APU emission control system methodologies

D6.6

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Content

List of abbreviations and definitions

A-CDM	Airport Collaborative Decision Making
AI	Artificial Intelligence
AODB	Airport Operational Database
APU	Auxiliary Power Unit
AIBT	Actual In-Block Time - the time that an aircraft arrives in blocks at the stand
AIP	Aeronautical Information Publications
ATC	Air Traffic Control
AOBT	Aircraft Off Block Time - the time the aircraft has left the stand
GPU	Ground Power Unit
OAT	Outside Air Temperature
PCA	Pre-Conditioned Air - for ventilation of aircrafts
TOBT	Target Off-block Time - the time that an aircraft operator/ground handler estimates an aircraft to be ready, all doors closed, boarding bridge removed, push back vehicle available and ready to start up/push back immediately upon reception of clearance from ATC
Turnaround	Refers to the process of preparing an aircraft for its next flight after it has landed e.g. the transition between arriving and departing flight using the same aircraft, in total two flight operations per turnaround.

A. Executive summary

This deliverable outlines methodologies for implementing an auxiliary power unit (APU) monitoring system and explores business models aimed at reducing APU use, with the goal of lowering local greenhouse gas (GHG) emissions, noise, and air pollution. Using Copenhagen Airports (CPH) as a case study, the report presents a data-driven approach that combines thermal camera technology, artificial intelligence, and integration with existing airport IT and turnaround systems. Finally, it examines how airports can leverage this system to enforce APU restrictions through control measures and integration into the A-CDM framework

B. Target audience

The primary audience for this report is professionals working within the aviation sector, particularly those involved with airport operations, emission monitoring, and environmental management.

1 Foreword

This report presents key insights and recommendations for establishing a robust system to monitor greenhouse gas (GHG) emissions from aircraft APU use at stands. From the gap analysis and best practices outlined in ALIGHT deliverable 6.3 (GHG monitoring system), it became evident that monitoring of APU emissions could be improved. In response, a new task 6.3.1 was introduced to develop a dedicated APU monitoring system at aircraft stands.

The report provides an overview of APU restrictions and current monitoring practices at CPH and introduces a thermal camera-based detection system enhanced by artificial intelligence and a centralized IT platform. It offers practical guidance for airports seeking to improve the accuracy and efficiency of their GHG monitoring systems.

2 APU restrictions at aircraft stands

The restriction of APU use at aircraft stands has since 1997 been part of CPH's local regulation for noise abatement (CPH: Local regulations) and the aeronautical information for pilots (AIP) for Copenhagen Airport (CPH: EKCH). Restrictions of aircraft APU use and idle main engines on-ground will in addition to reduced local noise impact, also result in reduced air pollution and GHG emissions.

Previously mentioned gap analysis has identified potential GHG reductions during the entire landing and take-off cycle (LTO) to be modest for APU use (5 %) compared to idle/taxiing (ca. 50 %). However, regarding the local environmental impacts at aircraft stands near terminal areas, restrictions of APU use are still relevant as polluted air and noise contribute to a poor working environment. The purpose of APU emission control is to reduce APU run times at aircraft stands, hence reducing local noise and air pollution.

The time stamps during aircraft turnarounds are defined in the Eurocontrol guide (2017) for airport collaborative decision making (A-CDM) at CPH (CPH: A-CDM).

At CPH the use of APU on aircraft stands shall be limited as much as possible.

APU may be used:

- Arrival: 5 minutes after "On Block" (AIBT)
- Departure: 5 minutes before Target Off-block Time (TOBT)

Exemptions for prolonged APU use depends on type of aircraft, and dispensation can be granted by Airside Operations centre upon radio call in case of following conditions:

- Outside air temperature (OAT) is below –10°C or above +25°C
- Airport supply of power or air conditioning is unserviceable

Restrictions of APU use on aircraft stands are also practised in other airports, such as Amsterdam Schiphol (AMS) and Brussels Zaventem (BRU).

3 Current practice for APU control at CPH

Human inspections with visual and auditive observation of APU on/off is the only current possibility to control APU use on aircraft stands during turnaround. However, it is a very labour-intensive task with 100 active aircraft stands and 120.000 turnarounds on aircraft stands corresponding to 240.000 flight operations (total arrivals and departures in 2024).

3.1 APU control inspections

Inspection campaigns targeting APU use started as part of CPH's environmental compliance for noise abatement in 1997. The APU control inspections rely on visual and auditory observations conducted by staff from the Environmental Department and Airport Security. Historically, these inspections have identified non-compliant APU use in approximately 10–20% of cases, with departures showing higher rates of non-compliance than arrivals.

In 2025, a new campaign was launched to map APU use across all aircraft stands at CPH. This initiative involved comparing observed APU activity with data from the airport's A-CDM IT system, and the availability of ground power and ventilation. Preliminary analysis revealed discrepancies between manual observations and objective data sources, including video footage, highlighting the limitations of current methods and underscoring the need for a technical solution to accurately monitor APU use.

3.2 Airport community app self-reporting tool

The “report APU/noise” application was developed at CPH as part of existing Airport Community app and was launched in June 2021 (Figure 1). The tool is highly reliant on human awareness to observe and report while carrying out aircraft turnaround, and yet, there are no objective systems to monitor APU use.

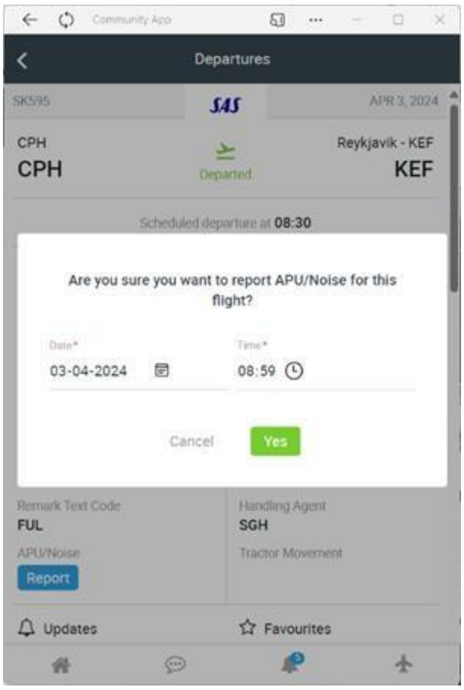

Figure 1: Airport community app view of APU/Noise reporting at CPH.

The observations from “report APU/noise” must be checked for granted dispensations of APU use and time stamps. Analysis of APU/noise reports during the period from June 2021 to February 2024, resulted in a total of 1349 cases of non-compliant APU use, corresponding to less than 1 % of the total aircraft turnarounds (Figure 2).

While APU control campaigns typically detect 10–20% noncompliance, the self-reporting tool identified less than 1%, indicating that it is both inefficient and prone to human observational errors.

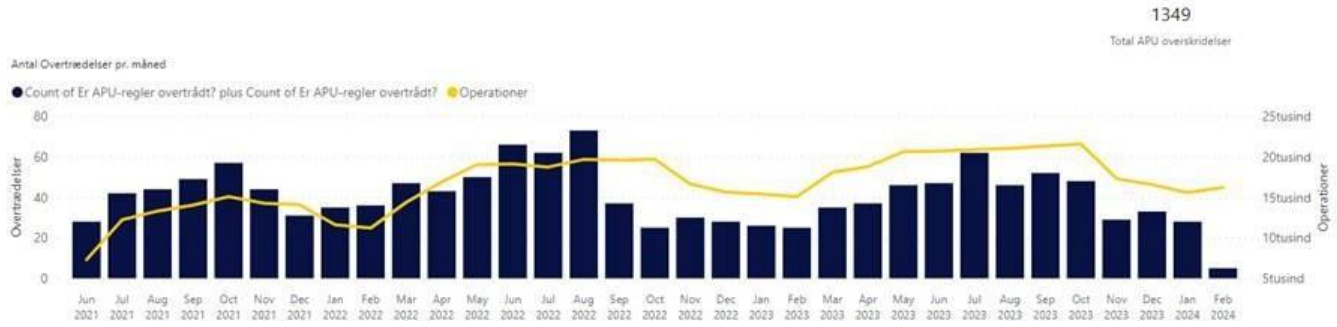

Figure 2: Overview of APU/Noise reports at CPH.

3.3 Dispensations for APU use

Dispensations for APU use was given with the following reasons:

- Aircraft systems defects/power plug
- Frozen aircraft
- Defects in ventilation at aircraft stand
- Aircraft APU technical issues
- Sensible cargo
- Outdoor temperature

3.4 Non-compliance to APU rule

Reports of non-compliance due to prolonged use of APU are filed by Airport security guards. In most cases the pilot's explanation of APU use is caused by the need for cooling the aircraft cabin, for which airport ventilation does not deliver sufficient ventilation and cooling.

In case of noncompliance with the APU rules, the resulting discussions with pilots, handlers, airport security and airside operations are mainly reliant on personal perceptions of the same situation, that is varying considerably between the parties.

Human manual observations are subjective and will always be a subject for discussion due to lacking "hard evidence" and technical proof in cases of noncompliance. Hence, the APU rules have so far not resulted in environmental fees or sanctions, other than being placed on remote aircraft stands, away from the terminal area, to reduce the impact on ground handlers working on the ramp.

4 APU monitoring systems

This section aims to assess identification of best available technologies to monitor APU use by data-driven monitoring tools in an operating airport. Cameras can detect APU on/off by monitoring of either sound frequencies or thermal radiation from the aircraft APU plume.

4.1 APU Noise detection by acoustic cameras

Acoustic cameras are advanced devices equipped with an array of microphones or acoustic sensors strategically positioned to capture sound from different directions. These sensors work in unison to detect and analyse sound sources in real time, providing a visual representation of noise distribution.

4.2 APU Heat detection by thermal cameras

Thermal cameras detect aircraft plumes by capturing infrared radiation (mid to long wave) emitted from hot gases in the exhaust plume. This radiation is converted into temperature-mapped images, allowing visualization and analysis of the plume's thermal signature and spatial distribution.

4.3 Evaluation of APU monitoring systems

Acoustic cameras have recently proven effective in detecting running APUs during environmental noise monitoring at Eindhoven and Schiphol airports in 2024-2025.

In 2021, CPH conducted preliminary tests using thermal cameras to evaluate their potential for detecting APU activity. Results showed that thermal cameras could reliably detect APU on/off status by capturing the characteristic heat plume emitted during operation. However, accurate detection was highly dependent on optimal camera placement—specifically, achieving the correct angle and elevation to clearly view the APU exhaust area located at the rear of the aircraft. These findings provided an incentive to pursue further development of a technical monitoring solution based on thermal cameras.

From 2023 to 2024, CPH collaborated with an IT partner to identify the most effective solution for monitoring APU emissions. During this process, Assaia launched a commercially available

Emissions Control System that integrates APU detection with artificial intelligence and a centralized IT platform. Following internal testing and a proof-of-concept trial at Seattle Airport (Assaia), CPH found that thermal cameras delivered more accurate and reliable APU detection than acoustic sensors. Based on these results, CPH decided to proceed with the full deployment of Assaia's Emissions Control System.

5 Aircraft stands for APU monitoring

To establish full deployment of APU monitoring, aircraft stands were evaluated for adaptability for setup of APU monitoring system, representation of different types of aircrafts and operations.

5.1 Operations

Operational data from 2023 were analysed, identifying 42 aircraft stands that together account for approximately 80% of all turnarounds at CPH. The selection aimed to ensure broad coverage of turnaround types, encompassing a diverse range of aircraft and stand locations.

5.2 Infrastructure

The stands must be equipped with electricity and network cable for cameras, fixtures to setup the cameras, such as buildings or masts. The stands accommodate various aircraft types (small, narrow and wide body) depending on size and design. Supply of ground power and ventilation varies across the airport; hence a wide selection of aircraft stands was chosen.

To avoid APU use during turnaround, the aircraft stands at CPH have either fixed or mobile ground power units (GPU) and in most cases also ventilation with preconditioned air (PCA).

6 IT project description

6.1 Contract with supplier of IT system (Assaia)

CPH has entered a contract with Assaia for APU Emission Control services, including system maintenance and support. Under this agreement, Assaia is responsible for the service and maintenance of all system components, while CPH manages the installation of camera hardware, cabling, and related infrastructure.

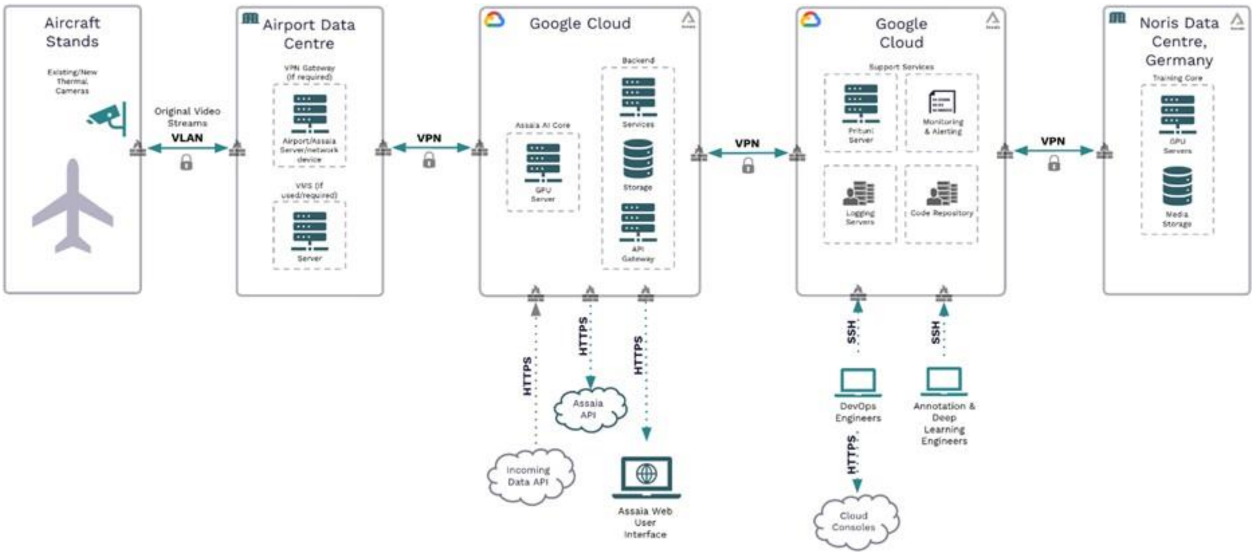

Figure 3: System architecture (Assaia)

The system architecture diagram (Figure 3) shows five main components: Aircraft Stands (with an airplane & camera icon), CPH data center (with a building icon), Google Cloud Platform (with a cloud icon), and Norris Data Center (with a building icon). Each component is connected by arrows indicating data flow between them.

6.2 Thermal cameras

Thermal cameras from the AXIS Q19 series have been installed at each aircraft stand to monitor the tail section of the aircraft. Typically, one camera is dedicated per stand, except for two cameras that are positioned to cover two stands each.

Assaia and CPH has collaborated on the camera selection and planned the ideal camera placement for the given stand. CPH has installed 40 cameras with the respective network connections, covering 42 aircraft stands. See figure 4 for locations of thermal cameras.

Figure 4: Locations of thermal cameras

6.2.1 Calibration

Assaia are currently calibrating the system – "training" the AI - to detect APU use across different stands, aircraft types and other variables. The expected duration of calibration is 3-4 months.

6.2.2 Connectivity provided by CPH

CPH has installed dedicated wired Cat6 Ethernet cables at each thermal camera location to provide both power and network connectivity. To ensure optimal performance and prevent data interference, no other devices are connected to these cables. The data streams from the cameras are transmitted to Assaia via a dedicated VPN connection, and all cameras are configured within a dedicated VLAN for secure and isolated network communication.

6.2.3 Backend

The backend software is in the supplier's cloud environment, see figure 3. The backend software receives data streams from the cameras and Assaia's software analyses these incoming streams and determines whether an APU is on or off.

The backend software also receives the flight information feed from CPH. The information from the flight feed is used by Assaia to establish if an APU is allowed to be used (relative to in-block time and/ or estimated off-block time).

6.2.4 Frontend

The desktop application displays an airport map with all active turnarounds. Any flight will be marked with a red color in case of a violation of current APU regulations in real time view, see example in Figure 5. A violation will also be shown as an alert in the notification feed on the left side of the screen.

Additionally, all historical data about past violations are stored in CPH's Airport Operational Database (AODB), including flight details such as airline name, flight number, etc. CPH can view reports generated based on these historical records.

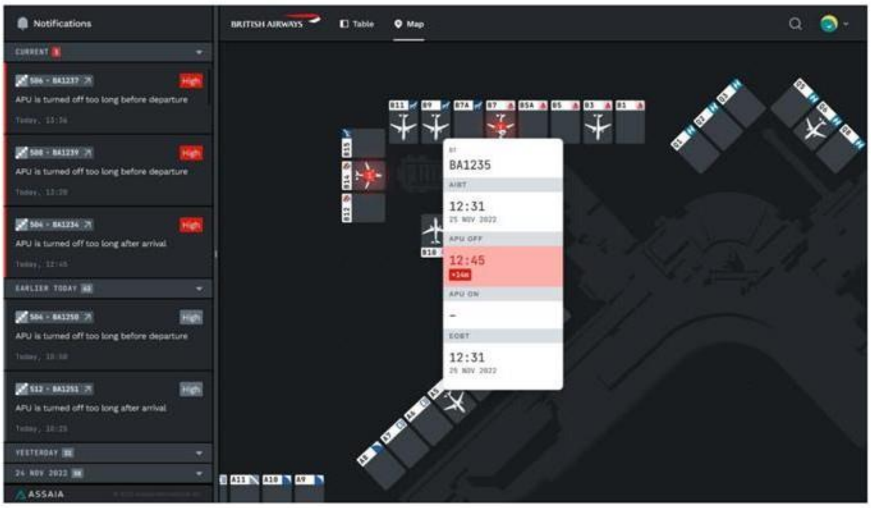

Figure 5: Example of web desktop application for APU monitoring.

6.3 Integration with airport IT-systems

The APU monitoring system will be integrated into the existing airport IT eco-system for data-assisted aerodrome collaboration and decisions making (A-CDM).

The Assaia solution will be fully integrated into CPH's Airport Operational Database (AODB), enabling users to monitor APU usage alerts in real time. This integration allows for a proactive approach to managing APU emissions, moving beyond reactive responses to complaints from ground handlers or other affected parties.

In addition, CPH will develop a comprehensive reporting framework that integrates operational data with APU usage metrics, weather conditions, and technical data on the use of ground power units (GPU) and pre-conditioned air (PCA) systems at the stands. This setup will support deeper insights into APU-related emissions and operational efficiency.

7 Models for implementation of APU control

The purpose of APU control is to reduce unnecessary APU run times at aircraft stands.

The A-CDM process defines a set of milestones in the aircraft turn-round process, allowing all A-CDM partners to identify possible deviations from schedule. A-CDM is about partners - airport operators, aircraft operators (AO), ground handlers (GH), air traffic control (ATC) and the Network Manager Operations Control (NMOC) - working together more efficiently and more transparently by sharing data. It allows better decision making based on more accurate and timely information, with all airport partners having the same operational picture. The improved decision making by the A-CDM Partners is therefore facilitated by the sharing of accurate and timely information and by adapted operational procedures, automatic processes and user-friendly tools.

7.1 Business setup

The overall approach for CPH to successfully utilize the APU monitoring system is an extensive collaboration between all stakeholders. Stakeholders in this context is both external partners and local departments in CPH:

- CPH infrastructure & technical maintenance
- Ground handlers
- Airlines and pilots
- Air Traffic Control – Naviair
- CPH Ground operations – Airside Coordination Center
- Compliance: CPH Sustainability – Legal – Airline sales
- CPH infrastructure & technical maintenance

7.2 Handling of non-compliance

The collaborative effort to reduce APU usage is structured around two primary objectives: Addressing ongoing instances of unauthorized APU operation, and advancing long-term initiatives aimed at minimizing APU use.

CPH is currently evaluating a range of sanctioning mechanisms to address non-compliance with APU regulations. In the initial phase, most violations are anticipated to be resolved through direct engagement with the respective airlines, as part of the ongoing collaborative framework between CPH and its airline partners.

The Ground Handlers, though employed by the airlines, are also part of this framework and must adhere to guidelines and instructions around the use of CPH equipment as stated in training and terms of airside operations.

The implementation of sanctions related to APU use must be approached with caution, due to several important considerations:

- CPH must be able to substantiate that the ground-based infrastructure provided to the airline was fully operational at the time of the APU usage.
- Ground Handlers must be properly trained to ensure correct use of airport infrastructure, ground power and ventilation/PCA, and timing during turnaround
- Sanctions may adversely affect the passenger experience, potentially impacting both the airline and the airport.
- The enforcement of sanctions may result in additional operational burdens for CPH, such as the need for stand reallocation and the rescheduling of passenger transport services.

CPH is in the process of developing sanctions for managing unauthorized APU usage. The proposed approach outlines a process consisting of the following steps:

1. Initial written notification: The airline receives a formal letter including statistical data on instances of unauthorized APU use. This standardized communication will also contain documentation of the violations and outline potential consequences.

2. Request for explanation and corrective Action: A follow-up letter is issued requesting the airline to submit a formal explanation for the unauthorized APU use, along with a proposed corrective action plan.
3. Operational consequences: The airline may be assigned to a remote stand, either for a single turnaround or for an extended period, depending on the severity or recurrence of the violation.
4. In case of repeated violations, an environmental fine will be imposed on the airline.

The ongoing collaboration to reduce persistent unauthorized APU use is facilitated through various forums and bilateral meetings. These engagements provide a platform for CPH and airline representatives to discuss recent APU usage trends (e.g., from the previous quarter), share initiatives aimed at reducing APU reliance, and exchange feedback on how CPH's infrastructure can better support efficient aircraft turnaround operations.

7.3 Data and analysis

CPH have designed reports where turnaround APU off/on times are combined with relevant data on flights arrivals and departure time stamps, like AIBT (actual in block time), TOBT (target off block time) and AOBT (aircraft off block time), weather, infrastructure (ground power/GPU, ventilation/PCA) and other relevant data.

The reports allow for in depth analysis of the cause of APU use and the possibility of a close follow up on the effect of initiatives to reduce APU use.

7.4 Business model

The APU monitoring system is designed for real-time monitoring and can automatically generate alerts if APU use is noncompliant with airport local regulations.

Handling of actual non approved use of APU is a daily collaboration between CPH Ground operations, ground handlers and airlines. CPH is working on designing the specific elements of the process, where roles and responsibilities should be in place before launch. The key elements are:

- Who monitors APU alerts?
- Who contacts the pilot? – e.g. ground handlers

- Who are responsible for ground handling procedures and timing?
- What are escalation procedures if the pilot does not comply to the rules? - e.g. Airport guards are called in
- What are the guidelines for exceptions to the APU rules and who can grant exceptions?
- What are the consequences if airlines continue to be non-compliant to airport APU rule, see section 7.2.

7.5 Future perspectives

The APU monitoring system is designed to support the goal of reducing APU run times during aircraft turnaround by providing real-time operational data. Looking ahead, its implementation at CPH's airside operations within the A-CDM framework represents a key step toward more sustainable and efficient ground operations.

Achieving this requires a coordinated effort across multiple domains: the deployment of technical infrastructure at aircraft stands, integration with existing and evolving IT systems, and the revision of operational procedures. Equally important is the development of targeted training and awareness programs for all A-CDM stakeholders—particularly ground handlers, airlines, terminal operations, flight control, and the airport ground coordinator.

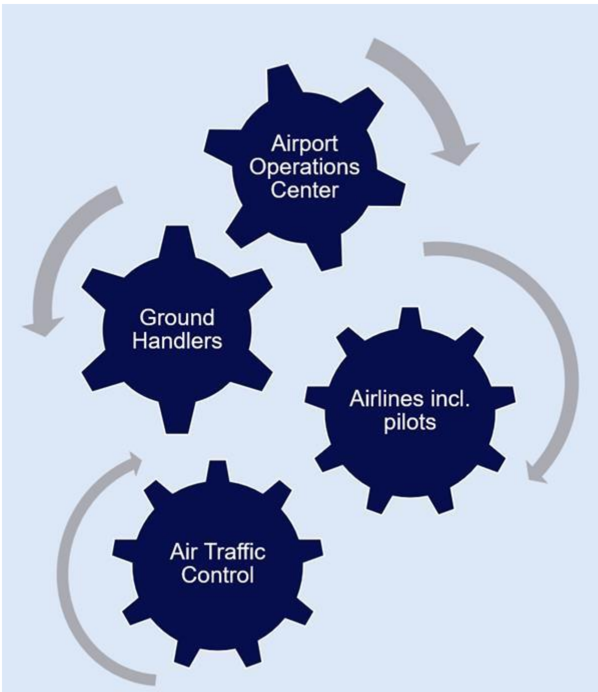

Figure 6: Stakeholders in aircraft turnaround processes

Figure 6 outlines the key stakeholders involved in the turnaround process, all of whom will be influenced by the APU monitoring system. For example, the “ground handlers” category includes services such as baggage handling, cleaning, catering, and refueling—all of which must align their workflows with the updated procedures to ensure effective APU minimization.

8 Conclusion

This report presents a practical roadmap for airports aiming to reduce APU-related emissions, noise, and air pollution through data-driven monitoring. Drawing on the experience of Copenhagen Airports (CPH), it describes how thermal camera technology—combined with artificial intelligence and integration into existing airport IT systems—can provide a reliable and scalable solution for monitoring APU usage.

At CPH, the system will undergo calibration during summer 2025, after which it will begin real-time detection and logging of APU activity across selected aircraft stands. If implementation proceeds as planned, CPH will begin monitoring and enforcing restrictions on non-approved APU use from 2026 onward at selected stands equipped with a proven and reliable technical support setup. This phased approach ensures a stable rollout while enabling early environmental benefits. As operational experience grows and data insights deepen, CPH will evaluate opportunities to expand the system to additional stands, further supporting its sustainability and efficiency goals.

By integrating APU monitoring into daily operations, the system becomes a valuable data point within the broader turnaround process—supporting more informed decision-making, enhancing operational efficiency, and contributing to future-ready airport infrastructure.

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