TULIPS

# EU-ATLAS

## On Circularity in Airports


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# Chapter 1 State of the Art

## 1.1 Introduction

This chapter presents the current state of circular economy (CE) implementation across airport stakeholders, focusing on Europe while drawing from global trends. Airports are complex ecosystems that combine infrastructure, operations, commerce, and partnerships. Their scale and environmental footprint position them as pivotal actors in accelerating the transition toward circularity. This chapter aims to inform airports, airlines, regulators, and sustainability experts about emerging frameworks, practices, and measurement tools driving circular transformation in the aviation sector.

Unlike many other sectors, airports combine infrastructure ownership, operational control, commercial influence, and regulatory responsibility within a single ecosystem. This positions them uniquely as system integrators capable of accelerating circular economy implementation across multiple value chains simultaneously.

# 1.2 Circular Economy Trends, Regulations, and Airports

## 1.2.1 Regulations and Relevant Frameworks

The circular economy is guided by principles of waste prevention, product life extension, resource efficiency, and closed-loop systems.

Airports, as microcosms of cities and mobility hubs, face both challenges and opportunities. They handle large material flows, generate considerable operational and construction waste, and consume substantial resources.

Within Europe, the **EU Green Deal** and **Circular Economy Action Plan (CEAP)** have accelerated the shift toward circular systems. Legislative measures on **waste management, eco-design,** and **sustainable product policy** increasingly shape how airports build, procure, and operate. The CEAP prioritises high-impact sectors such as construction and buildings, positioning airports as key testing grounds for circular infrastructure.

The **Corporate Sustainability Reporting Directive (CSRD – Directive (EU) 2022/2464)** further strengthens accountability by introducing the **European Sustainability Reporting Standards (ESRS)**. In particular, **ESRS E5** addresses Resource Use and Circular Economy, requiring organisations to disclose circular impacts, targets, and material flows under the double-materiality principle - capturing both financial and environmental relevance.

For airports, these regulatory developments translate into three concrete obligations:

1. Increased transparency on material flows across construction and operations.
2. Integration of circular criteria into procurement, concession agreements, and asset management.
3. The ability to demonstrate progress through auditable, comparable indicators.

Circular economy is therefore no longer a voluntary sustainability ambition, but an emerging compliance and governance topic for airport operators.

## 1.2.2 Circular Economy in Aviation

The International Civil Aviation Organization (ICAO) has incorporated circular economy principles into its environmental reports, featuring dedicated sections that outline how airports can reduce resource consumption through circular design and operational practices. Global mechanisms such as **Sustainable Aviation Fuel (SAF)** and **CORSIA** complement this agenda by tackling carbon and resource challenges simultaneously.

The **International Air Transport Association (IATA)** also supports CE objectives through initiatives that reduce waste, improve efficiency, and promote sustainable practices. Its programmes on cabin-waste management, SAF, and voluntary offsetting align with the long-term goal of achieving **net-zero $CO_2$ emissions by 2050**.

**Airports Council International (ACI)**, particularly its Latin America and Caribbean branch (ACI-LAC)[1], has developed a four-step circular-economy framework guiding airports to:

1. Define scope and secure executive commitment.
2. Map resource flows (materials, water, energy).
3. Identify opportunities for reuse, recycling, and waste reduction.
4. Implement actions and monitor outcomes.

Within this landscape, airports increasingly act as the operational anchor between global aviation frameworks and local implementation. While airlines, caterers, and service providers operate across multiple jurisdictions, airports provide the physical, contractual, and data infrastructure where circular practices can be tested, coordinated, and scaled. This makes airports a natural focal point for translating international aviation ambitions into measurable, place-based circular outcomes.

In response to this growing need for coordination, a Circular Airports Working Group was initiated by Royal Schiphol Group in collaboration with EU-funded programmes such as TULIPS[2], Stargate[3], and OLGA[4], and **with the support of ACI Europe**. The Working Group emerged as a practical knowledge-sharing platform where airports could exchange experiences, compare pilots, and discuss common challenges related to circularity, measurement, and regulation. Its informal, practitioner-led nature allowed airports to move beyond theoretical discussions and focus on operational feasibility.

### 1.2.3 Global Trends

Across regions, the circular economy is increasingly framed not as a waste-management agenda, but as a systemic approach to resource security, resilience, and value retention. For airports—complex infrastructures embedded in global supply chains—this shift is particularly relevant. International trends reveal a convergence around digitalisation, innovation in materials and business models, and a growing emphasis on measurable outcomes.

At global level, three overarching trends are shaping how circularity is operationalised in transport hubs and large infrastructure operators:

- **Digitalisation as a circular enabler**

  Digital tools are becoming foundational to circular implementation. Technologies such as Digital Product Passports (DPPs), AI-enabled sorting systems, and IoT-based waste and asset tracking are enabling organisations to move from estimations to evidence-based circular management. These tools improve traceability of materials, support compliance with emerging reporting requirements, and allow organisations to quantify resource inflows, outflows, and value retention.

  For airports, digitalisation is particularly impactful given the diversity of stakeholders and material streams. Digital systems make it possible to connect construction, operations, and waste data across terminals, airlines, and tenants—laying the groundwork for harmonised monitoring and future automation.

[1] Source: 2024-Whitepaper-Circular-economy-in-airports.pdf
[2] Home - TULIPS
[3] Home - Stargate
[4] OLGA | hOListic & Green Airports

- **Shift from linear disposal to value-retention models**

  Globally, circular strategies are moving upstream along the value chain. While recycling remains important, increasing attention is given to reuse, life extension, modularity, and service-based models. Leasing, take-back schemes, and asset retrofitting are gaining traction as ways to preserve material value and reduce dependence on virgin resources.

  In the airport context, this trend is visible in reusable systems for food and beverages, extended lifecycles for vehicles and equipment, and reuse of construction materials. These approaches align with higher-value R-strategies and offer both environmental and operational benefits, including cost avoidance and increased resilience against supply-chain volatility.

- **From ambition to measurable performance**

  A global shift is underway from qualitative commitments to quantitative accountability. Governments, investors, and regulators increasingly expect organisations to demonstrate circular performance through standardised indicators. This is reinforced by sustainability disclosure frameworks and emerging international standards that emphasise material flows, lifecycle boundaries, and system-level impacts.

  For airports, this trend highlights a critical challenge: while many pilots and initiatives exist, measurement practices remain fragmented. The lack of airport-specific, harmonised indicators limits comparability and slows scaling. As a result, global momentum is building around the use of common frameworks—such as ISO standards and circularity metrics—to translate pilots into replicable, credible performance.

**Regional emphasis: Europe**

Within this global context, Europe plays a leading role in translating circular principles into policy-driven action. Key European priorities include:

- Implementation of the Circular Economy Action Plan (CEAP) and eco-design regulations.
- Increasingly stringent recycling, recovery, and waste-reduction targets.
- Focused strategies on packaging, plastics, textiles, and construction materials.
- Development of end-of-waste criteria and secondary-material markets.
- Financial incentives and public-procurement rules that favour circular solutions.

For European airports, these priorities are not abstract policy signals but concrete drivers shaping procurement, infrastructure design, tenant engagement, and reporting obligations. As a result, airports are emerging as practical testbeds where global circular trends are translated into operational reality—often ahead of other sectors.

Airports that align early with these trends are better positioned to scale pilots, comply with future regulation, and integrate circular economy principles into core operational decision-making.

Together, these global and European trends highlight a clear shift from isolated circular initiatives toward integrated, system-level approaches. For airports, this means moving beyond individual projects and addressing circularity across the full airport ecosystem—where infrastructure, operations, commercial activities, and partnerships intersect. To translate these external trends into actionable strategies, it is necessary to structure circular interventions around the core functional domains of the airport.

The following section therefore introduces a practical framework that organises circular economy implementation across terminals, offices, airlines, and construction—reflecting where material flows concentrate and where airports have the greatest ability to act, influence, and scale impact.

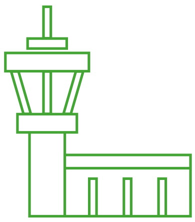
# 1.3 Circular Economy Framework in Airports

Empirical evidence shows that airports apply circular economy principles across four main strategic domains: **Terminals, Offices, Airlines,** and **Construction**.

These domains are not independent silos, but interconnected parts of a single material system. Decisions made in one domain—such as procurement standards in construction or concession requirements in terminals—directly influence material flows, waste generation, and reuse potential elsewhere in the airport ecosystem.

These areas represent the largest material flows and the strongest opportunities for circular interventions.

**Terminal**



As the primary interface with passengers, terminals generate large quantities of consumer waste - food packaging, bottles, and disposable items. Circular strategies include:

- Collaboration with food and retail concessionaires on reusable or recyclable packaging.
- Integration of circular clauses into concession contracts.
- Deployment of on-site sorting, donation, and food-waste separation systems.

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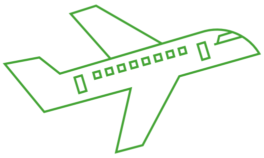
**Offices**

Circularity in administrative and operational spaces focuses on internal procurement and daily consumption:

- Promotion of reusable containers and office materials.
- Inclusion of CE requirements in facility-management contracts.
- Streamlining procurement to prioritise low-impact, durable goods.

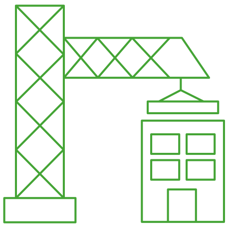
**Airlines**



Airline operations produce major waste streams, especially **cabin waste** on international flights constrained by biosecurity regulations. Circular progress is being made through:

- Joint trials for separate cabin-waste collection.
- Digital traceability systems for waste flow monitoring.
- Advocacy for harmonised international cabin waste rules.

**Construction**



Construction and refurbishment activities offer airports direct control over resource efficiency. Current circular strategies include:

- Embedding CE clauses in design briefs and tenders.
- Reusing materials from deconstruction (e.g. flooring, concrete).
- Promoting modular, demountable infrastructure.
- Tracking materials with digital tools and passports.

The following table summarises the main stakeholders, dominant material flows, and the degree of control or influence airports typically hold in each domain—a key distinction when prioritising circular interventions.

| Area | Stakeholders | Current Main Focus | Airport's Role |
|---|---|---|---|
| **Terminal** | Concessionaires, retail & F&B partners, passengers | Consumer goods (food, packaging, cups, bottles) | Control and influence |
| **Offices** | Facility managers, employees | Office consumables, catering | Control and influence |
| **Airlines** | Airlines, Ground Handlers, Waste Contractors | In-flight products, cabin waste handling | Control and guide |
| **Construction** | Designers, contractors, demolition companies | Reuse of concrete, asphalt, bio-based materials | Control and guide |

Table 1: Circular Economy Focus Areas in Airports

# 1.4 Circular Economy Priorities at Leading EU Airports

In March 2025, a working session with ten major airports—Brussels, Copenhagen, Heathrow, Madrid, Oslo, Paris, Rome, Amsterdam Airport Schiphol, Stuttgart, and JFK—highlighted the diversity of approaches to circularity. Despite differing contexts, four common focus areas emerged: waste management, tenant collaboration, cabin waste, and construction. **Annex 1** presents the main topics discussed during the session and the table below summarises the key circular actions each airport is working on, grouped by functional area.

When mapped against the four functional domains introduced above, the priorities identified by the ten airports show a strong concentration on terminal operations, tenant interfaces, cabin waste management, and construction activities—confirming that circular efforts are emerging first where material volumes, visibility, and airport influence are highest.

| Area | Topic | What Airports Are Working On | Common Challenges |
|---|---|---|---|
| **Terminal and Offices** | Resource Management | AI-enabled sorting; passenger engagement; reusable take-away pilots; donation and recycling schemes. | Space constraints; behavioural barriers; high infrastructure costs; regulatory hurdles. |
| | Tenant Collaboration | Sustainability commitments; food-waste reduction; circular procurement; joint engagement programmes. | Varying tenant maturity; donation-logistics issues; lack of incentives and Key Performance Indicators (KPIs). |
| **Airlines** | Cabin Waste | Separate collection pilots; traceability systems; regulatory advocacy. | Lack of standardisation; complex international rules; limited data flow. |
| **Construction** | Circular Construction | Material reuse; modular design; embodied-carbon tracking; CE tendering. | Limited expertise; cost constraints; unclear ownership models. |

Table 2: Circular Economy Focus Areas and Challenges at 10 Leading Airports

While strategies differ across airports, collaboration and shared learning are vital. Harmonising metrics and frameworks would enable consistent benchmarking and accelerate progress toward shared EU circularity objectives.

# 1.5 Measuring and Monitoring: The Challenge

Despite growing activity, a major gap persists in how circularity is measured within airports. The absence of standardised indicators and datasets impedes comparability and transparency. This section outlines three recognised frameworks that provide a foundation for consistent monitoring.

## The R-Ladder (PBL Netherlands Environmental Assessment Agency)

The R-Ladder classifies circular actions according to their value-retention potential:

**R0 – Refuse** > **R1 – Rethink** > **R2 – Reduce** > **R3 – Reuse** > **R4 – Repair** > **R5 – Refurbish** > **R6 – Remanufacture** > **R7 – Repurpose** > **R8 – Recycle** > **R9 – Recover/Dispose**.

The closer a measure is to R0, the greater its impact. (See **Annex 2** for details.)

## Circularity Gap Report (CGR)

Produced by **Circle Economy**, the CGR remains the most widely adopted global benchmark. Its **Global Circularity Metric (GCM)** measures the share of secondary materials in the total input. Global circularity has dropped from 8.6% in 2021 to 6.9% in 2025, underlining the scale of the challenge.

CGR classifies:

- Input indicators: circular/linear flows, net stock build-up.
- Output indicators: recycled, incinerated, or landfilled flows.

(Summarised in **Annex 3**.)

## ISO 59020 - Measuring and Monitoring Circularity

This international standard provides a structured approach for assessing circular performance at organisational or system level. It measures:

- **Resource inflows** – virgin vs secondary materials.
- **Resource outflows** – reuse, recycling, recovery, and disposal.
- **Boundary and lifecycle context** – defining system scope and value retention.

Further detail appears in **Annex 4**.

Collectively, these frameworks offer a solid foundation for harmonised measurement. However, the aviation sector still lacks airport-specific indicators. Developing a standardized definitions and shared dataset—aligned with ISO 59020 and CGR methodologies—would significantly enhance comparability, transparency, and strategic collaboration among airports.

## Towards a minimum viable measurement set for airports

Based on current practices across the ten airports, an initial, pragmatic measurement baseline could include:

- Total material inflow (virgin vs secondary) for construction projects
- Waste generation per passenger (by major stream)
- Share of reuse and closed-loop recycling in priority streams
- Asset life-extension indicators (vehicles, equipment, infrastructure elements)
- Circular procurement criteria applied (% of tenders)
- $CO_2$ avoided through circular interventions (where robust data exist)

Such a baseline would allow airports to move from qualitative storytelling to comparable, decision-ready circular performance tracking.

# 1.6 Key Takeaways and Implications for Airport Action

European airports are steadily embedding circular economy principles into their operational and strategic agendas. The developments outlined in this chapter show that circularity is no longer an abstract ambition, but an emerging operational reality that cuts across terminals, offices, construction projects, airline interfaces, and procurement practices.

Alignment with EU frameworks such as the Circular Economy Action Plan, the Waste Framework Directive, and the CSRD is accelerating this shift. At the same time, implementation remains uneven. Data availability is limited, definitions differ across countries, and monitoring systems are often not designed to capture circular performance in a comparable or decision-ready way.

Despite these challenges, airports are actively experimenting with digital tools, reuse models, and new governance arrangements. These early initiatives are building practical knowledge, strengthening internal coordination, and clarifying where airports have the greatest leverage to retain material value and reduce dependency on virgin resources.

Overall, the sector is entering a formative phase. Foundational elements—strategies, partnerships, pilot projects, and initial measurement baselines—are now in place. The critical question is no longer whether circularity is relevant for airports, but how it can be implemented at scale, supported by credible data, shared standards, and cross-stakeholder collaboration.

The insights in this chapter provide the analytical backdrop against which operational practice can be assessed. They define the conditions, constraints, and opportunities that shape how circular strategies are translated into real-world airport operations.

## 2.1 Introduction

This chapter shifts from analysis to practice. It presents ten concrete use cases illustrating how European airports are implementing circular economy principles within real operational environments.

The cases span a wide range of airport functions, including construction, terminal operations, cabin waste management, asset life extension, and digital optimisation of resource flows. Each example reflects a specific operational challenge and shows how airports are testing circular solutions under regulatory, safety, spatial, and behavioural constraints.

Rather than showcasing best practices in isolation, the cases are presented as practical experiments. They highlight enabling conditions, trade-offs, data limitations, and organisational learning processes that shape circular implementation in complex airport ecosystems.

Together, these use cases provide an evidence base for understanding how strategic ambitions, regulatory drivers, and measurement frameworks materialise on the ground. They also form the empirical foundation for the cross-case lessons, governance insights, and scaling pathways discussed in Chapter 3.

# 2.2 Amsterdam Airport Schiphol

## Reusing Secondary Materials in Construction


### Airport Profile

Amsterdam Airport Schiphol (Schiphol) is the Netherlands' principal aviation hub, handling **66.8 million passengers** and **1.4 million tonnes of cargo** in 2024. As part of the **Royal Schiphol Group (RSG)**, it aims for full **circularity by 2050**.

Circular design, digitalisation, and value-chain collaboration are central to RSG's sustainability strategy. The group is embedding circular principles into procurement, construction, and infrastructure management, recognising that construction and demolition are among its most material-intensive processes.

### Challenges

Large-scale capital projects and continuous terminal upgrades generate significant material flows. Traditional linear practices often resulted in unused stock, long-term storage costs, and a lack of visibility of available surplus materials.

Meanwhile, EU regulatory shifts—such as the **Corporate Sustainability Reporting Directive (CSRD), Circular Economy Action Plan (CEAP),** and forthcoming **Digital Product Passport (DPP)** requirements—demand transparency, traceability, and measurable reuse. Schiphol recognised that without a digital system to map surplus materials, valuable resources were being lost, both environmentally and financially.

### Pilot Description

In 2024, Schiphol partnered with **Heijmans** (construction partner) and the **Excess Material Exchange (EME)** digital platform as part of TULIPS, to test a **digital marketplace for secondary construction materials**.

The pilot created a structured approach for identifying, cataloguing, and reusing materials from ongoing or completed works:

- **Material inventory:** Surplus items (e.g. flooring, lighting fixtures, furniture, tiles) were photographed, measured, and uploaded to the EME platform.
- **Digital passports:** Each item received a QR code with embedded information on composition, quantity, condition, and reuse potential.
- **Matching and exchange:** Project managers could reserve materials for new works or maintenance.

- **Tracking:** Logistics and storage data were managed through Schiphol's **warehouse**, ensuring full traceability and accountability.

The pilot ran for six months and focused on a few cubic meters of materials stored in the warehouse. Although limited in duration and scope, it successfully embedded circularity into project management systems—reducing dependence on virgin materials and enhancing cross-departmental collaboration.

## Measures and Outcomes

Results were both quantitative and qualitative:

- **450 materials identified, 320 digital passports created,** and **347 items reused**
- **9.4 tonnes of $CO_2$** avoided through avoided production of new materials
- **3.7 tonnes of avoided waste**
- **€49,000** saved in procurement
- Enhanced transparency between the asset, construction, and sustainability teams

The initiative validated the use of digital tools to measure **resource inflows and outflows**, consistent with **ISO 59020** and **CGR input indicators.** This pilot serves as a strong example of RSG's data-driven approach to circularity—simultaneously advancing business goals, such as cost savings, and sustainability objectives, like material reuse.

This positions Schiphol as a **reference case**, not just one example.

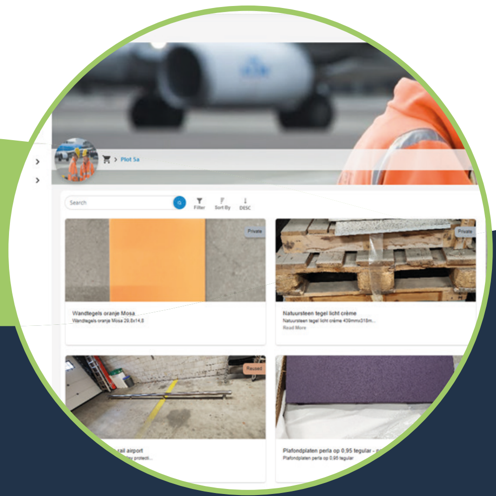
## Next Steps and Replicability

Over the coming years, the goal is **to integrate secondary material data** into Schiphol's databases and extend the system across all RSG airports. By 2035, the airport aims to embed a reuse system into every project tender, making circularity a default part of procurement.

This pilot offers a replicable model for large airports seeking to operationalise CEAP and CSRD principles. It also supports the **EU Green Public Procurement (GPP)** framework, showing that circularity and cost efficiency can align. This also aligns with **ESRS E5** reporting requirements and **strategic frameworks** like ISO 59020, the Circular Economy Action Plan, and the EU Green Deal (including, Digital Product Passport, DDP).

**R-Ladder correlation:** R2 Reduce --> R3 Reuse

**Frameworks:** ISO 59020 (in/out flows); CGR (input stock)



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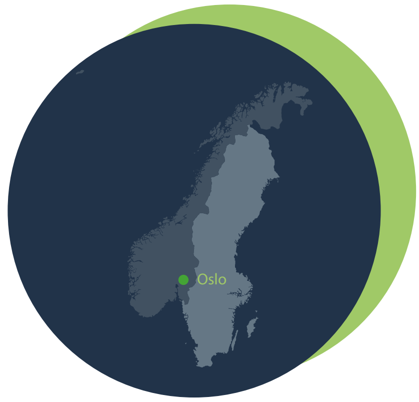
# 2.3 Avinor Oslo Airport

## From Waste to Re-Use: Confiscated Rechargeable Batteries




### Airport Profile

Oslo Airport (OSL) is Norway's largest airport, managed by **Avinor**, serving **26.4 million passengers** in 2024. Oslo Airport's sustainability strategy targets **Zero Waste by 2030**. Circularity plays a central role in waste management, procurement, and resource management.

### Challenges

In 2025 airport security confiscated ca **4 tonnes (around 13 700 pieces)** of lithium-ion batteries and power banks from checked-in luggage due to IATA Dangerous Goods restrictions. It is a **50% increase** compared to the year before. While functional, these items were sent directly to recycling, resulting in unnecessary resource loss and disposal costs.

Storage constraints, fire-safety standards, and lack of legal reuse pathways hindered revalorisation. Avinor aimed to find a compliant, safe, and economically viable method to reintroduce functional items into circulation.

### Pilot Description

In 2025, Avinor partnered with a certified Norwegian electronics reseller to implement a **battery re-use pilot**. The process combined security compliance with material recovery:

- Confiscated batteries were placed in **fire-safe "safebox" containers** compliant with international rules of road transport of hazardous materials.
- Containers were regularly collected by the partner, who tested each unit for functionality and safety.
- Working batteries have been sold through bulk re-sale agreements.
- Avinor received detailed data on battery type, weight, and fate.

The initiative required collaboration between security teams, the environmental department, and the external partner, ensuring both safety and circular integrity. This strengthens its relevance for **policy and safety-constrained environments**.

## Measures and Outcomes

- Shifted waste management from **R8 Recycle** to **R3 Reuse**.
- **≈900 kg waste avoided** and **€4,000** saved in disposal costs.
- Reduced carbon emissions by 1,142,800 kg $CO_2$ equivalent.
- Secured re-use of 2855 power banks, tool batteries and camera batteries.

This project demonstrated that even high-risk waste streams can be safely incorporated into circular models when proper protocols and partnerships are in place.

## Next Steps and Replicability

Oslo Airport aims to reduce the need for confiscation of batteries by information campaigns towards passengers and seeks to achieve 95% re-use rate by 2030. This pilot offers a blueprint for **safety-regulated reuse** applicable to other transport hubs and aligns with the **EU Waste Framework Directive** and **ESRS E5** reporting requirements.

**R-Ladder correlation:** R3 Reuse

**Frameworks:** ISO 59020 (outflows); CGR (reuse metrics)

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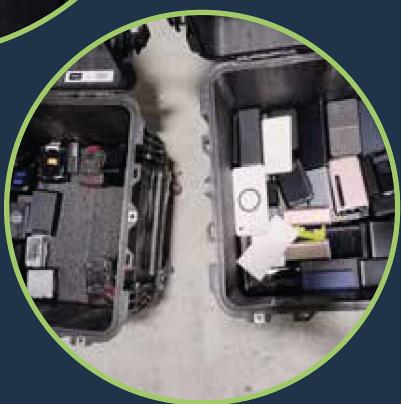
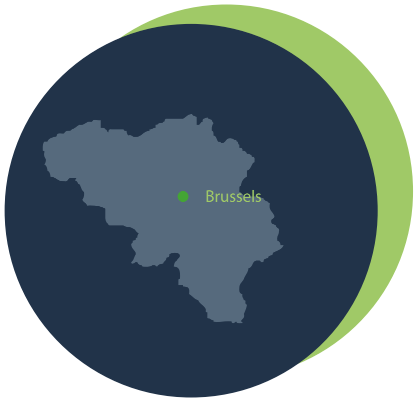


# 2.4 Brussels Airport

## Less Waste, More Value




### Airport Profile

Brussels Airport Company operates Belgium's national airport, handling **23.6 million passengers** and **733,000 tonnes of freight** in 2024. Around **64,000 employees** work on-site, representing airlines, logistics, and service providers.

Its **Shift 2027 strategy** focuses on five pillars: decarbonisation, circularity, local environmental quality, intermodal connectivity, and social inclusion. Under this framework, circular economy efforts are embedded in procurement, waste management, and tenant collaboration, aligning with EU objectives under **CEAP 2.0** and **CSRD**.

### Challenges

Brussels Airport's ecosystem involves numerous F&B operators, retailers, and cleaning contractors, each with distinct supply chains and operational routines. Implementing circularity required unified logistics, consistent data collection, and cultural change across partners.

The airport identified disposable coffee cups as a **visible, high-volume waste stream** and a strong candidate for reuse innovation. Achieving reduction would require collaboration across multiple stakeholders while maintaining hygiene, convenience, and passenger satisfaction.

### Pilot Description

In 2025, Brussels Airport launched a **Proof-of-Concept (POC)** as part of the **EU Stargate Project**, testing **reusable coffee cups** across selected F&B outlets.

**System design and operation:**

- Passengers and staff receive a reusable cup with their beverage purchase.
- After use, cups can be returned at designated **return points** throughout the terminal.
- Cups are washed at a central facility compliant with food-safety and hygiene standards.
- A digital system tracks usage, return rates, and losses to measure environmental impact and operational efficiency.

The airport coordinated F&B tenants, cleaning services, and sustainability teams to manage the logistics chain.

## Measures and Outcomes

Performance indicators include:

- **Return rate** of cups (% of cups returned).
- **Operational efficiency** (washing turnaround, logistics).
- **Stakeholder engagement** (participation rate among outlets).
- **Passenger acceptance** (survey results).

Tenants appreciated the airport's leadership and logistical support.

This PoC fostered a shared circular culture.

## Next Steps and Replicability

The airport plans to extend the system airport-wide, incorporating more outlets, reusable tableware, and smart-incentive models. Data will be integrated into Brussels Airport's sustainability dashboard for CSRD reporting.

The pilot demonstrates that multi-tenant reuse systems are operationally feasible when backed by leadership, data, and collaboration—setting a precedent for other European airports.

**R-Ladder correlation:** R2 Reduce --> R3 Reuse

**Frameworks:** ISO 59020 (resource outflows); CGR (reuse metrics)



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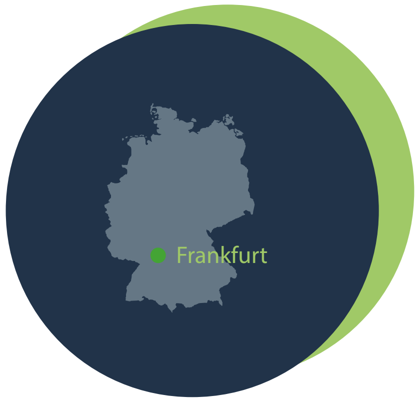
# 2.5 Frankfurt Airport

## Closing the Loop on Cabin PET Bottles




### Airport Profile

Frankfurt Airport, operated by Fraport AG, is Germany's largest airport and one of Europe's leading aviation hubs, serving approximately 63.2 million passengers and handling around 2.1 million tonnes of cargo in 2025.

As the primary hub for Lufthansa and the Star Alliance, it plays a central role in international air traffic. Fraport AG aims to achieve net-zero greenhouse gas emissions at Frankfurt Airport by 2045. Circular economy principles support this ambition through waste reduction, high-quality recycling, and collaboration across the aviation value chain.

### Challenges

Growing passenger volumes and expanding operations result in increasing amounts of waste generated across airport activities, including packaging and catering waste from aircraft cabins. Without targeted intervention, a significant share of this material would be incinerated, leading to material loss, avoidable emissions, and rising waste management costs.

Plastic beverage bottles represent a high-volume, high-visibility waste stream linked directly to the passenger journey. While technically recyclable, effective recovery depends on separation at source and coordination between airlines, ground handling, and recycling partners. The challenge was therefore to establish a closed-loop system that enables high-quality recycling while fitting within strict operational and safety constraints on the apron.

### Pilot Description

Frankfurt Airport implemented a closed-loop recycling pilot for PET bottles collected from Lufthansa aircraft after landing. During aircraft servicing on the apron, specialised staff from Airport Service Gesellschaft mbH (ASG), a Fraport subsidiary working on behalf of Lufthansa, separate PET bottles left in the cabin from other waste streams.

The collected bottles are transported to a regional recycling partner, Hassia Mineralquellen in Bad Vilbel. There, the material is cleaned, processed into PET granulate, and converted into new preforms for beverage bottles. These preforms are refilled and reintroduced into the supply chain, including use on future flights. This approach maintains material quality and avoids downcycling, enabling repeated use of the same resource.

Based on current Lufthansa traffic, the system enables the recovery of up to four million PET bottles per year, with potential to scale to higher volumes as processes are further optimised.

## Measures and Outcomes

- Approximately 4 million PET bottles recycled annually, equivalent to around 72 tonnes of material.
- Significant reduction of waste sent to incineration.
- Avoided emissions associated with virgin plastic production and waste treatment.
- Demonstrated feasibility of a closed-loop recycling system integrated into aircraft turnaround processes.
- High visibility of circularity at a key point in the passenger journey.

By maintaining material quality and avoiding downcycling, the initiative demonstrates how high-volume recycling streams can be upgraded into true circular loops.

## Next Steps and Replicability

The next phase focuses on scaling the system towards higher recovery volumes and expanding closed-loop cooperation across additional routes or partners. The initiative demonstrates how collaboration between airports, airlines, ground handlers, and recyclers can enable high-quality material loops within aviation operations.

The model is transferable to other hub airports with sufficient traffic volumes and offers a replicable pathway for integrating circular economy principles into cabin waste management.

**R-Ladder correlation:** R8 Recycle

**Frameworks:** ISO 59020 (resource outflows)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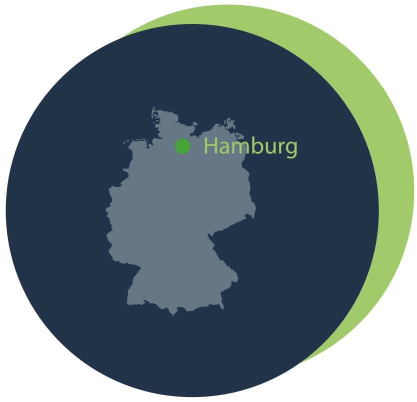
# 2.6 Hamburg Airport

## Extending Vehicle Lifecycles Through Hydrogen Conversion




### Airport Profile

Hamburg Airport is the largest international commercial airport in northern Germany and the fifth largest nationwide, serving approximately 14.8 million passengers in 2024.

The airport has been carbon neutral since 2021 and holds Airport Carbon Accreditation Level 3+. With its "Net Zero 2035" climate strategy, Hamburg Airport aims to eliminate $CO_2$ emissions by 2035. Implementation is structured around four pillars: heating supply, electricity supply, energy efficiency, and vehicle conversions. Circular economy principles support this strategy by prioritising life extension of assets, efficient use of materials, and the integration of low-emission technologies across airport operations.

### Challenges

Hamburg Airport operates a large and diverse fleet of ground support vehicles that are essential for daily operations. Many baggage tractors have been in service for decades, leading to increasing maintenance requirements, reduced reliability, and limited availability of spare parts. Replacing the full fleet would result in the disposal of significant quantities of high-quality materials, such as steel, and generate additional environmental impacts associated with manufacturing new vehicles.

At the same time, while existing baggage tractors already operate on compressed natural gas (CNG), meeting long-term climate targets requires a transition towards zero-emission propulsion. The challenge was therefore to identify a solution that reduces emissions, preserves material value, and ensures operational continuity within the demanding environment of airport ground handling.

From a circular economy perspective, the key question was whether emissions reduction could be achieved while preserving the material value embedded in existing assets.

### Pilot Description

Hamburg Airport launched a pilot to convert an existing CNG-powered baggage tractor to hydrogen propulsion rather than replacing the vehicle. The conversion was carried out by HTM Hydro Technology Motors and combines a hydrogen combustion engine with an electric drive system. This hybrid configuration enables continued use of existing vehicle structures while integrating low-emission propulsion technology.

Refuelling is conducted directly at the airport using a mobile hydrogen refuelling unit supplied by Ryze Power, providing exclusively green hydrogen. To minimise operational and safety risks, only one baggage tractor was retrofitted during the pilot phase. This allowed the airport to test performance, safety procedures, refuelling logistics, and operational suitability without disrupting passenger or freight handling. The approach extends vehicle lifespan, conserves materials, and reduces costs compared to purchasing new equipment.

## Measures and Outcomes

During testing, the converted baggage tractor demonstrated performance comparable to CNG-powered units. Driving behaviour, energy consumption, and noise levels were similar, confirming suitability for routine airport operations.

By using green hydrogen, $CO_2$-related emissions are close to zero. Only minor combustion-related emissions remain, which will be measured and monitored in subsequent phases to support transparent environmental reporting. The pilot demonstrated that hydrogen conversion is a technically viable and circular alternative to vehicle replacement for specific ground support equipment.

## Next Steps and Replicability

Building on positive results, Hamburg Airport plans to convert additional baggage tractors and progress towards a higher-capacity hydrogen refuelling station. Scaling hydrogen-powered ground operations can support economies of scale in hydrogen demand, strengthening the business case for hydrogen infrastructure at airports.

The project illustrates how retrofitting existing assets can simultaneously support circular economy objectives and long-term decarbonisation strategies, offering a replicable pathway for other airports managing aging vehicle fleets.

**R-Ladder correlation:** R3 Reuse

**Frameworks:** ISO 59020 (resource outflows)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# 2.7 Heathrow Airport

## Eliminating Single-Use Coffee Cups through Circular Innovation


### Airport Profile

Heathrow is the United Kingdom's largest airport, connecting to over **230 destinations in 85 countries** and handling **around 200,000 passengers daily**. With **80,000 colleagues** working at the airport, it is a small city in itself and a key driver of the UK economy.

Through its sustainability strategy, **Connecting People and Planet**, Heathrow aims to 'Avoid material consumption, and maximise reuse, recycling and recovery of materials used at Heathrow'. Reducing single-use materials and transitioning towards reuse systems are central to the strategy, which complements its net-zero ambition.

### Challenges

Heathrow identified disposable coffee cups as a high-impact waste stream, with **11–13 million cups** discarded annually across terminals and offices. Despite being recyclable in theory, contamination with liquid and lids make most unrecyclable.

Addressing this issue across the airport requires balancing **hygiene, convenience, and behavioural change** in a high-turnover environment. The airport therefore launched a pilot in its main administrative hub, the **Compass Centre**, to test how a reuse system could function effectively before extending it to passenger areas.

### Pilot Description

In **2024**, Heathrow introduced a **reusable-cup system** in partnership with **Eurest** (catering provider) and **CauliBox** (circular packaging start-up). The **CauliCup**, a durable polypropylene cup usable up to **400 times** before being remanufactured into new products, replaced disposable cups across the Compass Centre cafés.

Staff obtained their drink in a CauliCup, scanned a **QR code** to register a £1 refundable deposit, and returned the cup at smart kiosks located throughout the campus. Returned cups were washed in industrial dishwashers using **water-efficient commercial dishwashers** than single-use systems.

A digital dashboard monitored usage, return rates, and environmental savings, while internal communications, posters, and storytelling campaigns encouraged participation and made the results visible.

## Measures and Outcomes

The pilot quickly demonstrated both operational and environmental benefits:

- **78,885 single-use cups avoided** within nine months.
- **≈2.1 tonnes of $CO_2$** and **28,200 litres of water** saved.
- Noticeable reduction in littering and collection costs.

Real-time feedback and visible impact fostered strong user engagement and normalized circular habits. Internally, it enhanced cross-departmental collaboration and showed how circular criteria can be embedded in supplier contracts. By voluntarily aligning with EU and UK plastics initiatives, Heathrow positioned itself as a frontrunner in operational circularity.

## Next Steps and Replicability

Following the success of the Compass Centre pilot, Heathrow plans to expand the reuse system across all colleague restaurants in the operations and trial a reusable coffee cup solution in passenger facing areas in 2026.

Heathrow's experience provides a replicable model for large airports seeking to combine operational rigour, digital monitoring, and visible cultural change.

**R-Ladder correlation:** R2 Reduce --> R3 Reuse

**Frameworks:** ISO 59020 (resource outflows); CGR (reuse metrics)



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# 2.8 Marco Polo Airport Venice

## Reduce, Reuse, Recycle: The Road towards Airport Circularity


### Airport Profile

VeneziaAirport

Venice Marco Polo Airport (VCE) serves as northern Italy's principal international gateway. In 2024 it welcomed nearly **12 million passengers**, operating as part of the **SAVE Group**, which also manages Treviso, Verona, and Brescia airports.

The airport holds **Airport Carbon Accreditation Level 4+** and is firmly committed to achieving **Net Zero and Plastic-Free operations by 2030**. Circular economy (CE) principles are a core component of its sustainability strategy, aligning with both national and EU climate goals and with Veneto's regional innovation agenda.

### Challenges

Rapid passenger growth—forecast to double by 2037—creates mounting pressure on resources, particularly single-use packaging and water. Waste segregation performance varied between tenants, and limited space restricted infrastructure upgrades.

The surrounding lagoon ecosystem makes water use and pollution especially sensitive. The airport needed to modernise waste-collection logistics, encourage tenant participation, and use technology to improve data quality and decision-making.

### Pilot Description

Rather than addressing a single waste stream, this programme combined multiple circular levers into an integrated operational approach. VCE developed a **multi-component circular programme** combining reduction, reuse, recycling, and water efficiency:

- **Reusable mugs and plastic elimination:** Employees received cups made from recycled plastic; all F&B tenants replaced disposable tableware with aluminium cutlery and glass cups.
- **Enhanced segregation:** A new **door-to-door waste-collection system** introduced differential fees, rewarding high sorting rates and penalising contamination.
- **Smart waste bins:** AI-enabled bins recognise materials and advise users in real time to improve accuracy.
- **Water recycling:** A refurbished treatment plant now recovers 82 % of the 318 $m^3$ freshwater withdrawn daily for non-potable uses (e.g. toilets, landscaping).

The initiative was implemented in phases between 2023 and 2025, with strong support from local authorities and suppliers.

## Measures and Outcomes

- Residual waste reduced annually since 2023; target **–70 % by 2035.**
- Consistent decline in PET and mixed packaging.
- AI bins improved sorting accuracy by > 40 %.
- Recycled water substituted > 80 % of non-potable needs.

Tenant engagement improved markedly through transparent feedback and differentiated invoicing. The project demonstrates how digitalisation and behavioural nudging can coexist with operational efficiency.

Measurement is aligned with **ISO 59020 (in/out flows)** and **CGR output indicators**; performance feeds into SAVE Group's ESG reporting and CSRD readiness.

## Next Steps and Replicability

The next phase (2025–2030) aims for 90 % water reuse and smart bins across all terminal areas. VCE's experience offers a template for medium-sized airports to achieve significant circular gains through integrated digital and infrastructural approaches.

**R-Ladder:** R2 Reduce --> R3 Reuse --> R8 Recycle

**Frameworks:** ISO 59020 (in/out); CGR (output flows)


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# 2.9 Rome Fiumicino Airport

## Boosting Circularity with AI-Powered Smart Bins


### Airport Profile

Rome Fiumicino Airport (FCO), Italy's largest and most connected international hub, serves more than 50 million passengers annually and proudly holds the prestigious 5-star Skytrax rating. ADR leads in innovation and sustainability, targeting Net Zero emissions by 2030 and maximizing resource efficiency through circular strategies with strong partnerships.

AEROPORTI DI ROMA

### Challenges

Fiumicino embraces the opportunity to enhance waste separation in its vibrant, multicultural environment. By engaging diverse travelers and leveraging innovative solutions, ADR turns everyday passenger journeys into moments for positive environmental impact, promoting circularity and resource recovery as integral parts of the airport experience.

### Pilot Description

To improve waste separation in a multicultural airport, ADR partnered with Nando, an AI-based startup incubated at the Innovation Hub in Terminal 1, to pilot smart bins in busy terminal areas. These bins use sensors and an AI engine—trained on over 200,000 images—to recognize 72 waste types and provide real-time visual sorting instructions.

The system helps travelers quickly identify the correct bin, raising awareness about recycling and circularity. Additional benefits include real-time monitoring of bin fill levels and using bin areas for sustainability messaging.

## Measures and Outcomes

Passengers respond effectively to instructions when they are visual, immediate, and clearly positioned:

- +60 % improvement in correct plastic sorting.
- +48 % improvement in paper cup segregation.
- +36 % improvement in bag tags and receipts segregation.
- 80% passenger satisfaction rating

Big data showed potential to recover >90 % of mixed waste if scaled airport-wide.

This AI-driven approach also provides a rich dataset for aligment with ISO 59020 (outflows) and CGR (output flows) metrics. Beyond improved sorting, the system generated a granular dataset that supports ISO 59020-aligned monitoring and future predictive waste management.

## Next Steps and Replicability

ADR is rolling out the solution to approximately 100 bins across Rome Fiumicino terminal. The initiative demonstrates how digital innovation and behavioral nudging can turn infrastructure into a driver of circularity and passenger engagement.

**R-Ladder:** R7 Repurpose --> R8 Recycle

**Frameworks:** ISO 59020 (outflows); CGR (output flows)


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# 2.10 Rotterdam The Hague Airport

## Optimising Collection of Deposit PET Bottles and Metal Cans


### Airport Profile

Rotterdam The Hague Airport (RTHA) is a regional gateway within **Royal Schiphol Group**, serving around **2.2 million passengers** per year. It is pursuing **Zero $CO_2$ in ground operations by 2030, full circularity by 2050.**

Rotterdam The Hague Airport

With **ACA Level 5** certification, RTHA is a testbed for sustainable aviation solutions within the group.

### Challenges

In 2023, the Dutch government extended its **deposit-return scheme (statiegeld)** to include metal cans. Passengers expected return facilities within the airport, yet existing bins lacked refund functions and contamination of mixed plastics remained high.

The airport needed a solution that complied with national legislation, encouraged proper sorting, and enhanced its social responsibility profile.

### Pilot Description

In 2024, RTHA partnered with **Statiegeld Nederland** and charity **Stichting Jarige Job**[5] to launch a **deposit-return system** combining dedicated bins and reverse-vending machines (RVMs):

- Separate PET and can bins placed air- and land-side.
- An RVM in Departures allows passengers to claim refunds or donate to the charity.

### Measures and Outcomes

- ≈ **29 000 items** collected in the first year (11 400 via RVMs; 17 400 via bins).
- **€ 3 000** donated to Stichting Jarige Job.
- Notable reduction in contamination of mixed plastics.
- Positive feedback from passengers and local media.

The project proved how environmental and social value can be linked in one system, aligning with **EU Packaging and Packaging Waste Directive revision** goals.

[5] **Stichting Jarige Job** is a Dutch non-profit organization based in Rotterdam that ensures children living in poverty can celebrate their birthdays

The initiative illustrates how national circular policies can be operationalised locally through simple, visible infrastructure solutions.

## Next Steps and Replicability

A second RVM has been installed pre-security to increase coverage. The model is replicable for regional airports seeking low-cost, high-impact circular actions.

**R-Ladder:** R8 Recycle

**Frameworks:** ISO 59020 (outflows); CGR (input flows)


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# 2.11 Stuttgart Airport

## Closing a Persistent Residual Waste Loop


### Airport Profile

Stuttgart Airport (STR) is the largest airport in Baden-Württemberg, serving a catchment area of over 19 million people. Its network focuses mainly on European destinations with connections to international hubs.

Sustainability is embedded in the STRzero programme, which targets net-zero greenhouse gas emissions by 2040. Circular economy principles support waste reduction, resource efficiency, and environmental performance across airport operations.

### Challenges

Waste volumes at Stuttgart Airport fluctuate with passenger numbers and evolving regulatory requirements. Beyond reducing total waste generation, the airport identified the need to improve the treatment of specific residual streams that are difficult to prevent at source and largely driven by passenger behaviour in public areas.

One such stream is cigarette butts, which are generated throughout outdoor and semi-outdoor areas of the terminal. Cigarette butts contain plastic filters and toxic substances and were traditionally disposed of via incineration, resulting in material loss and avoidable emissions. Due to their dispersed generation and dependence on individual behaviour, prevention options are limited. The challenge was therefore to improve how cigarette butts are treated after collection, reducing environmental impact while remaining operationally feasible.

### Pilot Description

In October 2024, Stuttgart Airport launched a pilot to enable the separate collection and recycling of cigarette butts, in partnership with a specialised recycling company based in France. Cigarette butts are collected via existing ashtrays across the terminal and transferred to dedicated barrels. These barrels are shipped quarterly to the treatment facility.

At the facility, cigarette butts undergo a controlled recycling process. Tobacco remnants are separated and treated, while the plastic filters are thoroughly cleaned to remove hazardous substances. The cleaned material is then processed into a solid secondary raw material, which is used to manufacture durable urban products such as benches, bins, and ashtrays. The recycling partner provides regular reporting on quantities treated and environmental performance.

## Measures and Outcomes

Over a ten-month period, three shipments were completed. Initial implementation required changes to cleaning routines, as cigarette butts had previously been disposed of as general waste. Once procedures were embedded, the pilot delivered measurable outcomes:

- 900 kg of cigarette butts collected separately
- Approximately 2 tonnes $CO_2$ equivalent avoided compared to incineration

The initiative represents a shift from R9 (Recover) to R8 (Recycle) on the R-ladder.

## Next Steps and Replicability

Following positive results, the pilot has been extended. Stuttgart Airport aims to increase the capture rate of cigarette butts and improve awareness around correct disposal. As a next step, a bench produced from recycled cigarette butts is planned for installation in public areas, linking waste prevention behaviour with a tangible circular outcome.

The project demonstrates that even small, behaviour-driven and environmentally harmful waste streams such as cigarette butts can be integrated into circular models through targeted partnerships and clear operational processes.

**R-Ladder correlation:** R8 Recycle

**Frameworks:** ISO 59020 (resource outflows)

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# 2.12 Summary and Insights

The following table consolidates the ten use cases, highlighting how different circular strategies translate into measurable outcomes across airport functions:

| Airport | Project Title | Goal / Scope | Key Results | Indicators Used | Main Contribution | Area | Topic | Relevant Frameworks |
|---|---|---|---|---|---|---|---|---|
| **Amsterdam Airport Schiphol** | Reusing Secondary Materials in Construction | Digital marketplace for surplus materials | 347 items reused; 9.4 t $CO_2$ and €49 k saved | $CO_2$ savings, reuse rate | Circular construction and digital tracking | Construction | Circular Construction | R2–R3; ISO 59020 (in/out); CGR (input) |
| **Avinor Oslo** | Re-Use of Confiscated Batteries | Recover usable electronics via reseller | 900 kg waste avoided; €4 k saved | Weight avoided, reuse rate | Safe reuse of hazardous materials | Terminal | Resource Management | R3; ISO 59020 (outflows); CGR (reuse) |
| **Brussels Airport** | Less Waste, More Value | Reusable cup system across F&B outlets | High return rates; strong tenant collaboration | Reuse rate, partner participation | Scalable airport-wide reuse model | Terminal | Tenant collaboration | R2–R3; ISO 59020 (outflows); CGR (reuse) |
| **Hamburg Airport** | Hydrogen Conversion of Baggage Tractors | Extend vehicle lifetime through hydrogen retrofit | Comparable performance to CNG; near-zero $CO_2$ using green hydrogen | Operational performance; emissions | Asset life extension through conversion | Terminal (Ground Operations) | Resource Management | R3; ISO 59020 (outflows) |
| **Heathrow (London)** | Eliminating Single-Use Coffee Cups | Reuse pilot at head office | 78 885 cups avoided; 2 t $CO_2$ saved | Items avoided, $CO_2$ savings | Behavioural change for reuse | Offices --> Terminals | Resource Management | R2–R3; ISO 59020 (outflows); CGR (input) |
| **Frankfurt Airport** | Closed-Loop Recycling of Cabin PET Bottles | Closed-loop recycling of PET bottles from aircraft cabins | ~4 million bottles/year; ~72 t material recycled | Items recycled; material weight | High-quality closed-loop recycling at source | Airlines | Resource Management | R8; ISO 59020 (outflows); |
| **Marco Polo (Venice)** | Reduce, Reuse, Recycle | Reusable consumables + AI waste systems | 70 % residual-waste reduction target by 2035 | Sorting performance | Plastic reduction and AI monitoring | Terminals & Offices | Resource Management | R2–R8; ISO 59020 (in/out); CGR (output) |

| Airport | Project Title | Goal / Scope | Key Results | Indicators Used | Main Contribution | Area | Topic | Relevant Frameworks |
|---|---|---|---|---|---|---|---|---|
| **Rome Fiumicino** | AI-Powered Smart Bins | Improve sorting accuracy with AI | +60 % plastic; +48 % paper sorting | Sorting accuracy, satisfaction | Behavioural and digital innovation | Terminals | Resource Management | R7–R8; ISO 59020 (outflows); CGR (output) |
| **Rotterdam The Hague** | Deposit PET & Cans Collection | Reverse-vending machines + charity | 28 800 items collected; €3 000 donated | Items collected, donation value | Monostream collection + social impact | Terminals | Tenant Collaboration | R8; ISO 59020 (outflows); CGR (input flows) |
| **Stuttgart Airport** | Closing a Persistent Residual Waste Loop | Separate collection and recycling of cigarette-related waste | 900 kg collected; ≈2 t $CO_2$e avoided vs incineration | Weight collected; $CO_2$ avoided | Upgrading treatment of behaviour-driven residual waste | Terminal | Resource Management | R8; ISO 59020 (outflows) |

Table 3: Comparative table

Across Europe, airports are moving beyond isolated waste initiatives towards systemic, value-chain-oriented resource management. The ten case studies reveal six consistent patterns:

1. **Visibility creates impact**. Highly visible interventions along the passenger journey (Brussels, Heathrow, Frankfurt, Stuttgart) support behavioural change, improve sorting quality, and strengthen trust in circular solutions.
2. **Digital data enable evidence**. Schiphol, Venice, and Rome demonstrate how AI, digital marketplaces, and smart systems translate circular ambitions into measurable performance and decision-ready insights.
3. **Asset life extension matters.** Hamburg and Avinor show how reuse and retrofitting of existing assets can deliver both resource efficiency and emissions reductions, even in safety-critical or regulated environments.
4. **Collaboration is a force multiplier**. Brussels, Rotterdam, Frankfurt, and Avinor illustrate how partnerships between airports, airlines, tenants, service providers, and recyclers accelerate implementation and scaling.
5. **Measurement frameworks build credibility.** The use of ISO 59020, CGR, and ESRS-aligned indicators enables comparability, supports CSRD reporting, and shifts circularity from narrative to verifiable performance.
6. **Structural challenges remain.** Data fragmentation, regulatory variation, infrastructure constraints, and behavioural inertia continue to limit speed and scale across airports.

Together, these ten airports establish a coherent European baseline for circular practice—demonstrating that with leadership, cross-value-chain collaboration, and robust data, the aviation sector can transition from linear operations towards circular, measurable, and increasingly regenerative systems.

Chapter 3 builds on this evidence to synthesise lessons learnt, assess measurement and governance challenges, and outline pathways for scaling circular practices across the European airport sector.

# Chapter Conclusions

## 3.1 Overview

The ten airport cases presented in the previous chapter confirm that circular economy implementation in aviation is no longer experimental. Across Europe, airports are translating circular principles into operational decisions that shape infrastructure development, procurement, concession management, and daily operations.

Collectively, the cases demonstrate that airports are not merely locations where circular initiatives take place, but **system orchestrators**. By combining infrastructure ownership, procurement power, operational control, and stakeholder coordination, airports are uniquely positioned to translate circular economy policy into place-based, measurable outcomes across complex value chains.

This represents a significant shift. Until recently, circularity in aviation was largely framed as a waste-management or compliance topic. The cases in this Atlas show a transition toward **strategic circularity**, embedded in asset management, contractual frameworks, data systems, and governance processes. Circularity is increasingly treated not as a standalone sustainability initiative, but as an operational capability that supports resilience, efficiency, and long-term value creation.

Most initiatives currently operate in the low-to-mid range of the R-ladder (R2–R8), focusing on reduction, reuse, and recycling once assets or materials are already in use. This is a natural and necessary phase for a sector building confidence, testing feasibility, and establishing data baselines. These actions provide the learning foundation required to move upstream toward higher-value strategies such as redesign, refurbishment, and prevention at source.

This chapter synthesises the collective meaning of the ten cases. While Chapters 1 and 2 addressed the strategic context and practical implementation of circularity, Chapter 3 focuses on the **"so what"**: what these experiences reveal about how circularity can be governed, measured, harmonised, and scaled across the European airport sector.

The synthesis is structured around five themes:

1. Lessons learnt and emerging principles
2. Indicators and measurement
3. Harmonisation with EU policy and regulation
4. Governance, skills, and collaboration
5. Future outlook and strategic acceleration

# 3.2 Lessons Learnt

## Circularity Works When It Is Practical and Visible

The most effective circular initiatives are those that are operationally visible, intuitive, and directly experienced by users. Projects such as Brussels Airport's reusable-cup system, Heathrow's Compass Centre pilot, Frankfurt's closed-loop PET recycling, and Rome's AI-powered bins show that visibility accelerates participation, improves sorting quality, and builds trust in circular systems.

Airports are uniquely positioned in this respect. Millions of passengers and thousands of staff interact daily with airport infrastructure, making terminals powerful environments for normalising circular behaviour. When circularity is embedded into everyday interactions—returning a cup, sorting waste with AI guidance, or seeing reused materials in new construction—it becomes tangible rather than abstract.

At the same time, most visible initiatives remain concentrated in the R2–R8 range, addressing waste and assets once they exist. The next leap in impact will require moving upstream, embedding circular principles into design briefs, procurement criteria, and concession agreements—before waste is created. The current generation of visible pilots is therefore best understood as **enabling infrastructure for future systemic change**, not as an end state.

**Design principle:** Circular interventions should be designed to be operationally visible, not hidden in back-of-house processes.

## Behavioural Change Underpins Success

Across all ten cases, technology alone did not deliver results. Every successful initiative combined infrastructure or digital innovation with deliberate behavioural design. Airports that achieved high return rates or improved sorting accuracy invested in clear instructions, intuitive systems, and feedback loops that made correct behaviour easy.

Unlike many other infrastructures, airports repeatedly expose the same users—employees, tenants, frequent travellers—to circular systems. This repetition creates strong conditions for habit formation over time. Rome's AI bins, for example, improved sorting accuracy by more than 40% by providing immediate, visual guidance at the moment of disposal.

In multi-tenant environments, behavioural alignment takes time. However, airports are increasingly learning to design circular systems that are frictionless, inclusive, and supported by transparent impact reporting. In doing so, they are cultivating a culture of shared responsibility across airport campuses—an essential prerequisite for scaling circularity.

**Design principle:** Circular systems must be built around user behaviour, not assumed compliance.

## AI and Data Are Unlocking a New Generation of Circular Tools

Digitalisation is emerging as one of the most powerful enablers of circular transformation. From Schiphol's digital product passports to Venice's and Rome's AI-driven waste analytics and Frankfurt's closed-loop material tracking, data is providing the traceability that circular systems require.

These initiatives signal a shift from reactive waste management toward **resource intelligence**. By connecting sensors, logistics data, and procurement systems, airports can begin to monitor material flows in near real time, identify value losses, and plan interventions proactively.

AI applications extend well beyond waste. They can support material inventory management, predictive maintenance, lifecycle analysis, and scenario modelling—capabilities that are essential for embedding circularity into corporate strategy. However, most digital pilots still operate in isolation. Without shared definitions, clear data ownership, and governance agreements across the value chain, digital tools risk remaining local optimisations rather than system enablers.

**Design principle:** Digital tools must be interoperable and governance-ready to enable system-level circularity.

## Pilots as Essential Learning Laboratories

Nearly all initiatives in this Atlas began as pilots. This is not a weakness, but a strength. Pilots allow airports to test feasibility, manage risk, and build internal capability while generating operational data.

Taken together, these pilots constitute a growing European knowledge base on what works, what does not, and under which conditions circularity can be scaled. The next challenge is not launching more pilots, but **connecting learning across airports** so that progress in one terminal accelerates implementation in another.

Scaling will require a balance between standardisation (shared metrics, definitions, and reporting structures) and flexibility (room for local adaptation). EU-funded programmes such as TULIPS and Stargate demonstrate that structured collaboration can reduce duplication and de-risk innovation—provided that lessons are systematically captured and shared beyond project lifetimes.

**Design principle:** Pilots only create value if they generate transferable learning and comparable data.

## Circularity and Business Value Must Evolve Together

A recurring insight from the Atlas is that circular projects gain durability when they deliver tangible business value alongside environmental benefits. Cost avoidance, operational efficiency, tenant satisfaction, and improved passenger experience all emerged as relevant success factors.

While many early pilots prioritised environmental outcomes, the next generation of initiatives must systematically integrate economic and service-based KPIs. Schiphol's construction material exchange illustrates this evolution by combining material reuse with measurable procurement savings and improved asset management.

Linking circular outcomes to business objectives enables circularity to move from sustainability teams into core decision-making processes. Without this linkage, circularity risks remaining dependent on individual champions rather than becoming embedded in long-term airport strategy.

**Design principle:** Circularity must be framed as a value-creation strategy, not a cost centre.

# 3.3 Indicators and Measurement

## Current Practices and Gaps

All participating airports track waste generation and recycling rates, and several now monitor asset reuse, material life extension, and closed-loop flows. These developments represent clear progress. However, because pilots define boundaries differently, results remain difficult to compare across airports.

The challenge is no longer data availability, but **data coherence**. Indicators often focus on end-of-life outcomes rather than value retention, material productivity, or system performance. Without shared definitions and boundaries, circularity risks remaining a collection of well-intended but incomparable initiatives.

Effective measurement should support decision-making—informing investment choices, procurement strategies, and operational priorities—rather than creating parallel reporting systems detached from daily management.

## Towards Harmonised Frameworks

Three frameworks consistently underpin the cases in this Atlas:

- **The R-ladder**, for strategic positioning of interventions.
- **ISO 59020**, as an operational backbone for measuring resource inflows and outflows.
- **The Circularity Gap Report (CGR)**, for macro-level benchmarking and context.

Together, these frameworks provide a credible and policy-aligned foundation for harmonisation. ISO 59020 supports operational measurement, CGR situates performance in a global context, and ESRS E5 provides the regulatory interface under CSRD.

A shared indicator library—potentially coordinated through ACI Europe or EU-funded collaborations—would significantly improve comparability, transparency, and strategic alignment across airports.

## From Waste Data to Resource Intelligence

Digitalisation is transforming how data are collected, visualised, and used. Smart bins, digital passports, and IoT devices generate granular insights into material composition, flows, and behaviour. When connected through AI, these data streams can evolve into predictive resource-management systems.

In practice, this could enable airports to forecast reusable inventory needs, anticipate construction waste flows, or identify where value losses occur across terminal zones. Such intelligence would support proactive planning, cost reduction, and more robust valuation of circular interventions.

The sector is still at an early stage, but the trajectory is clear: from compliance-driven reporting toward **data-enabled strategic steering** of material value.

# 3.4 Harmonisation with EU Policy and Regulation

European airports are at the forefront of translating EU circular economy policy into operational practice. The cases in this Atlas demonstrate concrete implementation of the Circular Economy Action Plan, the Single-Use Plastics Directive, and the Corporate Sustainability Reporting Directive.

Regulatory fragmentation remains a barrier. Differences in national interpretations of waste classifications, reuse standards, and data-sharing requirements limit cross-border scalability. Nevertheless, airports are navigating this complexity through iterative, innovation-driven approaches.

Importantly, airports are not only policy takers, but increasingly **policy translators**. By acting as living laboratories, they generate real-world evidence that can inform future regulation. Programmes such as TULIPS and Stargate illustrate how policy and practice can co-evolve when feedback loops are deliberately created.

To fully leverage this role, the Circular Airports Working Group should evolve toward a more formalised platform, with a mandate to:

- Share pilot data, metrics, and methodologies.
- Coordinate proof-of-concept trials.
- Engage with EU institutions on regulatory clarity.
- Accelerate development of standardised indicators.

As CSRD reporting cycles mature, airports with data-enabled circular systems will be better positioned to adapt with minimal disruption. Early circular pilots should therefore be understood as **strategic preparation for regulatory convergence**, not isolated sustainability actions.

# 3.5 Governance, Skills, and

## Embedding Circularity into Governance

Circular economy is moving from the margins of sustainability departments into core airport governance. Several airports now integrate circular KPIs into investment appraisals, tenders, and asset-management decisions.

This marks a shift from circularity as a project-based activity to circularity as a governance principle. When embedded in board-level strategies, operational manuals, and contract templates, circularity becomes business-as-usual rather than an exception.

A typical maturity progression can be observed:

1. Circularity as sustainability initiative
2. Circularity as operational programme
3. Circularity as governance principle

## Partnerships and Ecosystems

Airports operate as ecosystems, making collaboration indispensable. The Atlas highlights diverse partnership models, from tenant alliances and airline collaborations to digital innovation partnerships and social-impact linkages.

These examples show that circularity thrives when co-creation replaces compliance. Airports are increasingly acting as regional circular hubs, stimulating innovation beyond their perimeter and connecting public, private, and academic actors.

## Skills and Culture

Circular transformation requires new competencies: data literacy, lifecycle thinking, and collaborative innovation. Several airports have invested in training and awareness programmes to support this transition.

Cultural change is as critical as technology. Circularity requires a shift from ownership to stewardship and from control to collaboration. Developing these capabilities is essential for managing increasingly complex, data-driven circular systems at scale.

# 3.6 Future Outlook

## From Pilots to Integrated Systems

The next phase of circular development will connect individual initiatives into coherent, airport-wide systems. By the mid-2030s, leading airports are expected to operate integrated circular infrastructures, combining shared reuse logistics, centralised material hubs, and AI-supported monitoring platforms. Digital twins will play a key role by linking asset management, procurement, and resource data in a single decision-support environment.

## From Waste Management to Value Retention

Circularity is increasingly understood as value management rather than waste management. The greatest opportunities lie upstream, in design, procurement, and operations. Airports with long asset lifecycles and concession agreements are particularly well positioned to benefit from early integration of circular requirements.

## AI and Data as Accelerators

AI will accelerate circularity by enabling predictive analytics, scenario modelling, and optimisation across energy, material, and asset systems. As value-chain connectivity improves, airports will be able to close loops internally and across regional partners.

## Collaboration as the Multiplier

Airports share similar structures, constraints, and regulatory contexts. Collaboration therefore offers strong economies of scale. Consolidating the Circular Airports Working Group will institutionalise peer learning, accelerate standardisation, and amplify Europe's influence in shaping circular aviation practice.

# 3.7 Closing Remarks

Circular transformation in airports is well underway. The cases presented in this Atlas demonstrate that progress is real, measurable, and accelerating. What began as isolated experiments has evolved into a shared European movement that connects sustainability with innovation, policy with practice, and digital intelligence with human behaviour.

The evidence shows that circularity in airports has moved beyond experimentation. What is now required is consolidation: shared metrics, stronger governance, and deliberate scaling of what works. Airports that succeed in this transition will not only reduce environmental impact, but also strengthen resilience, operational efficiency, and long-term value creation.

For European airports, circularity is no longer a question of ambition, but of **execution, coordination, and scale.**

# Annexes

## Annex 1: Summary of the working session, March 6th

Participating airports:

- Brussel
- Copenhagen
- Heathrow
- JFK
- Madrid
- Oslo
- Paris
- Rome
- Schiphol
- Stuttgart

Topics discussed during the meeting:

### 1 Circular Construction

- **What airports are working on:**
  - Reuse of materials: Paris, Oslo, and Schiphol are piloting reuse of sanitary equipment, office floors, and construction materials.
  - Waste data consolidation: Heathrow and Brussels are focusing on tracking construction waste.
  - Sustainable design: Paris and Stuttgart are integrating modularity and embodied carbon measurement.
  - Contractual requirements: Oslo and Stuttgart are embedding circularity into construction contracts.

- **Common topics:**
  - Reuse of building components (e.g., toilets, floors, pavements).
  - Data collection and KPIs for circularity.
  - Collaboration with contractors and internal departments.
  - Pilot projects to test reuse feasibility.

- **Challenges:**
  - Lack of technical expertise and industrialized reuse processes.
  - Data inconsistency and limited availability.
  - Cost and time constraints.
  - Quality assurance for reused materials.
  - Need for clearer ownership and financial model

## 2 Managing Waste Streams

- **What airports are working on:**
  - Smart bins and AI: Schiphol and Stuttgart are testing AI-supported waste sorting.
  - Passenger engagement: Paris and Rome use pictograms and donation incentives.
  - Food and beverage waste: Paris and Oslo are piloting reusable take-away and food waste separation.
  - Special waste streams: Madrid is recycling cigarette butts; JFK is donating unused materials.

- **Common topics:**
  - Smart infrastructure for waste sorting.
  - Reuse and recycling of food packaging and F&B waste.
  - Collaboration with concessionaires and cleaning teams.
  - Data-driven waste monitoring.

- **Challenges:**
  - Space and logistical limitations.
  - Human behavior and engagement.
  - Cost of infrastructure (e.g., bins, containers).
  - Legal and operational barriers for donation and reuse.

## 3 Collaboration with Tenants

- **What airports are working on:**
  - Waste charters and alliances: Brussels and Paris have formalized sustainability commitments with tenants.
  - Food waste reduction: Heathrow and Oslo are piloting food donation and tracking.
  - Tenant services: Stuttgart offers waste management as a service.
  - Education and engagement: Oslo and Paris provide learning materials and host summits.

- **Common topics:**
  - Stakeholder engagement and buy-in.
  - Shared targets and reporting.
  - Food waste tracking and donation.
  - Internal and external communication.

- **Challenges:**
  - Varying levels of maturity and commitment.
  - Legal and logistical issues with food donation.
  - Difficulty in scaling initiatives across all tenants.
  - Need for incentives and clear KPIs.

## 4 Cross-Cutting Themes

- **Most airports are focusing on:**
  - Piloting reuse and recycling in both construction and operations.
  - Engaging stakeholders (contractors, tenants, passengers).
  - Data collection and KPI development for circularity.
  - Scalability of successful pilots to other terminals or airports.

- **Shared challenges:**
  - Data and quality assurance: Inconsistent data and uncertainty about reuse quality.
  - Cost and logistics: High costs and operational complexity.
  - Behavioral change: Need for education and incentives.
  - Lack of standardization: Different systems and definitions across airports.

## Annex 2: The R-Ladder - Circular Strategies

The R-Ladder is a model that categorises circular economy strategies by their level of circularity impact. It is arranged in descending order of preferred action, starting with refusal (R0) and ending with disposal (R9).

| General Strategy | R Type | Description |
|---|---|---|
| Smarter creation and use of products | R0: Refuse | Turning a product redundant by cancelling its function, or by substituting it with a radically different product. |
| | R1: Rethink | Intensifying product use (e.g. via product sharing or multifunctional products). |
| | R2: Reduce | More efficient use and/or manufacture of products through the use of fewer natural resources and materials. |
| Extending the lifespan of products and parts | R3: Reuse | Reuse of discarded yet still usable products for the same purpose, by a different user. |
| | R4: Repair | Repair and maintenance of broken or malfunctioning product, to enable continuation of its original function. |
| | R5: Refurbish | Refurbishing and/or modernizing an older product, so that the improved version can be used in the product's original function. |
| | R6: Remanufacture | Using parts of a discarded product in a new product of the same function. |
| | R7: Repurpose | Using discarded products or their parts in new products with a different function. |
| Useful application of materials | R8: Recycle | Processing of materials to achieve the original high-quality or reduce to low-quality. |
| | R9: Recover | Incineration of materials, recovering their energy. |

Table 4: Circular strategies in the production chain

Source: Circular economy: what we want to know and can measure. PBL Netherlands Environmental Assessment Agency,2018. Pag. 27.

## Annex 3: Summary of Circularity Gap Report Indicators (2025)

- **Input Indicators:**
  - Circular Material Flows: Materials reused, recycled, or remanufactured before entering the economy
  - Linear Material Flows: Virgin materials extracted and used once
  - Net Stock Build-up: The balance of material inflow that is added to long-term stock (buildings, infrastructure)
- **Output Indicators:**
  - Circular Material Flows: Materials recovered after use and reintroduced into production
  - Linear Material Flows: Waste sent to landfill or incineration

In 2021, circularity stood at 8.6%. In 2025, it has dropped to 6.9%, driven by increased material extraction, global consumption, and limited recovery infrastructure.

## Annex 4: ISO 59020 Circularity Performance Indicators

- **Resource Inflows:**
  - Volume of primary (virgin) materials
  - Volume of secondary (recycled/reused) materials
  - Percentage of renewable materials used
- **Resource Outflows:**
  - Volume of materials reused or remanufactured
  - Volume of materials recycled
  - Volume of materials recovered for energy
  - Volume of materials sent to landfill or incineration

The ISO standard enables boundary setting and offers performance evaluation using life-cycle data, adaptable to an airport's scale and scope.