GHG Monitoring system

D6.3

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A. Executive summary

This report explores how airports can enhance their greenhouse gas (GHG) emissions monitoring systems, focusing on key sources of emissions within the sector. The goal is to improve data collection, reduce manual effort, and increase accuracy in emissions inventories. The primary emissions sources identified are:

1. Passenger and employee transportation to and from the airport (excluding flights)
2. Airport ground activities
3. Aircraft activities in the landing and take-off (LTO) cycle (up to 3,000 feet)
4. Aircraft activities during the outbound flight to the destination airport

The ALIGHT project has established best practices for monitoring these emissions sources, ensuring that airports can systematically track their carbon footprint and make informed decisions toward sustainability. Best practices include standardized data collection methodologies, integration of transport and fuel data, and the use of modelling tools to estimate emissions from limited data inputs.

In the report, the partner airports, Copenhagen Airport (CPH), Vilnius International Airport (VNO), Aeroporti di Roma (ADR), and Centralny Port Komunikacyjny (CPK) are examined for gaps in their current monitoring practices compared to the established best practices. Additionally, recommendations and discussions for monitoring emissions at airports under planning and construction are also included. Notably, the report presents the need for specific improvements in two key areas: transportation to and from airports and Auxiliary Power Unit (APU) usage at aircraft stands, the latter leading to a separate report, found within deliverable 6.6.

CPH has been used as a case study to further investigate transportation to and from airports. A methodology is developed for collecting and analysing data, including surveys of passengers and employees, parking registrations, and information from transport providers. A modelling tool developed during the project is introduced to estimate emissions, demonstrating how airports can estimate emissions with limited data and adapt the methodology across other airports, including those in the ALIGHT project.

Ultimately, the report suggests the potential for a wider platform for standardizing emissions data sharing. Such platform could help airports refine their reporting and collaborate more effectively on emissions reduction strategies, supporting a more sustainable airport sector.

B. Target audience

The primary audience for this report is sustainability professionals working within the aviation sector, particularly those involved with airport operations, emissions monitoring, and environmental management. This includes airport sustainability teams, GHG emissions analysts, and personnel responsible for transportation and energy management at airports.

In addition to airport-specific roles, the report is also relevant to stakeholders involved in broader GHG emissions monitoring and reduction efforts within the aviation industry, including policymakers, fuel suppliers, and government officials overseeing aviation-related sustainability regulations. The report offers practical insights into refining GHG emissions tracking for airport operations, including transportation to and from the airport, ground activities, aircraft emissions during the landing and take-off (LTO) cycle, and outbound flight. This makes it valuable for professionals in both the public and private sectors working to reduce the aviation industry's carbon footprint and meet sustainability goals.

The content is especially relevant for those tasked with implementing and improving monitoring systems for GHG emissions, and for those engaged in the development of sustainability strategies.

1 How to read this paper

This report outlines key insights and recommendations for developing a robust Greenhouse Gas (GHG) monitoring system and emissions inventory in the aviation sector, with a focus on airports. It begins by introducing well-established methods and models for emissions monitoring, followed by a gap analysis to identify areas for improvement in current practices. The report then highlights two selected cases for improvement, offering practical guidance on how airports can enhance their GHG monitoring systems. The findings are designed to be applicable and replicable by stakeholders outside the project, providing valuable inspiration for airports seeking to improve sustainability within their complex operational environments.

1.1 Introducing ALIGHT

The ALIGHT project is part of the EU 2020 Horizon program, designed to pioneer sustainable aviation solutions through partnerships. Its full name, *A Lighthouse for the Introduction of Sustainable Aviation Solutions for the Future*, reflects its role in guiding the aviation industry toward more sustainable practices. The project brings together 17 partners across 10 European countries, including airports, technology providers, and research institutions. In 2023, AIRBUS joined the consortium, contributing crucial perspectives from the aircraft manufacturing sector.

The project is divided into two main areas of focus:

- Workstream A: The supply, implementation, integration, and smart use of Sustainable Aviation Fuel (SAF).
- Workstream B: The development, integration, and implementation of a Smart Energy system.

1.1.1 Workstream A: Sustainable Aviation Fuels (SAF)

Workstream A focuses on Sustainable Aviation Fuels (SAF), a key element in the aviation industry's transition to sustainability. This workstream addresses several challenges:

- Airport Infrastructure: Planning for future airport infrastructure to support the widespread adoption of SAF.
- Procurement: Ensuring a reliable and sustainable supply of SAF, which can be produced from various feedstocks, each with different environmental impacts.
- Sustainability: Addressing the challenges of maintaining the sustainability of SAF throughout its lifecycle.

This workstream aims to help airports in the ALIGHT project overcome these hurdles, while also evaluation future SAF usage scenarios beyond mass-balance[1] handling and how this might impact the airport system.

1.1.2 Workstream B: Smart Energy Systems

Workstream B focuses on Smart Energy systems, covering the entire energy management chain, from energy supply to storage and usage. Key activities include:

- System Mapping: Mapping out the existing energy systems at airports.
- Energy Management: Developing strategies for efficient energy use, incorporating renewable energy sources.
- Energy Storage: Investigating how Battery Energy Storage Systems (BESS) can support airports in increasing their use of renewable energy.

As part of this focus, a BESS has been installed at the lighthouse airport (Copenhagen Airports) to gain hands-on experience with energy storage solutions. This will help understand how storage can balance the intermittent nature of renewable energy and contribute to the wider adoption of green energy solutions.

1.1.3 Work Package 6: Sustainability and the purpose of the report

The objective of Work Package 6 (WP6) is to ensure that best practices in sustainability are embedded across the project, supporting airports, airlines, and suppliers in advancing their

[1] The blend of SAF with conventional jet-fuel

environmental performance. WP6 also provides sustainability innovation input for replication and strategic planning, ensuring the long-term impact of the ALIGHT project.

This report aims to provide valuable insights to enable more robust emissions monitoring. Tracking reductions in emissions and ensuring the accuracy and transparency of emissions accounting are crucial for gaining a higher degree of sustainability. A comprehensive and reliable emissions inventory enable airports to effectively measure their environmental impact, track progress toward sustainability goals, and make informed decisions about further emission reductions. As sustainability is increasingly defined by tangible, verifiable actions, an accurate emissions monitoring is critical for mitigating environmental impact and climate change and ensuring the credibility of emissions reductions within the aviation sector.

2 Limitations

This section of the report will introduce the limitations and scope of the report as the field of monitoring emissions at an airport is complex and to ensure the understandability as well as usability of this report limitations are necessary. Furthermore, understanding the scope of both the sources of emissions as well as the types of emissions are necessary.

2.1 Parameters

To ensure consistency and accuracy in monitoring emissions, it is crucial to establish a common use of parameters. This ensures both accurate measurements and the ability to track developments over time, as well as the ability to compare data across partners. The chosen parameters are based on those currently in use at fellow airports and existing industry.

Further, since all airports in the ALIGHT project are accredited within the Airport Carbon Accreditation (ACA) (see section 4.1. for further details), each airport is required to report on emissions based on CO_2e (Carbon Dioxide Equivalent) which the ACERT calculation tool provides (the tool is described in section 3.2).

Carbon dioxide (CO2) is the most common GHG from human activities. However, other greenhouse gases are also significant contributors to global warming. These gases can be commonly referred to as CO_2e, accounting for the global warming potential for all GHG's (e.g., Nitrous Oxide [N_2O] and Methane [CH_4]). CO_2e expresses the amount of each gas, that would have an equivalent global warming impact as a given amount of CO_2.

Therefore, it is decided that CO_2e will be the primary parameter, with specific equivalent values provided based on available data.

2.2 Sources of Emissions

This section provides context for understanding both the scope and limitations of the monitoring system. The report covers a wide range of emissions sources at airports, from the landing and take-off cycle (LTO) to outbound flights to destination airports, as well as the transportation of passengers to and from the airport.

The following emission sources have been defined within the report and will be explored in detail below. Additionally, the industry-acknowledged Scopes 1-3 will be introduced, with an explanation of how they relate. Table 1 illustrates the emission sources, addressed in the report.

1	Passenger's and employee's transportation to and from the airport
2	Airport activities on ground
3	Aircraft activities in the LTO cycle (up to 3,000 feet)
4	Aircraft activities to destination airport/outbound leg

Table 1: Material sources of emissions identified and established within Task 6.3 of WP6 in the ALIGHT project

2.2.1 Scope 1, 2 and 3 emissions

The predefined emissions sources above do not cover the full range of emissions from an airport. Therefore, this section introduces the industry-standard Scopes 1, 2 and 3 emissions, providing a framework for understanding how the categories defined in this report relate to broader emissions scopes.

The GHG Protocol[2] is the widely used framework for classifying GHG emission, within the following scopes:

- Scope 1: 'Direct GHG emissions' from sources owned or controlled by the company (e.g. emissions from combustion in owned boilers and vehicles).
- Scope 2: 'Indirect GHG emissions' from the generation of purchased electricity and district heating by the company.
- Scope 3: 'Other indirect GHG emissions' resulting from all activities occurring in the value chain of the entity but is not controlled by the entity (e.g. passenger and employee transportation to and from the airport and the combustion of jet fuel, including both emissions from LTO cycle and outbound flight as established in previous section).

The four areas of monitoring defined in this report (see section “2.2 Source of Emissions”) cover different aspects of the above defined Scopes 1-3. Understanding when and how these emissions categories are covered by the industry-acknowledged scopes is essential for reporting and monitoring. Parties across industries should strive to report and monitor all emissions from all three scopes to make sure emission mitigation efforts are managed efficiently and resources are allocated to areas creating the most impactful emission reduction. However, for this report, the focus remains on the categories specified in section 2.3 as they have been identified as the current most material gaps in monitoring and reporting. These categories relate to the scopes defined by the GHG Protocol as the following:

- Scope 1: Emissions from own fuel consumption, specifically the airport’s own vehicles and equipment used on own premises. Additionally, natural gas used for energy generation at airport premises.
- Scope 2: Emissions from electricity and district heating used by the airport for office buildings, terminals, and charging of electric vehicles.

[2] ghg-protocol-revised.pdf (ghgprotocol.org) p. 25

- Scope 3: Electricity use by partners at airport premises, as well as emissions from fuel consumption by partner's vehicles and equipment. Included as well are emissions from fuel consumption of aircraft, both the LTO cycle and the full outbound flight.

While the terminology of Scopes 1, 2, and 3 will not be used in the rest of the report, understanding how these relate to the pre-defined areas of monitoring is important. All airports involved in this project are accredited under the Airport Carbon Accreditation (ACA) program at various levels, which requires them to report on these scopes to varying degrees. Therefore, it is important to recognize the relevance of these scopes in the context of this project, particularly as airports aim to meet future sustainability goals and regulatory requirements.

3 Best available monitoring tools

This section aims to introduce existing monitoring tools which can be used for monitoring various sections of emission sources stemming from an operating airport. Understanding the different tools provides an insight to the complexity of emissions monitoring at an airport, as well as how using multiple tools can be a necessity for various reasons.

3.1 LASPORT

LASPORT[3] is a programme developed for the calculation of airport-related pollutant emissions and concentrations in the lower atmosphere. It has been approved for use by ICAO (International Civil Aviation Organization) and is supported by a graphical interface, which provides the following:

- Definition of source groups, emissions and other parameters
- Preparation and evaluation of journals with individual aircraft movements
- Calculation of overall emissions for each source group and pollutant
- Preparation, start and control of the dispersion calculation with LASAT

[3] Janicke Consulting (2018), LASPORT, *Janicke consulting environmental physics.*

- Result analysis and graphical visualisation

The source groups for which the system accounts for are aircraft traffic, Auxiliary power units (APU), ground power units (GPU), engine startups, ground support equipment, de-icing and motor traffic both airside and landside. A database provides engine emissions, aircraft types, airports (worldwide) and default emissions of fuel burn.

3.2 ACERT

Airport Carbon and Emissions Reporting Tool (ACERT)[4] is an Excel-based tool developed by the Airport Council International (ACI), allowing airports to independently calculate their own greenhouse gas (GHG) emissions. The tool is designed to be easily navigable, requiring no specialized knowledge in emissions or environmental science. Users can input available operational data to generate emissions calculations. The tool categorizes emissions based on the degree of control, corresponding to the established Scope 1-3 framework.

For monitoring and reporting emissions of a calendar year, the following data is needed:

- Total aircraft movements, including both passenger and cargo flights
- Fuel consumption by airport and tenant vehicles, buildings, emergency generators and fire training
- Electricity and heat purchased by the airport operator and tenants[5]
- Aircraft movements categorized by specific aircraft type, generic aircraft type, or total fuel loaded on the aircraft
- Aircraft taxi times, APU usage, and engine run-ups
- Glycol-based de-icer usage
- Sewage and waste disposal data
- Either a detailed landside traffic study or estimates of passenger and staff ground access, including public transport usage, car, taxi, bus, and train activity

[4] ACI (nd.), ACERT v6.0 Do-it-yourself airport greenhouse gas inventory tool, *Airport Council International.*
[5] Additional information such as percentage of Renewable energy within the amount purchased, how much is sold to tenants as well as determining electricity emission factor either through accurate EF information or through a country default provided by the tool. More information is provided in the tool it self.

- Corporate travel data for airport staff
- Scope 1 and 2 offsets used to calculate the remaining emissions or achieve net zero emissions

The above data, when processed through ACERT, generates an inventory report that includes a summary table of GHG emissions and visual representations such as pie charts. The tool has been tested by several international airports, e.g., Toronto and SeaTac, with results indicating that ACERT's scope 1 and 2 emissions estimates were within 5-10% of those derived from more detailed calculations[6].

It should be noted that a potential risk is that frequent updates or changes to the tool could complicate comparisons of historical data, as new versions may be based on different methodologies and/or emission scopes definitions.

3.3 AEDT

AEDT is a software system designed to model aircraft performance in both space and time, estimating fuel consumption, emissions, noise and air quality. This comprehensive tool provides stakeholders with detailed information on these specific environmental impacts, as outlined by the Federal Aviation Administration (FAA). AEDT is capable of modelling individual studies with varying levels of scope, ranging from single flight to regional, national and global scales. The system utilises Geographic Information System (GIS) and database technology, offering users the ability to explore and present results interactively[7]. Funded by the U.S. government, AEDT is available without purchase, but access to detailed system information is limited. While AEDT operates similarly to LASPORT in terms of air quality monitoring, it does not account for employees and passengers' transportation to and from the airport.

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[6] ACI (nd.), ACERT v6.0 Do-it-yourself airport greenhouse gas inventory tool, *Airport Council International.*
[7] FAA (nd.) Aviation environmental design tool (AEDT), Federal aviation administration. [FAA: AEDT Support Website] [accessed 5/1-23]

3.4 Discussion on the tools

The three tools described above all aid in the monitoring of emissions based on input and data provided by the user to then calculate emissions. ACERT is used by all three active airports (CPH, VNO and ADR), as all are accredited through ACA. The tool is user friendly and provides an overview of the primary sources of emissions expected at an airport, thus it can be navigated by different levels of competencies or experience. LASPORT is not used by any of the airports for their emissions monitoring, however the tool is used within the ALIGHT project to calculate the correlation between the spread of local air pollution and an uptake of SAF, more detailed information can be found in deliverable 3.5. AEDT is used in CPH as an addition to the tool ACERT. AEDT is used for calculating the emissions from aircraft as well as for the calculation of air pollutant components emitted at the airport. Thus, not one single tool provides a comprehensive monitoring of emissions, below examples of best practise will be described as well as how a best practice could look for an airport.

4 Best practices

The purpose of this section is to summarise the best practices assessed throughout the work within ALIGHT, and general experiences from selected project partners. This will include insights into effective monitoring methods, challenges encountered, and lessons learned. Firstly, monitoring according to Airport Carbon Accreditation (ACA) is introduced, as all airports within ALIGHT are accredited under this certification. Additionally, airports have used their own established monitoring systems to varying degrees, which will also be explored. This section will provide a comprehensive overview of GHG emissions monitoring from the planning phase of new airports to general best practices established in the task. Additionally, current gaps in best practices for the existing airports within the consortium are identified and discussed.

4.1 Monitoring according to ACA (ACI)

The Airport Carbon Accreditation (ACA) program was launched in Europe by the Airports Council International (ACI) in 2009 as a voluntary global carbon management standard for airports. Its primary goal is "... *to encourage and enable airports to implement best practices in carbon management and achieve emissions reductions"* [8].

Airports can be accredited through seven progressive levels, with the option to offset residual emissions at Levels 3 and 4, leading to the respective sub-levels of 3+ and 4+. These levels are as follows[9]:

1. *Mapping*: Footprint measurement and identification of emissions sources.
2. *Reduction*: Carbon management to reduce the airport's carbon footprint.
3. *Optimization*: Third-party engagement to reduce carbon footprint further.

   3+. *Neutrality*: Achieving carbon neutrality for direct emissions through offsetting.

4. *Transformation*: Transforming airport operations and those of business partners to achieve absolute emissions reductions.

   4+. *Transition*: Compensating for residual emissions with reliable offsets.

5. *Net Zero*: Maintaining a net zero balance for scopes 1 and 2 emissions, actively addressing Scope 3 emissions, strengthening third-party engagement, and offset removals for residual emissions.

The sub-levels were introduced in 2020 to better align with the goals of the Paris Agreement, aiming to limit the global temperature rise to well below 2°C and pursue efforts to limit the increase to 1.5°C. The latest level, Level 5, was added in 2024 and focuses on maintaining a Net Zero balance across scopes 1, 2, and 3 emissions.

ACA primarily focuses on CO_2 emissions, given that they represent the majority of airport emissions. However, other greenhouse gases (GHGs), such as CH_4 and N_2O, may also be included voluntarily as part of best practices. The Airport Carbon and Emissions Reporting Tool (ACERT),

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[8] ACA (2020, A) Short guide to airport carbon accreditation, *Airport Carbon Accreditation.*
[9] [7 levels of accreditation - Airport Carbon Accreditation]

as mentioned earlier, calculates CO_2e emissions, covering methane (CH_4) and nitrous oxide (N_2O) emissions as well.

An independent third-party verification, conducted by an approved verifier, is a crucial part of obtaining and maintaining ACA accreditation. This verification ensures that the GHG emissions are accurately reported and consistently monitored[10].

ACA recommends monitoring emissions using ACERT, either with the aid of consultants, or by own employees, and the monitoring should cover at least a 12-month period. The data should be submitted using either the GHG Protocol worksheets, ISO 14064-1, ACERT, or a combination of these tools. Verification according to ISO 14064 ensures that reported climate change impacts are calculated reliably.

ACA also recommends training relevant staff to ensure accurate carbon footprint calculations. The training would preferably cover the use of carbon footprint tools, monitoring software, and the inclusion of stakeholders and tenants in the process.

Mapping the carbon footprint can help identify key emission sources or "carbon hotspots", leading to more effective emissions reduction strategies[11]. From an airport's perspective, the ACA accreditation enables benchmarking against other airports and demonstrates to industry stakeholders, passengers, and the broader public the airport's commitment to reducing CO_2e emissions. Table 2 shows an overview of the partner's ACA accreditations

Airport	ACA level	Date
CPH	4+ *Transition*	2023
ADR	4+ *Transition*	2021
VNO	3 *Optimization*	2022

Table 2: Overview of ACA accreditation

[10] ACA (2020, A) Short guide to airport carbon accreditation, *Airport Carbon Accreditation.*
[11] ACA (2020, B) Guidance on reducing emissions before offsetting, *Airport Carbon Accreditation.*

4.2 Monitoring from the design Phase of a new airport

As part of the ALIGHT project, the new airport Centralny Port Komunikacyjny (CPK) is under development. Unlike existing airports, CPK is not yet operational, meaning its emissions monitoring must account for the planning, design, and construction phases rather than ongoing airport operations.

4.2.1. Monitoring System for the Planning and Design Phase

A robust emissions monitoring system for a new airport should be developed in alignment with both legal and technical requirements. The system must take into account Scope 1, 2, and 3 emissions, which include direct, indirect, and value chain emissions as outlined in section 2.3.2. It should also provide a mechanism for Landing and Take-Off (LTO) Cycle Reporting, enabling airlines to report emissions from aircraft operations up to 3,000 feet above the airport, as discussed in section 2.2. Additionally, the system should generate data that supports annual emissions monitoring plans, helping to optimize operational procedures and refine algorithms to improve airport efficiency. To ensure consistency and accuracy, the system should adhere to internationally recognized standards for emissions reporting and monitoring. Furthermore, the system should specifically account for aviation fuel consumption, as it is the primary source of carbon dioxide emissions in the aviation sector. Details regarding the monitoring of fuel-related emissions will be further explored in the section dedicated to operational airports.

4.2.2. Methodology for Measuring the Carbon Footprint of CPK

The methodology for measuring the carbon footprint during the construction of CPK airport will be defined in accordance with the requirements of the Building Research Establishment Environmental Assessment Method (BREEAM), which sets standards to ensure the sustainability of new buildings.

According to the BREEAM New Construction methodology, the carbon footprint must be controlled through a life cycle impacts analysis, including embodied carbon, over the full life cycle of a given building, in this case the airport infrastructure. The project must focus on a life cycle assessment (LCA) to evaluate the environmental impact of all building elements.

This methodology also promotes the specification and design of energy-efficient building solutions, systems, and equipment, supporting sustainable energy use and long-term operational management. The BREEAM certification will enable improvements in energy efficiency, reducing inherent emissions, and reduction in carbon footprint through optimized construction and operational strategies.

Furthermore, an energy metering system must be installed to track energy consumption and assign it to specific end uses, aiding in the future definition of Scope 3 emissions.

In addition to construction-phase emissions, the methodology also accounts for lifetime carbon emissions monitoring from operational energy use. A suitably qualified engineer (e.g., a building services engineer) must conduct calculations to assess energy consumption and emissions projections. Assumptions and methodologies for savings in greenhouse emissions must be considered as well.

4.2.3 Monitoring Emissions During Construction

A separate, but crucial component of emissions monitoring is the construction phase of the airport as well as any construction projects at an established airport. During this phase, monitoring should encompass both on-site emissions and indirect emissions related to the use of materials and energy. This includes tracking energy consumption, such as the electricity and heat used during construction activities. It should also account for fuel use, detailing the type and quantity of fuels used to power construction machinery and vehicles. Additionally, emissions associated with the production, processing, and supply of construction materials, often referred to as embodied carbon, must be monitored. Furthermore, the monitoring system should include the quantity and type of materials used, as well as the methods of transportation and storage for these materials.

4.3 Best Practice Established for Monitoring GHG Emissions

The following section will establish a best practice approach to GHG emissions monitoring based on the experiences and knowledge obtained from the ALIGHT project group along additional stakeholders and focus on the areas of monitoring as established in section 2.2.

4.3.1 Passenger's and Employee's Transportation to and from the Airport

Emissions[12] related to the transportation to and from the airport encompass a variety of transport modes, which vary depending on an airport's surrounding infrastructure. While taxis and private cars are common across airports, the proportion of each mode will differ. Public transportation options, on the other hand, vary significantly. For instance, CPH has a metro system directly connecting with one of its terminals, whereas ADR relies on an express train to the city center.

To effectively monitor these emissions, a best practice framework must account for such infrastructural differences while ensuring comprehensive data collection. This framework should primarily focus on monitoring transportation of passengers and employees, though it should also consider other transport-related emissions (e.g., truck drivers, charter buses) as a step toward a more holistic emissions assessment.

The following best practice principles have been established:

- Surveys of relevant stakeholders (passengers, taxi drivers, etc.) should be conducted.
- Data availability must be considered, as it varies from airport to airport.
- Existing transportation infrastructure must be accounted for, including:
    - Public transportation (bus, train, metro)
    - Taxis (conventional, electric, hybrid)
    - Private cars (drop-off and parking)
    - Shared rides

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[12] For the monitoring of transportation to and from the airport, CO_2e is used as the parameter. Although for the transportation sector the difference between only CO_2 and CO_2e is relatively small, as emissions primarily stem from fossil fuels, with the majority being CO_2.

4.3.2. Airport Ground Activities

Emissions from airport ground activities originate from a range of sources, including vehicles and equipment used for airport operations and maintenance. As well as energy consumption required for terminals and office buildings.

This complex area of monitoring is informed by the collective knowledge and experience of ALIGHT partners and the guidance from Airport Carbon Accreditation (ACA) on emissions sources at airports[13].

To ensure comprehensive monitoring, emissions must be tracked based on energy use, which includes:

- Fuel consumption from airport vehicles and Ground Support Equipment (GSE) (both owned and partner-operated).
- Electricity consumption (own operations and partners), accounting for country-specific emission factors.
- Natural gas consumption (own operations and partners).
- District heating (own operations and partners), considering:
    - Country-specific emission factors.
    - Availability of district heating (which varies across regions).

This approach ensures that all relevant energy sources and operational emissions are accounted for in a consistent and scalable manner.

4.3.3 Aircraft Activities in the LTO Cycle

The Landing and Take-Off (LTO) cycle is a well-defined term covering four distinct modes of engine operation as outlined by ICAO[14]: **Idle (Taxi):** The lowest engine speed at which an

[13] Airport Carbon Accreditation (2020) Short-Guide-to-Airport-Carbon-Accreditation-November-2020.pdf (airportcarbonaccreditation.org)
[14] European Environment Agency (2016) (https://data.europa.eu/doi/10.2822/385503)

aircraft can operate without stalling. During this phase, the engine is running at its minimum required power, typically when the aircraft is taxiing on the ground or idling before take-off. **Approach**: This phase occurs when the aircraft is descending towards the airport, typically from cruising altitude, and preparing for landing. It involves the gradual reduction of altitude, with the engines operating at reduced thrust to ensure a controlled descent. **Climb:** The phase when the aircraft begins its ascent after take-off. The engines are running at higher thrust to ensure the aircraft can gain altitude and safely clear any obstacles in the immediate vicinity of the airport. **Take-off:** The phase where the aircraft accelerates along the runway to reach the speed required for lift-off. This phase requires maximum thrust from the engines to achieve sufficient speed for take-off.

Simplified the LTO cycle includes the following aircraft movements as illustrated in Figure 2: **Approach:** Aircraft descend from 1.000 meters above ground level. **Landing and taxiing:** Movement from runway to parking stands and taxiing to the runway. **Departure and climb-out:** Aircraft take-off and ascent to 1.000 meters above ground level.

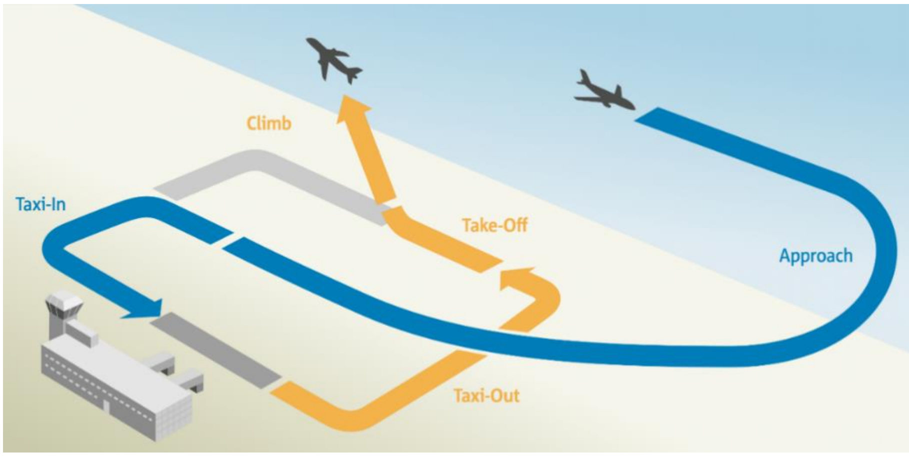

Figure 1: LTO cycle as defined by the European Environment Agency & European Union Aviation Safety Agency ("European Aviation Environmental Report 2016", Publications Office of the European Union, 2016).

Monitoring should account for emissions from:

- Main engines
- Auxiliary Power Units (APUs)
- Engine run-ups

4.3.4 Aircraft Activities - Outbound Flight

Emissions[15] from aircraft departing to their destination airport are also relatively standardised across airports. Based on experience and current industry knowledge, the best practice approach involves monitoring fuel tanking while accounting for:

- Fuel density (t/m^3)[16].
- Carbon emissions per unit of fuel (CO_2e/t), as defined by ICAO[17].

Monitoring should account for emissions from:

- Fuel consumption from aircraft over the outbound flight (including take-off, climb-out, and cruise phases)

4.4 Gap Analysis of Current Systems Against Best Practice

This section identifies potential gaps in the current emission monitoring practices at the airports involved in ALIGHT, comparing them to the best practice approaches outlined above. Each airport (CPH, VNO, ADR and CPK) will to the best of its ability, describe its current practices and assess how well they align with the established best practices. As CPK is not yet operational, the airport will describe its planned future monitoring, incorporating lessons learned from the ongoing work in ALIGHT.

4.4.1 Current Practice and Gaps Identified Against Best Practice (CPH)

Monitoring Emissions from Passenger and Employee Transport to and from the Airport

[15] For aircraft activities, the primary source of emissions is CO_2, with only trace amounts of other greenhouse gases (GHGs) such as N_2O and CH_4. When monitoring emissions for the full destination flight using tools like ACERT, both CO_2 and CH_4 are accounted for, ensuring a comprehensive assessment of the emissions from fuel consumption.
[16] Fuel density is generally defined as being 0.8 t/m^3 on average Air Transport Action Group (2021) fact-sheet_13_saf-metrics-and-conversions_4.pdf (aviationbenefits.org)
[17] ICAO (2018) applications.icao.int/icec/Methodology ICAO Carbon Calculator_v11-2018.pdf

In 2013, CPH commissioned the consultancy firm COWI to analyse emissions from transport to and from the airport. This analysis was updated in 2022 and forms the basis of the current overview. While the focus is primarily on passenger and employee transport, the analysis also includes emissions from goods transport, in line with the scope defined in Section 4.3.1.

Trip length estimates for **private cars** parked at CPH are sourced from the Connected Cars database, which tracks approximately 150,000 vehicles in Denmark and provides average values for distance, speed, and fuel consumption. Each parking event at CPH accounts for two trips (arrival and departure), with estimated travel patterns covering the Zealand region, parts of Jutland and Funen, and Southern Sweden. In 2019, COWI recorded 2,116,846 parkings.

The ***Kiss and Fly*** segment includes vehicles that drop off passengers outside Terminal 2 without parking. While only in- and outflow is recorded, origin data is unavailable. To estimate annual activity, January and February 2020, prior to the Covid-19 lockdown, were used as representative months, leading to a projection of 1,132,890 trips per year. A survey of 565 *Kiss and Fly* users conducted over two days gathered origin data, with 5.6% of responses excluded to avoid overlap with long-term parkers. The average driving distance was estimated at 38.5 km, with most users originating from the Copenhagen area, North Zealand, or Southern Sweden.

Taxi estimates are based on 2019 data, a stable pre-pandemic year, with 935,726 rides. A similar passenger survey was conducted over two days, collecting destination and trip purpose data from 269 taxi users. COWI estimated travel distances using route planners, assuming symmetric trip patterns. Most passengers were headed to Copenhagen neighbourhoods, and a small share travelled to Sweden. The average taxi trip length was calculated at 13.5 km.

The analysis also covers goods deliveries and air cargo transport. Due to limited availability of systematic data on delivery patterns, COWI supplemented the analysis with interviews from key suppliers to estimate emission levels based on typical transport types and volumes.

Charter buses dedicated to airport transport were included based on estimates from CPH and survey data from 58 drivers.

For **public transportation** (including regional trains, InterCity trains metro, and city buses), emissions data were obtained directly from transport companies. Other transport modes were assessed using CPH's internal data and surveys conducted by COWI. To ensure representativeness, 2019 was selected as the baseline year, following established best practices and to avoid distortions from the Covid-19 pandemic.

Emission calculations for the remaining categories were based on activity data and standard emissions factors provided by the Danish Energy Agency. As shown in Table 3 and Figure 2 below, private cars account for nearly half of all emissions from ground transport to and from CPH, with regional trains also making a significant contribution.

Category	Specific Mode	Trips/year	Distance (km/year)	Emissions (tCO_2eq/year)
Private Vehicle Transport	Private Cars (Parking)	2.116.846	90.903.751	12.545
	Kiss & Fly	1.132.890	43.616.265	6.019
	Taxis	935.726	12.632.301	1.677
Heavy Ground Transport	Goods Vans	16.250	271.477	53
	Goods Trucks		214.111	134
	Cargo Vehicles	17.700	531.000	403
Bus Transport	Charter Buses	96.974	5.139.622	3.762
Public Transport	Regional Trains	---	---	10.359
	InterCity Trains	---	---	3.166
	Metro	---	---	285
	City Buses	---	---	169

Table 3: Annual estimated distances and emissions by transport mode from COWI analysis (CPH, 2019 baseline)

Figure 2: Share of tCO2e/year per category and specific mode of transport based on the COWI report.

Identified Gaps

Manual Monitoring: The current monitoring process requires extensive manual effort due to the variety of emission sources. Surveys and data collection from external sources make the process time-consuming. A more automated or streamlined approach could improve efficiency.

Survey Frequency: To enhance the representativeness of data, surveys should be conducted more frequently and on a recurring basis. Further, where the surveys are conducted and which passengers are asked should be distributed across the airport to ensure a representative data set of the various modes of transportation to an airport.

Monitoring Emissions from the Airport's Ground Activities

Emissions from airport ground activities are currently primarily monitored through fuel consumption data. The monitoring of vehicles and ground support equipment (GSE) depends on whether it is owned by CPH or by external partners.

For CPH-owned vehicles and equipment, fuel consumption is monitored using MyVolkswagen, which is specifically designed for Volkswagen vehicles. This system, which also uses the Connected Cars database (previously employed for the private car transportation emissions analysis by COWI), tracks fuel use directly from the vehicles. A similar system will be implemented for non-Volkswagen vehicles in the future. In addition, CPH uses the Fuelomat software to track fuel consumption from the airport's fueling stations.

For partner-owned vehicles, fuel consumption is calculated based on an estimated total fuel usage. As of 2024, a new initiative requires partners to report their fuel consumption data quarterly, which will improve accuracy and consistency in monitoring emissions.

Regarding electricity usage, CPH applies an emissions factor that reflects an average over the past five years. This factor is based on the Danish electricity grid, considering the proportion of renewable energy present on the grid. The same methodology is applied to district heating and natural gas consumption, with an emissions factor calculated using a five-year average to ensure accuracy in monitoring consumption-based emissions.

During the project period (January 2025), CPH has procured a Power purchase agreement (PPA) covering 95.5% of the electricity consumption by CPH and tenants, with the remaining 4.5% being covered by on-site solar panels, thus allowing for a net-zero electricity consumption.

Identified Gaps

Partner emissions consolidation: Emissions from partner vehicles and ground support equipment (GSE) need to be better consolidated. While a new reporting initiative was launched in 2024, improvements are needed to efficiently collect data.

Grid variation: The emissions factor for electricity is based on the Danish grid, which may not reflect the energy mix in other countries. This discrepancy should be addressed for airports in regions with different grid compositions.

District heating: The use of district heating is specific to certain regions like Denmark. This may not apply to airports in other countries, necessitating different monitoring practices.

Monitoring Emissions from the LTO Cycle

Currently, CPH reports emissions from the LTO cycle primarily based on fuel consumption data. Emissions from the main engines, which account for approximately 95% of total emissions, are monitored using the AEDT model. This model calculates fuel consumption and provides accurate emissions factors for CO_2 and CO_2e, based on different combinations of aircraft types and engines.

Emissions from the Auxiliary Power Unit (APU), which represent about 5% of total emissions, are monitored using conservative estimations. These estimations assume that every aircraft uses the same type of APU and has a consistent usage duration. While this approach is based on estimates, it ensures that APU emissions are accounted for.

Finally, emissions from engine runups, which contribute about 0.3% of the total, are monitored through CPH's internal database. This database tracks every engine runup, and the data is cross-referenced with the ICAO emissions database to ensure accuracy.

Identified Gaps

APU estimations: The APU is as mentioned based on a conservative estimate to account for a valid emissions total, as an accurate estimation is difficult to obtain from each aircraft. Actual monitoring of when and how long the APU is turned on would aid in reducing emissions as well as being able to report on actual reductions.

Engine runups: Emissions from engine runups are based on data from the ICAO database, with occasional assumptions needed for engine types not found in the database. However, this is a minor percentage of total emissions.

No gaps are identified concerning the monitoring of emissions stemming from the main engines using the model AEDT.

Monitoring Emissions from the Full Outbound Flight

CPH monitors emissions based on fuel tanking, with data provided by BKL regarding the amount of fuel tanked. The emissions factor from ICAO is then applied to calculate emissions. This method is considered effective, as aircraft are unlikely to over-tank due to high fuel costs, and internal analysis by CPH has shown a strong correlation between fuel tanked and actual emissions.

Identified Gaps

Uncertainty in methodology: While the current methodology shows a minimal uncertainty, it is based on the assumption that fuel tanked correlates closely with actual emissions. However, fluctuations in fuel prices or future regulatory changes (e.g., CO_2 taxes) could potentially introduce uncertainties in the long run. The approach will likely become more accurate as carbon taxes are introduced for aviation.

4.4.2 Current Practice and Gaps Identified Against Best Practice (VNO)

Monitoring Emissions from Passenger and Employee Transport to and from the Airport

Currently, Vilnius Airport (VNO) collects data on passenger access to the airport through surveys conducted twice a year. These surveys, however, are not specifically designed to track transportation modes to and from the airport. Instead, they primarily aim to gauge overall passenger satisfaction with airport services. The surveys are part of the ACI's Airport Service Quality (ASQ) program, which uses a standardized questionnaire.

The survey includes two key questions:

1. *Which transport mode did passengers use to travel to/from the airport?* (Options include private/company car, private car dropped off by someone, ridesharing, taxi/limo, bus/shuttle/coach, rental car, rail/subway, or other).
2. *Did you use parking services?*

The most recent survey results from 2023 revealed that the majority of passengers (73%) travel to the airport by private or company cars, ridesharing, or are dropped off by someone. Notably, 28% of passengers use ridesharing services. Despite Vilnius Airport being only 5 km from the city and having a well-developed and convenient public transport network, only 11% of passengers rely on buses.

Identified Gaps

Lack of data on travel distances and fuel types: VNO does not collect data on travel distances or the type of fuel used for private/company cars, ridesharing, or cars used for drop-off. Given that these modes account for 73% of all travel, it is necessary to expand the survey or implement a dedicated survey.

Lack of data on long-distance coaches: There is a gap in information regarding the number of passengers arriving by long-distance coaches, including those from Belarus and other Lithuanian cities.

Monitoring Emissions from the Airport's Ground Activities

Emissions from airport ground activities at VNO are primarily driven by fuel use for vehicles and machinery, as well as electricity and heat production be it for vehicles or electricity/heat production. For mobile sources, including vehicles and Ground support equipment (GSE), VNO uses a combination of diesel and A95, with a few electric and hybrid vehicles in operation. The VNO Accounting Department compiles and reports the fuel consumption data, which is verified using invoices from fuel suppliers.

For fuel consumption data from VNO's partners and tenants, the information is collected through direct communication with each partner, with the two main ground handlers accounting for the majority of fuel consumption. The data is gathered via email exchanges, and any discrepancies or gaps are addressed through follow-up communication.

Electricity and heat for VNO are supplied by the public grid by central suppliers. The energy consumption is metered or calculated based on the area or volume of leased properties and is collected in an Excel sheet by the Exploitation, using monthly invoices from suppliers.

Emission factors for calculating CO_2e emissions from electricity production in Lithuania are sourced from the annual European residual mixes study by the Association of issuing bodies (AIB). For thermal energy, the emission factor is derived by dividing the total CO_2e emissions from the Vilnius city central heating system by the amount of heat supplied during the year.

Identified Gaps

Partner emissions consolidation: There is a gap in consolidating emissions data from partner vehicles and GSE. Data collection currently relies on manual reporting and communication, which can lead to inconsistencies and delays. A more structured and regular reporting mechanism is needed to streamline the process.

Fuel consumption data for non-partner vehicles: VNO does not collect fuel consumption data for non-partner vehicles or equipment that may contribute to emissions, which could lead to underreporting. Expanding the data collection process to include all vehicles on-site, regardless of ownership, would improve accuracy.

Electricity and heat metering: Not all premises at VNO are equipped with meters for electricity and heat consumption. This gap could be addressed by investing in additional meters for more accurate data collection and emissions calculation.

Grid variation: VNO uses emission factors based on the Lithuanian electricity grid, which may not accurately reflect the energy mix if the airport's energy source changes or if there are significant fluctuations in the grid's renewable energy share. A more dynamic approach to tracking the energy mix is recommended.

Monitoring Emissions from the LTO Cycle

For flights departing from and arriving at VNO, data (flight numbers, routes and types of aircrafts) on the departure and arrival phases of the LTO cycle is obtained from the Airport Management System (AMS) and noise monitoring system's software, SARA. This data is included in the ACERT calculator. Methodologies are consistent with the ACI Guidance Manual on Airport Greenhouse Gas Emissions Management and the GHG Protocol.

Information regarding APUs run-time measured through operational monitoring and multiplied by fuel flow figures for typical APU of each aircraft type. The number of annual engine run-ups is provided by FLtechnics, the main aircraft maintenance provider in VNO.

Identified Gaps

Aircraft types not included in ACERT: Not all aircraft types operating at VNO are included in the ACERT list. Therefore, similar aircraft types must be used as estimates, which could lead to inaccuracies.

Uncertainty in APU usage: There is a gap in the specific timing and length of APU use, which is estimated and could lead to deviations from actual emissions.

Lack of direct data on engine run-ups: There is no direct data available regarding engine run-ups, as this data is provided annually by FLtechnics. There may be more engine run-ups than accounted for, leading to potential underreporting.

Monitoring Emissions from the Full Outbound Flight

Currently VNO is not calculating emissions for the full destination.

4.4.3 Current Practice and Gaps Identified Against Best Practice (ADR)

Monitoring Emissions from Passenger and Employee Transport to and from the Airport

At ADR, passenger transport emissions are currently monitored through passenger surveys, which were updated and improved at the beginning of 2023. The updated survey now collects more detailed information, such as the load factor of the vehicle and the type of car (e.g. hybrid or electric). This data is used to calculate the emissions associated with each mode of transport used by passengers.

In 2023, most passengers continued to use cars as their primary mode of transport, with a significant number travelling with one or more companions. This increases the total emissions, as the vehicles emissions must be accounted for based on the number of passengers. The survey also revealed that a large portion of passengers use gasoline- or diesel-powered private cars. There has been an increasing trend in the number of passengers choosing public transport, particularly train services. Additionally, the percentage of public transport users is nearing pre-pandemic levels.

Identified Gaps

Manual Data Entry and errors: The process of calculating emissions is reliant on surveys, which require manual analysis and data entry. This approach is prone to errors, including incorrect answers or mis entered data, which can affect the accuracy of emissions calculations.

Lack of Automation: The current process involves a significant amount of manual work, making it time-consuming and prone to inaccuracies. The implementation of an automated system or platform where data owners can input information directly, along with supporting documentation, would help reduce errors and increase efficiency.

Monitoring emissions from the Airport's ground activities

At ADR, emissions from airport ground activities are monitored by tracking fuel consumption across all ADR companies, including data collected by the company responsible for the gasoline station. Additionally, emissions from electricity and thermal energy use are monitored through supplier invoices.

Once the data is collected, ADR calculates the CO_2e emissions using the specific emission factor approved by the certifying body during the ACA audits. The same approach is applied to emissions from natural gas use, based on invoices from the supplier, along with the relevant emission factor.

Identified Gaps

Manual Data Collection and Entry: Data collection is currently based on manual communication with data owners, which can be time-consuming and prone to errors.
Lack of Digital Data Entry Platform: The manual data collection process could be improved by creating a platform where data owners can input information directly, along with supporting documents, to streamline the process and reduce errors.

Monitoring Emissions from the LTO Cycle

ADR currently follows the methodology provided by the ACI and uses the ACERT tool to monitor emissions from the LTO cycle. Aircraft movements and the average minutes of the taxi times (in and out) are entered into the tool, which then calculates the LTO emissions values. The tool further calculates the duration of each sub-phase, distinguishing between narrow-body and wide-body aircraft.

Identified Gaps

Inaccurate Taxi Time Entry: A gap exists in the ACERT tool regarding the entry of taxi times. The tool does not allow for fractional minutes to be entered, which means slight reductions in taxi time (and the resulting emissions reductions) are not captured accurately.

Monitoring Emissions from the Full Outbound Flight

Emissions for outbound flights are calculated by multiplying the jet fuel consumed by the corresponding emissions factor. The emissions associated with the LTO cycle (taxi out, climb, and take-off) are then subtracted from the total emissions to account for the cruise phase emissions.

Identified Gaps

No significant gaps have been identified in this section, although ADR acknowledges the potential gap on tankering emissions noted by CPH, even though this is considered unlikely in their case.

4.4.4 Discussion from the Perspective of a new Airport (CPK)

For newly established airports, implementing a robust GHG emissions monitoring system should begin with the development of a comprehensive sustainable development strategy. It is crucial to plan ahead and implement solutions that will be effective once the airport becomes operational. From an operational standpoint, one of the most challenging tasks is constructing a system to accurately collect and manage emissions. This includes the planning of measurement points across all airport facilities and selecting the appropriate software for data collection and processing.

A key aspect of successful implementation is drawing on the experiences of existing airports. Established airports have likely faced similar challenges, and their insights can offer valuable guidance for developing a new system, as presented throughout section 4.4.1-4.4.3. Therefore, fostering collaboration and knowledge sharing within the aviation industry is vital to advancing sustainability efforts and mitigating climate change.

For a new airport, one of the most complex tasks is the collection of emissions data, particularly when it comes to differentiating emissions into the various scopes. Scope 3 emissions, which cover indirect emissions from sources such as construction activities and the energy consumed by vehicles operating on the airport grounds, present a particularly intricate challenge.

A well-defined and well-executed strategy for data collection and management is essential to address these challenges. Such a strategy will not only help meet regulatory requirements but will also identify opportunities for reducing the airport's carbon footprint. By taking a proactive approach, new airports can ensure they are positioned to contribute to the global effort to combat climate change from the outset.

4.4.5 Conclusions

Monitoring Emissions from Passenger and Employee Transport to and from the Airport

All airports use surveys as the basis for monitoring emissions from passenger and employee transport, though the level of detail varies. CPH monitors all transport to and from the airport, while VNO only tracks passenger transport, and ADR includes both passengers and employees. A key gap to address is expanding the scope of monitoring to cover all transport modes, not just passenger travel. Additionally, all airports identified the manual nature of data collection as a challenge. To improve data accuracy and automate the process, increasing the frequency of surveys and transforming their methodology could help account for changes in societal trends or airport-specific developments. This would help capture more up-to-date and accurate data, facilitating better emissions reductions tracking.

Monitoring Emissions from the Airport's Ground Activities

For emissions from airport ground activities, all airports in the project base their calculations on fuel consumption and corresponding emissions factors. A common challenge is the communication with partners to obtain accurate data. Airports should aim to consolidate data from their partners to ensure more efficient and accurate monitoring. One potential improvement could be to make data provision a part of the operational requirements for companies working at the airport. Regarding electricity and heating emissions, these are calculated based on consumption and country-specific emission factors, with no significant gaps identified in this area.

Monitoring Emissions from the LTO Cycle

CPH uses the AEDT tool for monitoring the LTO cycle, while VNO and ADR rely on ACERT. In all cases, assumptions are sometimes necessary when specific aircraft engine types are not included in the respective databases. Additionally, estimating APU emissions is a challenge for all airports due to the difficulty in obtaining precise timing data for each aircraft. Furthermore, engine run-up data is based on estimates at all three airports. CPH faces this issue in cases where the specific engine time data is missing from the ICAO database, VNO relies on an external partner's estimation for engine run-ups, and ADR uses conservative estimations for the same purpose.

Monitoring Emissions from the Full Outbound Flight

For outbound emissions, CPH and ADR calculate emissions based on the tanking and fuel consumption, which are directly correlated. The assumption here is that aircrafts are not typically over-fueled due to high fuel costs. However, a potential gap could arise if fuel prices decrease, leading to more tankering practices[18]. Given the ongoing societal shift toward sustainability, however, it is likely that fuel prices will continue to rise, making this estimation more robust. Additionally, the new EU regulation (RefuelEU)[19] will likely minimise this gap, as it mandates that aircraft operators ensure fuel tanked at EU airports is at least 90% of the yearly fuel requirement by 2025, thus reducing the incentive for unnecessary tankering and minimising additional emissions. Notably, VNO does not currently account for the full destination emissions.

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[18] Tankering refers to the practice of loading more fuel than necessary for a trip to take advantage of lower fuel prices at the airport of origin.
[19] EU (2023) [RefuelEU aviation initiative: Council adopts new law to decarbonise the aviation sector - Consilium (europa.eu)]

Table 4 provides an overview of identified common gaps between the fellow airports based on explanations above for the emissions scope established in Table 1.

Emissions area	Airport	Current practice	Common gaps identified
Transportation to and from the airport	CPH	All transport to and from the airport	Expanding the scope of monitoring to cover all transport modes, not just passenger travel. Manual nature of data collection as a challenge.
	ADR	Passenger transport	
	LTOU	Passengers and employee transport	
Airport ground activities	CPH	Monitoring based on fuel consumption and corresponding emissions factor. For electricity and heating emissions, monitoring is based on consumption and country-specific emission factors.	Communication with partners to obtain accurate data. No significant gaps identified for electricity and heating.
	ADR		
	LTOU		
LTO cycle	CPH	AEDT tool	Estimating APU emissions is a challenge due to the difficulty in obtaining precise timing data for each aircraft.
	ADR	ACERT tool	
	LTOU	ACERT tool	
Full outbound flight	CPH	Monitoring of emissions based on the tanking and fuel consumption, which are directly correlated.	A potential gap could arise if fuel prices decrease, leading to more tankering practice
	ADR		

	VNO	Does not account for the full flight.	

Table 4: Providing an overview of identified common gaps between the fellow airports

5 Improving the monitoring of GHG Emissions

As the aviation industry progresses towards greater sustainability, improving the monitoring of greenhouse gas (GHG) emissions has become increasingly critical. This is especially true for airport operations and transportation to and from airports. While several monitoring systems are currently in place, gaps remain in comprehensive data collection and in addressing emerging sustainability practices, such as the increased use of Sustainable Aviation Fuel (SAF). Strengthening these systems will not only enable airports to better track their progress toward emissions reduction targets but also enhance the transparency of their emissions reporting.

This section outlines how refining monitoring systems, particularly for passenger and employee transport and APU usage, can strengthen the overall emissions inventory and promote more sustainable initiatives in the airport sector. A key focus is improving data collection processes, reducing manual efforts, and increasing accuracy to support more effective emissions management.

5.1 Improving Monitoring Transportation to and from the Airport

Transportation to and from airports contributes significantly to overall emissions, with private cars, taxis, buses, and other ground transport being major contributors. While existing data collection methods, such as surveys, are in place, there is room for improvement in ensuring consistent and accurate emissions tracking. A more structured approach to gathering traffic data will help airports better understand emissions and implement targeted reduction strategies.

To address this, it is proposed refining and extending the model developed at CPH for monitoring catchment area traffic, enabling systematic annual data collection at any given airport. This model will help airports maintain up-to-date emissions inventories and provide a framework for continuous improvement. Supported by templates, it will ensure consistent data gathering and easy annual updates, facilitating better oversight and promoting greener initiatives.

The goal is to create a framework for use in the ALIGHT project, where transport data and insights can be applied across airports. CPH provided a guide for developing calculation models, but individual airports will be responsible for updating and maintaining their data. The gap analysis identified the significant manual effort required for data collection, highlighting the need for airports to improve their data processes and governance.

5.1.1 Methodology Used for CPH as a Best Practice Model

Emissions from transportation to and from the airport are calculated based on the distance travelled in kilometres by different modes of transportation. To achieve this, it is essential to determine the number of travellers, the average distance per passenger and the distribution of transportation modes. By collecting data and calculating the number of kilometres travelled, each mode must be matched with the appropriate emission factor, which can be found in national databases or, alternatively, international averages may be used.

The first step is to identify the types and number of transportation modes. For CPH, these include; private cars (diesel, gasoline, electrical and hybrid vehicles), taxi (diesel, gasoline, electrical and hybrid vehicles), trains, metro, public buses, charter buses, walking, and cycling. Before conducting any catchment traffic analysis the airport must identify means of transportation.

The second step is to identify available data and the extend of this data. The objective is to understand the transportation pattern of all passengers arriving and departing from the airport.

Once the transportation modes are established, it is necessary to collect data regarding number of travellers and the distance for each mode.

If it is only possible to account for 50%, it will be necessary to extrapolate. Conversely, as was the case for CPH, more travellers were identified than just passengers and employees. This is due to CPH functioning as a mobility hub for individuals travelling between Copenhagen and

Sweden for work, as well as for locals who live near the airport and utilise its public transportation options without necessarily travelling themselves.

Data Sources

The data sources can be divided into two categories: passenger data and staff data.

For employee commuting, the method was to use surveys which examines the number of days, kilometres and means of transportation for all staff members as well as the postal code of the part of Denmark where they travel from. For CPH the survey had a 10% response rate. From the HR system it could be determined how many employees came from each postal code. Thereby the total number of kilometres travelled and could be determined by extrapolation to cover all staff members.

Passenger data was a mixture of data from Copenhagen's internal systems and external transport suppliers. A lot of passengers who arrive by cars book a spot in the parking lots in advance and provide information about where they travel from in the booking process. This provided a high-quality data point. The distribution of cars could only be made by national averages. From this the average distance per car was calculated and multiplied with the total numbers of parked cars at the airport. From CPHs internal taxi system it was possible to determine how many taxis arrived of each type and from surveys it was established how far an average traveller arrived from and how many travelled by each cap.

All external passenger data from busses, metro, trains and chartered busses and leased cars were collected by asking the companies directly to provide data for number of passengers and kilometres travelled to and from the airport by the different means of transportation. An issue for all external data was that the verification process was long so that validated figures for a full year was only available in February/March. However, CPH experience great willingness and interest in providing data.

From this data it was possible to calculate emissions for all modes of transportation.

All data handling were done in excel format, for future development it is desired to implement the model in either PowerBI or similar to update data quarterly for CPHs own datapoints.

5.1.2 Developing a Modelling Tool: A Case Study

From the data collected and analysis done with CPH as the case, it was possible to develop drivers which could be used to estimate the emissions from the fellow airports. This serves as a case study on how collecting multiple data points from multiple airports will enable other airports to make an estimate on their emissions from catchment traffic[20] based on very few details. However, it also shows why it is necessary for more airports to do a full calculation of their catchment traffic.

CPH developed drivers based on area of airport, number of passengers and total number of passenger flights and number of employees.

All airports were early in the process asked to deliver the following data on their airports based on the full year 2023.

1. Total number of flights
2. Total number of passengers
3. Area of airport

Airport	Total tons CO_2 estimate [Passengers/Employees]	Total tons CO_2 after conducting surveys [Passengers/Employees]	Total CO_2 with complete data
CPH	---	---	[54.352/ 1.151]
ADR	[85.924/ 2.604]	[138.808/ 16.573]	---
VNO	[9.337/ 531]	[28.323/ 726]	---
CPK	[70.994/ 3.500]	---	---
KUN	[2.756/713]	---	---
PLQ	[651/256]	---	---

Table 5: Showcasing different emissions estimations based on various inputs.

[20] Transportation to and from the airport

From this information the airports catchment traffic emissions were estimated based on the comprehensive data collected for CPH. The results of the analysis were very much dependent on number of passengers. The results are seen in Table 5 above in the first column.

ADR and VNO then conducted their own passenger and staff surveys based on the best practice guide from CPH. These data inputs changed their results significantly to a higher value for emissions. The reasons were that especially for ADR the catchment area is much larger than for CPH resulting in an average distance travelled to the airport being significantly higher. As for VNO the changed result was caused primarily on the lesser use of public transportation than for CPH. The results can be seen in the table in the second column.

For CPH the emissions are shown in the 3rd column which is based on a more complete data set including as mentioned before, surveys, parking registration, data from public transport companies and so forth.

To improve these results, it would require a larger sample of airports and possible more drivers. It is clear that by modelling and estimating multiple airports based on a single airport is not a scientific appropriate method. However, the model itself serves as a proof of concept. It exemplifies that it is possible to develop meaningful drivers, but in reality, it is necessary to base these on multiple airports and develop more drivers, maybe regional based or similar.

This opens up for industry tools where multiple airports report standard parameters and their own specific emissions from models based on the guidelines and principles described in this report. By doing so the industry could develop a proper tool which takes into account countries, different emission factors, different sizes and types of airports. This could lead to more precise first estimates for other airports, who is simply interested in a best guess for early reporting or emission reduction strategies before they conduct their own analysis. Such tool would require a common data hub or platform which could host data and operate the tool. The aim would be to help airports over time decrease their emissions and work strategically with converting catchment traffic to more sustainable options.

5.1.3 Description of Tool and Template

The above section provided the basis for the development of a tool or guidance for other airports to conduct a similar exercise to either improve their own monitoring exercise or to test current practices as this established within ALIGHT. A series of tools have been developed and can be found within the replication toolbox of ALIGHT, with short descriptions below.

The tool is an excel files which includes multiple "mini-tools" and best practices for airports to be inspired by or copy directly. Each airport must consider their own options and capabilities as it may be necessary to adjust the templates and tools to suit their needs specifically. Two of the tools are surveys, one for staff members, one for passengers arriving.

The other tool is an example of how to structure the data. This table includes number of passengers/journeys, total number of travelled kilometres for each type of transportation and each data source/ data point. Data points and sources can for example be data from parking houses or data for public transportation companies or staff surveys. The last tool is a methodology description on how CPH did their analysis from collection of raw data to extrapolation to match the total number of passengers and staff.

For related content on passenger transport, see *Deliverable D5.1 (Work package 5).*

5.2 Improving Monitoring of the use of APU at aircraft stands

Through the gap analysis and best practices described in this report, it became apparent that monitoring of APU related emissions could be improved. As part of ALIGHT a new task was added during the project period to describe a new and improved model for the monitoring of APU emissions at aircraft stands. Further details on the report can be found in the deliverable 6.6 *APU emission control system methodologies,* furthermore similar to the above section a guidance on how to implement an improved APU monitoring system has been developed.

The tool consists of an APU Monitoring system for data-driven communication with partners involved in aircraft turn around, and resulting in possible business models for GHG emission savings from reduced APU use.

With this advanced monitoring system, the airport will be able to:

- Identify active APUs and engage in discussions with pilots to encourage APU shut-downs
- Gather data from aircraft stands to analyse APU usage patterns
- Leverage this data to pinpoint initiatives aimed at reducing APU usage
- Monitor and assess the effectiveness of these initiatives over time

The aim of improving the monitoring system for APU use is to reduce GHG emissions where possible as well as being able to account for such potential reductions accurately, furthermore, reducing APU use could also hold potential for lowering the impact on the local air quality surrounding aircraft stands.

6 Conclusion

This report outlines a comprehensive approach for enhancing greenhouse gas (GHG) emissions monitoring systems at airports, focusing on improving data collection, reducing manual effort, and increasing the accuracy of emissions inventories. It identifies key emission sources—passenger and employee transportation, airport ground activities, aircraft activities during the landing and take-off (LTO) cycle, and outbound flights to destination airports—highlighting critical areas for monitoring.

The ALIGHT project has established best practices for emissions monitoring, including standardized data collection methods, integration of transport and fuel data, and the use of modeling tools to estimate emissions from limited data inputs. These practices have been evaluated across partner airports, including Copenhagen Airport (CPH), Vilnius International Airport (VNO), Aeroporti di Roma (ADR), and Centralny Port Komunikacyjny (CPK), revealing gaps and areas for improvement.

The report emphasizes two key areas for improvement: transportation to and from airports and Auxiliary Power Unit (APU) usage at aircraft stands. Addressing these areas is crucial for refining emissions inventories and advancing sustainability in the aviation sector.

The methodology developed, including data collection through surveys, parking registrations, and transport provider information, demonstrates how airports can estimate emissions with limited data. This approach is adaptable to other airports in the ALIGHT project and beyond, offering scalable solutions for emissions monitoring.

In conclusion, the report calls for the creation of an industry-wide platform to standardize emissions data sharing. Such a platform would help airports refine their reporting practices, collaborate on emissions **reduction** strategies, and support a more **sustainable** airport sector. By maintaining accurate emissions inventories, airports can significantly reduce their environmental impact and contribute to broader climate action goals.

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