined within TULIPS, and consequently, the assessment of whether the consortia WP6 objectives have been met, will be documented in Deliverable 6.6 by the end of 2025.*

To transition airports towards circularity within the TULIPS consortium is a collaborative effort between TU Delft, Excess Material Exchange and is validated by three airports (Schiphol Amsterdam Airport, Avinor Oslo Airport, and Hermes Larnaca Airport). Please refer to Appendix B for more information on these TULIPS' partners. Please be aware that certain airport-specific information is considered confidential and has not been included in this report. The figures in this report draw on existing frameworks but have been specifically created for this project by TUD (Elisabeth Tschavgova) and EME (Anne Rademaker), with input provided by participating partners. Any other images used are either developed by TULIPS or properly credited to the source.



### 3 Navigating the path to success: An overview of initiatives for KPI achievement of priority streams

This chapter provides a recap of the chosen priority streams and KPIs established by TULIPS' airports in their transition to a circular economy. It elaborates on the methods employed for collecting initiatives designed to meet the established KPIs and outlines the trajectory for scaling up these efforts.

#### 3.1 Priority resource streams at airports

TULIPS' airports have ranked all operational resource streams based on the results of the performed environmental impact assessment, discussions with key stakeholders, and insights from the performed Waste Safari. The top streams identified include Residuals, Food, Paper, and Plastic. For details of the assessment, please refer to Circularity Baseline Study<sup>6</sup>.

#### 3.2 Horizons and KPI to reduce priority streams

The circularity performance measurement system outlines three horizons designed to steer airports towards circularity:

- Horizon 1: Reducing priority streams by 2025,
- Horizon 2: Achieving zero waste by 2030, and
- Horizon 3: Transitioning to a circular economy by 2050 (please refer to Figure 3).



\* 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 prioritize the regeneration of nature so that resources can restore, renew or revitalize their own sources of energy and materials.

Figure 3 - Overview three horizons

The overarching KPI for Horizon 1 in the framework is to reduce residuals produced per passenger by 20%, based on weight and the 2019 level, excluding CAT1 waste handled by contracted waste partners at airports. To ensure the translation of this KPI into SMART targets, three strategies have been identified to address the prioritised four waste streams (plastic, paper, food, and residuals):

<sup>6</sup> TULIPS. (2023). Circularity Baseline Study.

1. Smarter product use and manufacturing.
2. Extending the lifespan of products and their parts.
3. Practical application of materials.

For details of KPIs per strategy and conceptual models applied to set up the system, please consult the Circularity Performance Measurement System – Part 1.<sup>7</sup>

### 3.3 Method of collecting initiatives

To perform the three strategies as outlined in section 3.2 for all priority streams (residual, plastic, food, and paper), initiatives were gathered by using three distinct methods:

1. **Co-creation sessions:** Within TULIPS, diverse co-creation sessions were organised and facilitated by TU Delft and EME. Participants were from Schiphol Amsterdam Airport, Avinor Oslo Airport, and Hermes Larnaca Airport and/or their respective stakeholders and business partners. MIRO was employed for facilitation in online sessions, while offline sessions utilised posters to guide active brainstorming. An example of a poster is provided in Appendix C. Please refer to Figure 4 for an illustration of a co-creation session that occurred in October 2023 at Hermes Cyprus Larnaca, with F&B, Retail, and Facilities stakeholders in attendance.



Figure 4 - Co-creation session at Hermes Larnaca Airport in October 2023

<sup>7</sup> TULIPS. (2023). Circularity performance measurement system – Part 1.



2. **Desktop research and best practices:** EME conducted an extensive literature and best practices review to collect waste reduction initiatives implemented at airports for priority streams. Additionally, lectures were held at various universities to facilitate open brainstorming sessions on creative ideas for preventing or reusing resources at airports. An example is illustrated in Figure 5, where Anne Rademaker (EME) is spending part of her lecture at the ESG Academy of the Business School of Amsterdam to brainstorm ideas.



*Figure 5 - Brainstorm at UVA Business School ESG Academy*

3. **TUD graduation projects:** Three students conducted thorough research and piloted ideas at Schiphol Airport related to:
  - a. Improving passenger waste separation behaviour through design.<sup>8</sup>
  - b. Developing a circular cup system at Schiphol Airport.<sup>9</sup>
  - c. Increasing the return of PET bottles/cans at Schiphol Airport.<sup>10</sup>

Please refer to respective reports for details on the ideas, pilot results and more. TUD will continue to place students on relevant topics at TULIPS's airports Oslo and Cyprus.

### 3.4 Scaling successes by launching a centralised initiative database for airports

Resulting from the three data collection methods described in section 3.3, almost 200 initiatives were obtained. These initiatives were directly associated with one of the priority streams and linked to a strategy (prevent, extend lifetime, or improve recycling). In cases where the initiative was more

<sup>8</sup> Nika den Ouden. (2023). Improving passenger waste separation behaviour through design at Schiphol Airport.

<sup>9</sup> Chen Yu. (2023). Developing a Circular Cup System at Schiphol Airport

<sup>10</sup> Anniek Keijer. (2023). Behavior change strategies for higher return of PET bottles/cans at Schiphol Airport.



universally applicable to all streams, a distinct category was defined, namely "logistical and operational processes".

For a breakdown of how the collected initiatives are distributed across the streams and strategies, please refer to Table 1. A comprehensive overview of all initiatives can be found in Appendix D.

Resource stream	Strategy 1: Prevent	Strategy 2: Extend lifetime	Strategy 3: Improve recycling	Logistical and operational processes	Total
Residual	3	6	4		13
Plastic	26	6	16		48
Food	26	19	21		66
Paper	15	2	15		32
Generic	9	7	11	13	40

*Table 1 - Quantitative overview of initiative per priority stream*

To expand the initiatives across airports, a website incorporating a database has been developed: [www.zerowasteairport.com](http://www.zerowasteairport.com). Airports can access and use the online initiative database or inspirations plus contribute their own initiatives to facilitate the sharing and scaling of successes. Future developments in the database may involve incorporating additional details, such as case studies, templates, and practical guidance per initiative.



## 4 Capitalising on circularity: Unveiling the CAPEX and OPEX landscape in an airport's waste management investments

This chapter provides an overview of OPEX and CAPEX in the context of waste management. It aims to assign financial values to estimate implementation and ongoing operation costs of waste reduction efforts as proposed in the initiative database highlighted in section 3.4.

### 4.1 Expenditures within airports

The airport industry is asset-intensive, leading to a cost structure characterised by substantial fixed expenses. These costs can be divided into OPEX and CAPEX<sup>11</sup>. OPEX covers day-to-day operational activities like staff, utilities, safety, and security, while CAPEX, representing funds used by an airport operator for the acquisition, construction, or improvement of fixed assets such as land and buildings. To comprehend the overall CAPEX and OPEX expenditures of airports, the Airport Council International (ACI) offers valuable resources that present industry benchmarks.

In Europe specifically, the average CAPEX expenses reported in 2020 (over 2013-2019) are 12.950 million € distributed across various categories, including aircraft movement, car parking, terminal buildings, integrated roadways, rail and transit, equipment and vehicles, and other facilities. Refer to Table 2 for details on the average division and spending<sup>12</sup>.

CAPEX spending EU	% of spending	Spending in million € *
Aircraft movement	24,00%	3.108 €
Car parking	2,00%	0.259€
Terminal Buildings	50,00%	6.475 €
Integrated roadways, rail & transit		0 €
Equipment & vehicles	6,00%	0.777€
Other facilities	18,00%	2.331 €
<b>TOTAL CAPEX</b>	<b>100,00%</b>	<b>12.950 €</b>

Table 2 - Europe average CAPEX per type (2013-2019)

\* Original source shows amount in million dollars: OANDA exchange rate used on December 19<sup>th</sup> (1.09153 USD)

<sup>11</sup> Franco Lucas Sartor. (2022). Airports need significant capital expenditure to alleviate slot constraints.

<sup>12</sup> Airports Council International. (2021). Global Outlook of Airport Capital Expenditure.



In Europe specifically, the average OPEX expenses in 2020 amounted to 11.100 million €<sup>13</sup> distributed across various categories. The operating cost structure used is based on previous ACI reports, encompassing personnel, contracted services, materials/equipment/supplies, communications/energy/waste, insurance/claims/settlement, maintenance, lease/rent/concessions, general and administrative and other<sup>14</sup>. Refer to Table 3 for details on the average division and spending<sup>15</sup>.

OPEX spending in EU	% of spending	Million euros*
<b>Contracted services</b>	22,00%	3.876 €
<b>Materials/equipment/supplies</b>	4,00%	705 €
<b>Communication/energy/waste</b>	6,00%	1.057 €
<b>Insurance (claims/settlements)</b>	1,00%	0.176 €
<b>Maintenance</b>	5,00%	0.881 €
<b>Lease/rent/concessions</b>	5,00%	0.881 €
<b>General and administrative</b>	7,00%	1.233 €
<b>Other</b>	13,00%	2.292 €
<b>TOTAL OPEX excl. staff</b>	63,00%	11.100 €
Personnel	37,00%	9.200 €
<b>TOTAL OPEX incl. staff</b>	100,00%	21.100 €

Table 3 - Europe average OPEX per type

The insights of the industry benchmarks in Table 2 and 3 are used by TULIPS' airports to define the current spending on waste management. Note that these are numbers across all assessed airports in various studies (approx. 200 airports), so amounts per airport include 105.500 EUR (OPEX) and 64.750 EUR (CAPEX). Please refer to sections below.

## 4.2 CAPEX in the context of waste management

CAPEX refers to the various expenditures made by airports to either create, maintain, improve, or expand the scope of their operations<sup>16</sup>. In the context of waste management, this would involve the investments made by airports for example to either sustain or expand their waste management capabilities, such as implementing new waste collection systems at airports or exploring farming around airports<sup>17</sup>. While industry benchmarks are available for total CAPEX spending (refer to section 4.1 table 2), there is no detailed overview of investments done specifically in and around waste management.

<sup>13</sup> ACI Europe. (2020). European Airport Financial results.

<sup>14</sup> ACI Europe. (2012). ACI EUROPE Economics Report 2012.

<sup>15</sup> Airports Council International. (2021). Global Outlook of Airport Capital Expenditure.

<sup>16</sup> ACI Europe. (2021) CAPEX overview.

<sup>17</sup> CNN Money. (2015). JetBlue opens farm at JFK airport.



In response to this gap, a three-tier categorization system—low, medium, and high—was developed. Refer to Table 4. This categorization system is consequently used to assess the initiatives (refer to Section 3.4) for waste reduction. The categories – low, medium, and high – are based on sector insights as observed in section 4.1, with average CAPEX spending on 64.750 EUR per airport.

<b>Categories</b> Based on current expenses estimated by TULIPS' airports*	<b>CAPEX in waste management up to 2025 in €</b>
<b>Low investment</b>	<50.000 €
<b>Medium investment</b>	50.000 € - 1.000.000 €
<b>High investment</b>	>1.000.000 €

*Table 4 - Criteria for CAPEX related to waste management*

\*The scales are formulated by consolidating the prevailing comprehension of low, medium, and high investments as per TULIPS' airports, while also accounting for the inherent diversity among any other airport in terms of size and financial capacity.

Anticipating the circular transition imperative, ACI estimates a staggering requirement of US\$170.1 billion solely for capital investments in 2040<sup>18</sup>. This forecast underscores the necessity for increased CAPEX across the aviation sector, a reality TULIPS' airports are prepared to acknowledge and address.

### 4.3 OPEX in the context of waste management

The composition of OPEX encompasses key elements such as personnel costs, operating costs, resource consumption (energy, waste), equipment and infrastructure maintenance, and other expenses<sup>19</sup>. Even though waste is specifically highlighted together with communication and energy, accounting for approx. 6% of total OPEX (refer to Table 3), waste management related investments are to be found across all other items as well. For instance, for employees involved in waste collection or prevention activities (such as marketing)<sup>20</sup>. Lacking a detailed overview of investments done specifically in and around waste management, a three-tier categorization system—low, medium, and high—was devised are based on sector insights as observed in section 4.1, with average OPEX spending on 105.500 EUR per airport.

Please refer to Table 5. These categories serve as essential criteria for evaluating and prioritising waste management initiatives, as outlined in Appendix D.

<sup>18</sup> Franco Lucas Sartor. (2022). Airports need significant capital expenditure to alleviate slot constraints.

<sup>19</sup> José Antonio Poyato Moreira. (N.B). "Airport terminal OPEX and CAPEX.

<sup>20</sup> Kamal Azrague, Miguel Ángel Górriz, Peris, Antonio Dobon. (2021). PlastiCircle: Improvement of the plastic packaging waste chain from a circular economy approach." Grant Agreement No 730292.



Categories Based on current expenses estimated by TULIPS' airports*	OPEX in waste management up to 2025 in €
Low investment	<50.000 €
Medium investment	50.000 € -1.500.000 €
High investment	>1.500.000 €

Table 5 - Criteria for OPEX related to waste management

\*The scales are formulated by consolidating the prevailing comprehension of low, medium, and high investments as per TULIPS' airports, while also accounting for the inherent diversity among any other airport in terms of size and financial capacity.

Similar to CAPEX, TULIPS' airports acknowledge that higher OPEX investments are expected to contribute to the development of sustainable waste management infrastructure, addressing long-term environmental and operational needs.

#### 4.4 Prioritising initiatives based on CAPEX/OPEX scale

All initiatives collected to achieve the KPIS as highlighted in section 3.4, require different investments which depend for instance on airport size or choices on running a pilot or full-scale implementation. Assigning a specific financial value to each collected initiative is therefore challenging. Thus, the three-tier categorization system—low, medium, and high—was employed to assess all initiatives. This approach enables airports to prioritise initiatives based on their potential cost-effectiveness, alongside evaluating their environmental impact (refer to chapter 6) and alignment with overall waste management goals. It entails striking a balance between CAPEX-intensive projects that may yield long-term benefits and OPEX-focused initiatives for immediate improvements. The assessment is based on current expenses and TULIPS' airports acknowledging that future investments will significantly increase. For a detailed assessment of all initiatives, please refer to Appendix D.

#### 4.5 Trends towards a net zero and a circular economy in 2050

On the path to a circular economy, both CAPEX and OPEX investments are required that go beyond the usual. CAPEX investments in cutting-edge technologies, such as IoT-enabled waste tracking systems and advanced recycling machinery or infrastructure revitalization set the foundation for a circular economy. More than half of these investments are expected in terminals to maintain and retrofit the region's ageing infrastructure (and hence in scope for D6.4 and D6.5 related to construction), as well as address capacity constraints in the face of growing passenger demand<sup>21</sup>. In the example of plastics in the global economy, an additional €500-700 billion in CAPEX is needed to develop the required circular infrastructure by 2050<sup>22</sup>. OPEX investments play a crucial role in sustaining and optimising circular practices daily. Factors like personnel training, regular maintenance of systems, and effective supply chain management are key contributors.

Airports within the Schiphol Group are actively advancing their sustainability efforts through significant CAPEX programs. These initiatives aim to facilitate a transition towards greater

<sup>21</sup> International Airport Review. (2021). Airport capital investment: Addressing challenges beyond the pandemic.

<sup>22</sup> Plastics Europe. (2022). The cost of net-zero and high circularity.



sustainability and the development of high-quality facilities. According to their sustainability roadmap, the 2030 objectives are considered achievable through existing or emerging solutions. The overall Total Cost of Ownership (TCO) is anticipated to remain relatively stable and potential increases in CAPEX are compensated by reductions in OPEX<sup>2324</sup>. Similarly, Avinor Group's priorities, encompassing both operating costs and investments, will be adjusted in alignment with the long-term outlook for the aviation industry<sup>25</sup>. Both airport groups demonstrate a proactive approach to sustainability, reflecting a commitment to environmental responsibility and long-term viability.

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<sup>23</sup> Schiphol Group. (2022). Annual Report 2022.

<sup>24</sup> Schiphol Group. (2019). Sustainability Roadmap 2030.

<sup>25</sup> Avinor. (2022). Annual Report 2022.



## 5 Exploring the waste maze: Releasing tags in a quest for transparency and traceability

This chapter illustrates the activities undertaken to comprehend the destination and fate of resources once they leave the airport premises. During 2023, various tags were attached to materials and products, then deployed within operational resource streams at Schiphol Amsterdam, Avinor Oslo, and Hermes Larnaca airports.

### 5.1 Destination of resource streams

After various inquiries with TULIPS' (stakeholders and) airports, it's still not always clear what fate awaits resource streams after collection and leaving the airport premises. The significance of transparency in the full value chain is increasing, particularly in anticipation of forthcoming legislation such as the Corporate Sustainability Reporting Directive<sup>26</sup> and the Digital Product Passports in the Eco-design for Sustainable Products Regulations<sup>27</sup>. Airports may utilise various unique identifiers to serialise their product and components so that they can achieve accurate identification and tracking. Examples include Quick Response (QR) codes<sup>28</sup>, RFID tags, Near Field Communication (NFC) sensors or data matrix codes<sup>29</sup>.

### 5.2 Active and passive tags

Using special codes to track materials has become crucial for efficient monitoring. These codes, called tags, can be active (with batteries) or passive (without batteries). Active tags regularly send signals (via Wi-Fi or Bluetooth), helping track materials in real-time. On the other hand, passive tags need external devices to activate them but are cost-effective for nearby tracking (such as QR codes). Both types enhance visibility, reduce delays, and improve supply chain management at airports. However, challenges may occur when products lack an active tracking system, leading to traceability issues after multiple sales transactions if the product information isn't updated correctly. The topic of stakeholders and tags were discussed during a dedicated Work Package 6 event taking place in May 2023, as visualised in Figure 6.

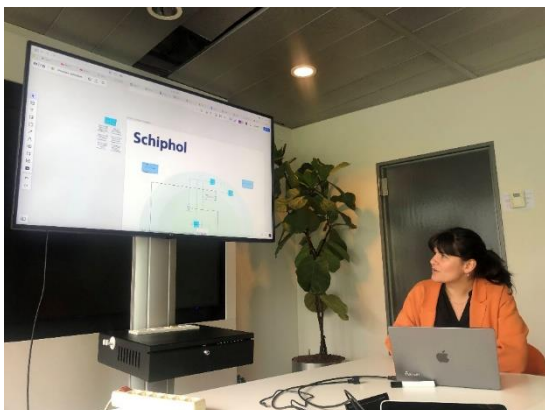


Figure 6 - Snapshot of WP6 May event 2023

<sup>26</sup> European Commission. (2023). Corporate sustainability reporting.

<sup>27</sup> European Commission. (2023). Commission welcomes provisional agreement for more sustainable, repairable and circular products.

<sup>28</sup> ISO/IEC 18004:2015. (2021). Information technology — Automatic identification and data capture techniques — QR Code bar code symbology specification.

<sup>29</sup> ISO/IEC 16022:2006. (2014) Information technology — Automatic identification and data capture techniques — Data Matrix bar code symbology specification.



### 5.3 Tag release TULIPS airports

During the WP6 event in May 2023, a total of twelve tags were distributed among the three TULIPS airports, with four tags allocated to each airport. These tags were sourced from both Apple ("Apple AirTag") and Android ("Tile"). Each airport conducted a brainstorming session to determine the specific products or materials they wanted to track. For reference, please consult the Figures 7, 8 and 9 taken at the WP6 event in May 2023 to choose the desired products/materials.



Figure 7 - Brainstorm tags Hermes Larnaca Airport



Figure 8 - Brainstorm tags Avinor Oslo Airport



Figure 9 - Sample selection by Schiphol Amsterdam Airport



After the brainstorm by each airport, the final sample selection per airport was made and described in Table 7. In the weeks following the brainstorming sessions, each airport released the tags along with instructions on how to attach them to specific materials or products. Please refer to Table 7 for an overview.

Airport	Materials/product	Disposed in bin	Tag identity
<b>Avinor Oslo Airport</b>	Screen monitor (EE)	EE	Tile #1
	Coffee Cup	Paper	Tile #2
	Plastic foil	Plastic	Apple #4
	Bottle on a plane	On plane with passenger	Apple #5
<b>Hermes Larnaca Airport</b>	Glass	Glass	Tile #4
	Plastic foil	Plastic	Apple #6
	Paper / Cardboard	Paper	Apple #8
	Can	Residual	Apple #7
<b>Schiphol Amsterdam, airport (also refer to Figure 9)</b>	Coffee cup	Office bin	Tile #3
	Contaminated paper wrapping	Paper bin	Apple #1
	PET bottle	Paper	Apple #2
	Paper bag	Paper	Apple #3

Table 6 - Overview materials/products and tags ID



As an illustration, Avinor Oslo Airport released a tag connected to a screen monitor (Figure 10). The subsequent monitoring of these tags was carried out through their respective apps, see also section 5.4



*Figure 10 - Tag released connected to a monitor*

## 5.4 Tracing the tags and conclusions

Given the release of both Apple Airtags and Android Tile tags, their movements were tracked using their respective applications. Please consult Table 8 for a detailed overview of the tag movements in the months following their release.

Tag identity	Tag released Airport	June - July 2023	August – September 2023	October - November 2023
Tile #1	Avinor Oslo Airport	Jernbanetorget, Norway	No longer traced	No longer traced
Tile #2		Oslo Airport	No longer traced	No longer traced
Apple #4		Jessheim, Norway	Folldal, Norway	Sarpsborg, Norway
Apple #5		Gardermoen, Norway Rhodes Greece (refer to Figure 11)	No longer traced	No longer traced
Tile #4	Hermes Larnaca Airport	Meneou, Cyprus	Meneou, Cyprus	Meneou, Cyprus
Apple #6		Larnaca Airport	No longer traced	No longer traced
Apple #7		Larnaca Airport	No longer traced	No longer traced
Apple #8		Gossie, Cyprus	No longer traced	No longer traced
Tile #3	Schiphol Amsterdam, Airport	Schiphol Airport	No longer traced	No longer traced
Apple #1		Schiphol Airport	No longer traced	No longer traced
Apple #2		Schiphol Airport	No longer traced	No longer traced
Apple #3		Schiphol Airport	No longer traced	No longer traced

Table 7 - Overview tags and locations in 2023

In conclusion, the initiative to release tags in order to trace materials and products for insights on their treatment faced several challenges. The acknowledged risk of losing tags was realised, with only 2 out of 12 tags successfully traced for more than 2 months. Some tags never indicated locations beyond the airport of release, suggesting potential breakage in press-containers before waste transportation. In addition, the main goal is to reduce waste, but the substantial loss of tags without obtaining the intended insights undermines this purpose. While some tags did reveal the intended information, such as the actual location of treatment aligned with the expectation of the respective airport (Avinor Oslo Airport), for most tags this remains a question mark.

Given these challenges, it's crucial to reevaluate the strategy, exploring alternative tracking methods for a high volume of tags or addressing the technical limitations of the current approach.

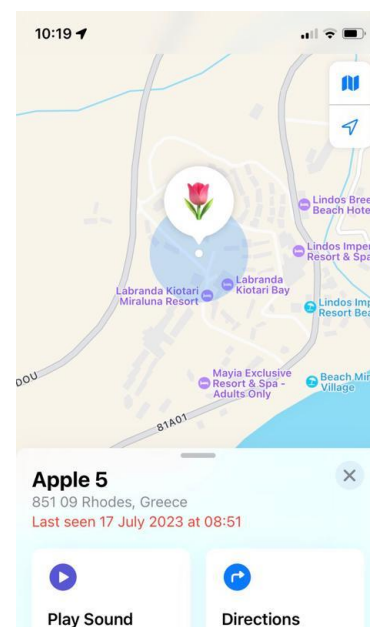


Figure 11 - Screenshot of tracing tags released in operational streams



## 5.5 Advancing transparency in operational streams

Transparency is rapidly becoming the standard, and resource tracing is becoming a reality, driven not only by compliance requirements but also by the potential financial benefits of localising stream treatments and ensuring material quality. Within TULIPS WP6, a tracking and tracing module is being piloted with construction streams, as outlined in Deliverable 6.4 (published at the end of 2025). Supported by pilots, participating airports are closely monitoring demolition, renovation, or new projects to verify the use of secondary materials. Various tags, both passive (such as QR codes) and active (such as RFID), are employed in these construction-related pilots.

For operational streams, EME is committed to exploring solutions for airports as well. Next to the efforts taken with the twelve released tags, workshops will be organised to delve deeper into how technology and tags can support airports' circular goals. The agenda for such workshops is provided in Appendix E, with the goal of releasing a substantial volume of tags, not only in construction streams (as per TULIPS scope) but also in operational streams. Insights from this exercise can act as additional data sources in the monitoring framework, refer to Chapter 6. Results will be published in D6.6.



## 6 Connecting data points for better monitoring

This chapter explores ways to enhance monitoring for a circular economy by integrating prevention and reuse aspects into dashboards. This approach involves linking the 2019 baseline environmental impact assessment (D6.1), subsequent years, different scenarios, and potential savings from these initiatives. The results will be presented in D6.6 (final deliverable end of 2025), offering a conclusive assessment of whether the set objectives have been achieved and providing valuable insights into the changing landscape of waste management practices.

### 6.1 Connecting data in dashboards

Airports typically receive tonnage breakdowns per waste stream from waste handlers, but the specific treatment details of these streams often remain unclear. Additionally, these figures lack a connection to the environmental impact of stream treatments (please refer to Circularity Baseline Study<sup>30</sup>). To address this gap, TULIPS has developed a dashboard that integrates data from waste handlers with environmental impact indicators, see a screenshot in Figure 12. This allows for linking volume to treatment costs, eco-costs, and waste per passenger. Utilising a data visualization tool such as PowerBI provides a comprehensive view, enabling a zoom-in on specific streams for a more detailed analysis.

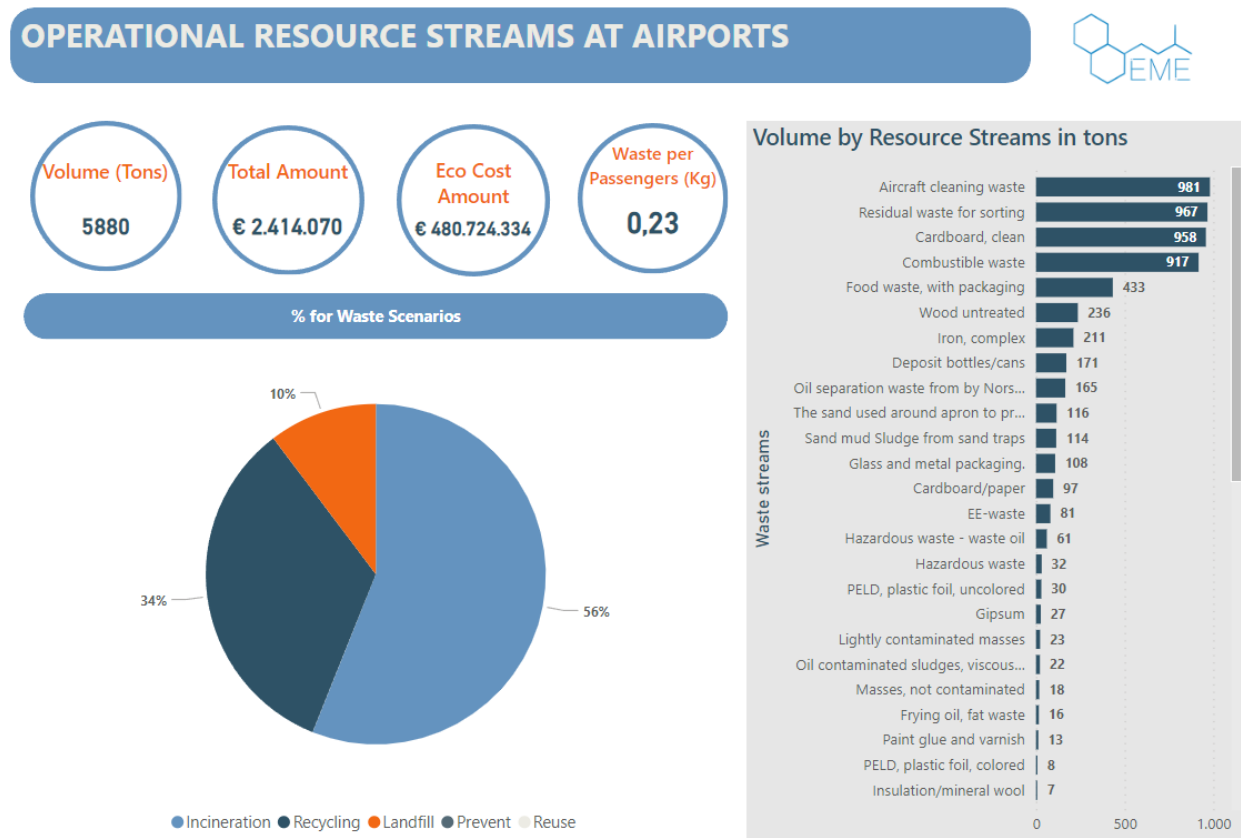


Figure 12 - Example dashboard connecting volume, (eco) costs and treatment

<sup>30</sup> TULIPS. (2023). Circularity Baseline Study.

By incorporating prevention and reuse into the monitoring framework, significant advantages emerge. Previously, the sole comparison of volume reduction across different periods was feasible. However, this approach lacked the ability to determine whether the reduction correlated with a decrease in environmental impact or if the waste transitioned from incineration to recycling. The enhanced monitoring framework can allow for the creation of scenarios (based on assumptions, as real data may not be available), offering a more comprehensive understanding of the overall impact of waste reduction initiatives.

## 6.2 From benchmarking historical data to future scenarios

The identified initiatives (see section 3.4) specifically focus on preventing or reducing priority streams. As waste monitoring data is usually coming from waste handlers, this will logically not include the efforts taken by airports to prevent or reuse waste streams. Perhaps a reduction in volume will be visible over time, but smaller pilots with initiatives will not be shown accordingly and it's hard for airports to make a business case to invest in such initiatives. In case airports will create data on prevention and reuse themselves, questions arise regarding the capture of such data, responsibilities for its management, and reporting procedures and how to connect it with data from waste handlers. In some instances, real data may be available. Refer to Table 9 for an example.

Initiative	Data	Environmental impact	Financial implications	Operational implications
Separate X kg of orange peels from swill for use in hand soap in airport toilets – Refer to Figure 13. <sup>31</sup>	Real data: Orange peels collected and shared with soap making company (kg).	Reduction in volume and impact of the 'food/swill' stream at the airport.  Potential environmental advantage (yet to be researched): A less impactful choice to buy compared to other soaps.	Reduced treatment and eco-cost for the 'food/swill' stream.  Possible financial benefit (yet to be researched): Cost savings on soap production as raw materials are provided by the airport.	The introduction of this initiative would require small kitchens at airports to accommodate an additional bin for collecting orange peels. Setting up logistics for the transport of orange peels to their treatment facility is also necessary.



In the example of Table 9, the real data from orange peel collectors can be added to the dashboard, which can logically be correlated to food amounts reported by waste handlers. Hence environmental and financial savings can be shown accordingly.

Figure 13 - Soap from orange peels at Schiphol Airport

<sup>31</sup> Schiphol Twitter. (2021). Dutch soap made from orange peels.

However, for most initiatives, there is no real data available (yet). Hence, assumptions can be used to understand the potential impact. Refer to Table 10 for an example.

Initiative	Data	Environmental impact	Financial implications	Operational implications
Implement dynamic pricing for bring-your-own cup/flask to incentivise reusable containers through variable pricing.	Assumptions: Dynamic pricing and advertising (prior to travel) will encourage x% of passengers to choose a reusable cup/bottle, thereby reducing plastic waste.	Reduction in volume and impact 'plastic' stream of airport.  Scenario-based impact calculation: By considering scenarios with varied adoption rates (e.g., 10% as a minimum and 30% as a maximum), the associated impact on plastic waste reduction can be calculated. Refer to Figure 14 to play with such scenarios in dashboards.	Reduced treatment and eco-cost for the 'Plastic' stream.  Potential sales opportunity for airport branded reusable cup/flask.	<ul style="list-style-type: none"> <li>Marketing efforts play a vital role, potentially including the sale of reusable bottles directly.</li> <li>Collaboration with F&amp;B partners is crucial to incentivise the use of reusable containers. Airport can provide vouchers to facilitate discounts.</li> <li>Effective coordination with stakeholders ensures the success of the initiative.</li> </ul>

Table 9 - Initiative with assumed data



Figure 14 - Scenario building in dashboard

If products and materials will be traced, such as proposed in Section 5.5, some assumed scenarios can become real data. For instance, by implementing airport specific reuseable cups/flasks in the terminal and tracing them. Supported by such data, potential savings can be calculated for initiatives such as work with the same cups/flasks across all airports so passengers can take and return anywhere and even enjoy their drinks on the plane without creating waste.

### 6.3 Next steps

The findings of the work performed highlight several areas for further investigation. Alongside the ongoing work on the initiative database, there's a need to enhance the monitoring framework, focusing more on prevention and reuse and moving away from relying solely on existing data from waste handlers. The monitoring tool is designed to integrate the 2019 baseline environmental



impact assessment, subsequent years' data, various scenarios, and the (potential savings) from (implemented) initiatives. These findings will be presented in D6.6, the final deliverable offering conclusive insights into whether the outlined objectives have been achieved and providing valuable perspectives on the evolving landscape of waste management practices.



## 7 Conclusion

Addressing the goal of circular airport operations, this report marks the second phase of exploring the performance management system introduced in June 2023. Having laid the foundation in the initial report, D6.2 Circularity performance measurement system – Part 1, the focus now extends to a more in-depth examination of its practical implementation.

Through collaborative efforts involving stakeholders from various airports, extensive desk research, and the valuable contributions of graduation students, an initiative database has been launched. The initiatives are categorised across three different waste management strategies, namely prevention, reuse, and recycling (to avoid landfill or incineration) and serves as inspiration for airports looking to embrace circular solutions for priority resource streams such as residual, plastic, food, and paper. The accompanying website ([www.zerowasteairport.com](http://www.zerowasteairport.com)) aims to broaden the reach of this initiative to a wider audience of airports, fostering a community of shared knowledge.

In parallel, an assessment of CAPEX and OPEX related to waste management took place wherein TULIPS' airports acknowledge the crucial role played by these investments in establishing and maintaining a circular operational model. Current investments differ from industry estimates aimed at achieving circular ambitions, for example with ACI World suggesting the need for US\$170.1 billion solely for capital investments by 2040. This report connects the initiatives in the database to low/med/high levels of CAPEX and OPEX based on current investment levels, serving as a practical guide for determining feasible actions within a chosen horizon.

The increasing importance of transparency in waste management, in line with upcoming legislative measures such as the Corporate Sustainability Reporting Directive and the approved Digital Product Passports, is underscored by the airports. Consequently, tags were deployed within operational resource streams across TULIPS' Airports. The outcomes indicate that most tags were not located, prompting questions about their fate and the resources they were associated with. For overall monitoring progress, this type of data (downstream transparency) plays an important role. Airports commonly receive data from waste handlers regarding volumes, treatment costs, and/or separation rates. However, a critical gap exists, as this data often lacks a connection to the actual treatment of waste and its associated environmental impact. To address this issue, insights from previous work package deliverables (such as D6.1 Circularity Baseline Study) are used to generate insightful dashboards. Notably, a monitoring framework towards circularity would need a more pronounced focus on 'prevention' and 'reuse,' supported by either real data or well-informed assumptions to better understand the potential impact of various reduction initiatives. The progress of the KPIs, as defined within TULIPS, and consequently, the assessment of whether the consortia WP6 objectives have been met, will be documented in Deliverable 6.6 by the end of 2025.

In conclusion, this report underscores the tangible progress made in operationalising the circular performance management system, providing practical insights and tools for airports to embark on their sustainable journey. As the aviation sector increasingly adopts circular economy principles, the valuable insights gained from this initiative have the potential to guide airports globally.

Future developments are outlined as follows:

- The initiative database may be enlarged by other airports and incorporate additional details in the future, including case studies, templates, environmental/financial impact savings, and guidance for initiatives. These additions are aimed at supporting airports in their circular transition.
- The release of tags at three different airports demonstrated the potential for initiating a high-volume release of additional (and smaller) tags, thereby enhancing tracking capabilities



and understanding the real flow of resources leaving the airport premises. More research on the tracking capabilities for operational streams are enforced by workshops and releasing a high volume of tags (to be reported in D6.6). For track and trace module and more tags in construction streams, please refer to D6.4.

- The monitoring framework can be customised for each airport by selecting horizons, dedicated KPI (as presented in D6.2) and initiatives. The chosen initiatives can subsequently demonstrate both environmental and financial savings, based on either real data or assumptions used.



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## Appendix B: 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 C: CO-CREATION SESSION

# Brain dump on priority streams

Please map ideas to prevent or reduce waste on the priority resource streams.

Residual	Food	PMD	Paper	Cabin Waste

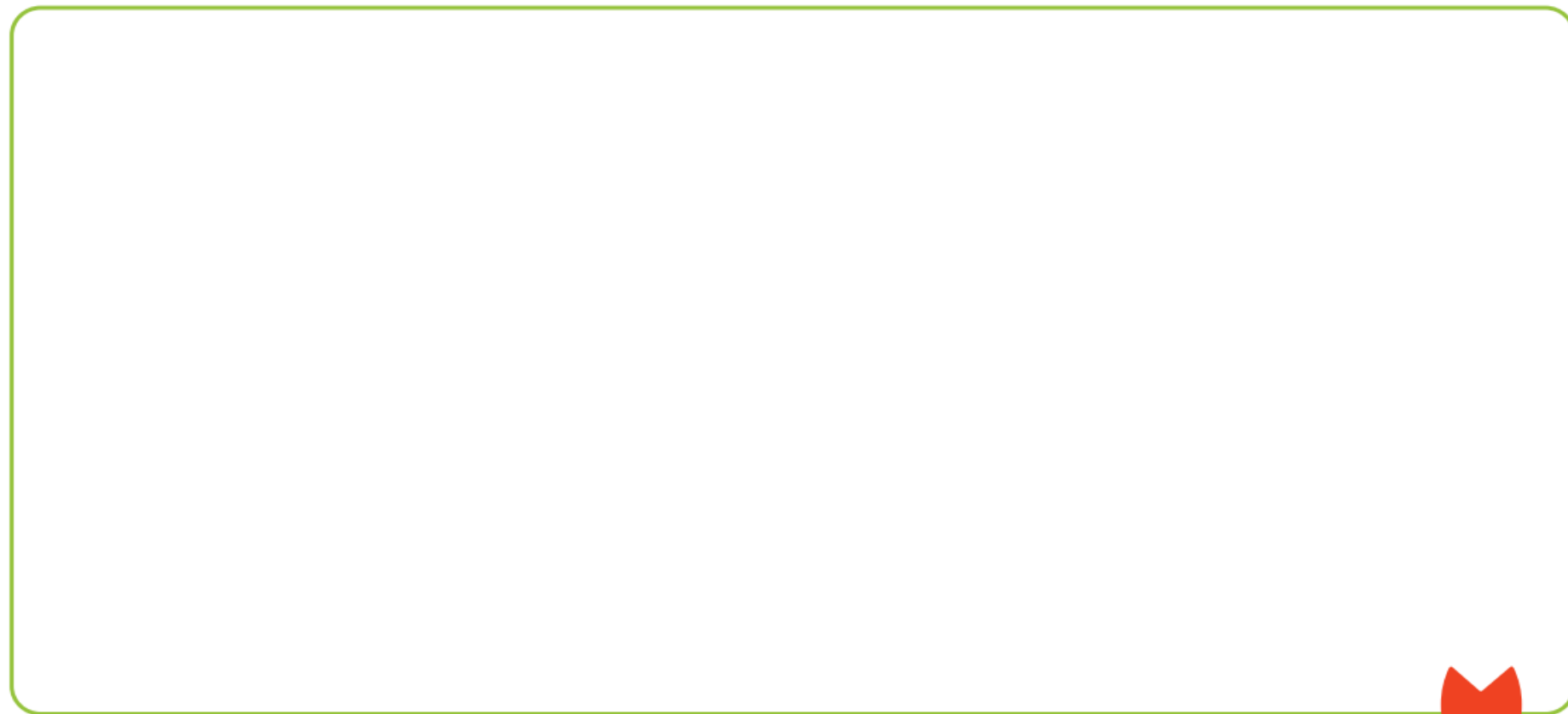
Other ideas





# Prioritized quick wins

Let's have a discussion about which ideas should be prioritised and why.





# 9R Framework

Circular Economy



Strategies

Smarter product use and manufacture	<b>R0 Refuse</b>	Make product redundant by abandoning its function or by offering the same function with a radically different product	
	<b>R1 Rethink</b>	Make product use more intensive (e.g by sharing product)	
	<b>R2 Reduce</b>	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials	
Extend lifespan of product and its parts	<b>R3 Reuse</b>	Reuse by another consumer of discarded product which is still in good condition and fulfills its original function	
	<b>R4 Repair</b>	Repair and maintenance of defective product so it can be used with its original function	
	<b>R5 Refurbish</b>	Restore an old product and bring it up to date	
	<b>R6 Remanufacture</b>	Use parts of discarded product in a new product with the same function	
	<b>R7 Repurpose</b>	Use discarded product or its parts in a new product with a different function	
Useful application of materials	<b>R8 Recycle</b>	Process materials to obtain the same (high grade) or lower (low grade) quality	
	<b>R9 Recover</b>	Incineration of material with energy recovery	

Map the ideas to a R-strategy. For example, better bin signage supports R8. Replacing virgin plastic bags by biodegradeable ones supports R2.





## Appendix D: INITIATIVE DATABASE

Please refer to details of all initiatives in delivered EXCEL file plus [www.zerowasteairport.com](http://www.zerowasteairport.com)



## Appendix E: WORKSHOP HIGH-VOLUME TAG RELEASE

### 1. Introduction:

- Focus on experimenting with various tracking technologies and proxies to efficiently manage waste and secondary materials in an airport ecosystem.

### 2. Technologies for tracking:

- Explore different tagging options such as QR Codes, RFID Tags, Low Energy Bluetooth
- Use proxies like Boarding Passes to estimate waste generation based on passenger numbers and profiles, Flight schedules to predict waste generation patterns, Passenger Load Factors for waste estimation, etc.

### 4. Systems Behind Using Identifiers:

- Data collection and management and Analytics and Reporting
- Security and privacy concerns: Evaluate implications, especially with personal data proxies.

### 5. Testing and Implementation:

- Pilot Projects: Implement pilots for each technology and proxy.
- Cost-Benefit Analysis: Conduct analysis for economic feasibility and ROI.
- Stakeholder Feedback: Gather feedback from airport authorities, waste management companies, and passengers.

### 6. Evaluation of Benefits:

- o Comprehensive Waste Management Strategy:
  - Holistic Approach: By tracking various waste streams (F&B partners, terminal and bathroom bins, construction and demolition, office waste), you can develop a comprehensive waste management strategy. This isn't just about reducing waste but transforming how waste is perceived and handled across the entire airport ecosystem.
  - Big Picture Analysis: Detailed data allows for a 'big picture' analysis, identifying systemic issues and opportunities for large-scale improvements, not just incremental changes.



- Significant Cost Reductions:
  - Economies of Scale in Waste Handling: Detailed tracking leads to more efficient waste segregation and recycling, reducing costs at a scale that impacts the overall budget.
  - Reduced Procurement Costs: Understanding waste generation patterns helps in optimising procurement, potentially leading to significant savings, especially in high-volume areas like construction materials.
- Major Environmental Impact:
  - Substantial Reduction in Landfill Waste: Effective segregation and recycling can significantly reduce the amount of waste going to landfills, making a considerable impact on your environmental footprint.
  - Carbon Footprint Reduction: By reducing waste and enhancing recycling, you can make a marked difference in the airport's carbon emissions, contributing meaningfully to climate change mitigation.
- Innovative Recycling and Upcycling Initiatives:
  - Partnerships for Circular Economy: Detailed tracking can open up opportunities for innovative recycling and upcycling initiatives, potentially transforming waste into valuable resources through partnerships with local businesses or environmental organizations.
  - Pilot Projects for Sustainable Practices: Use the data to initiate pilot projects, like converting food waste into bioenergy or repurposing construction materials, setting benchmarks for the industry.
- Enhanced Operational Efficiency and Predictive Analytics:
  - Streamlined Operations: With better waste data, you can streamline operations, reducing the time and resources spent on waste management.
  - Predictive Waste Management: Use historical data to predict future waste generation, allowing for proactive rather than reactive waste management strategies.
- Strengthening Airport's Reputation and Compliance:
  - Leadership in Sustainability: Detailed tracking positions your airport as a leader in sustainability, enhancing your reputation among airlines, passengers, and regulators.
  - Meeting and Exceeding Regulatory Standards: Being ahead in waste management can ensure compliance with existing and future environmental regulations.

#### 7. Conclusion:

- Summarise findings, highlighting effective technologies and proxies.
- Recommend steps for broader implementation and further research
- Releasing high volume of tags