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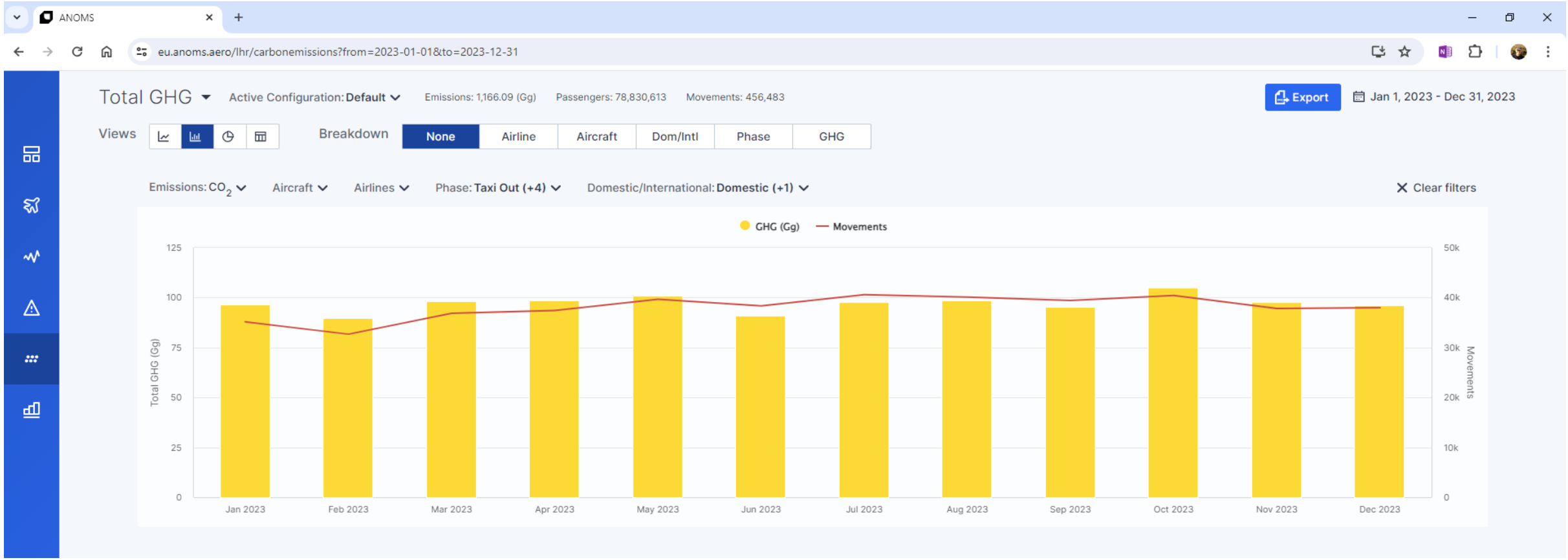
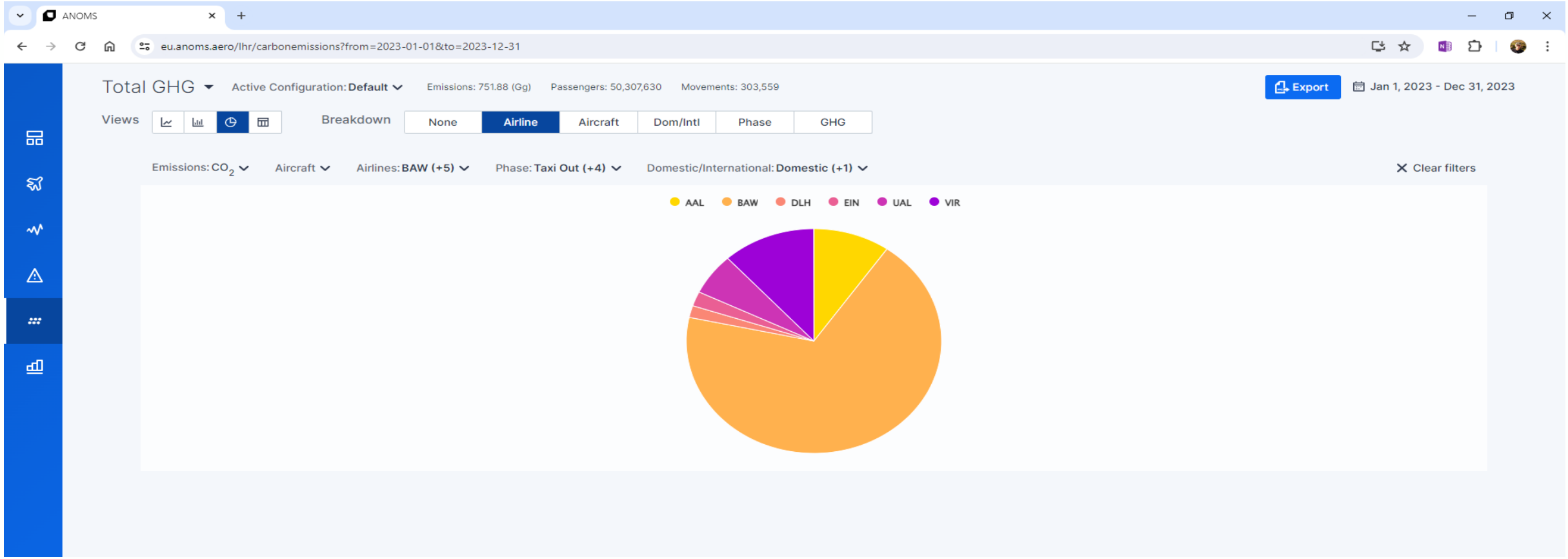
ANOMS
Carbon Emissions

What, How & Why

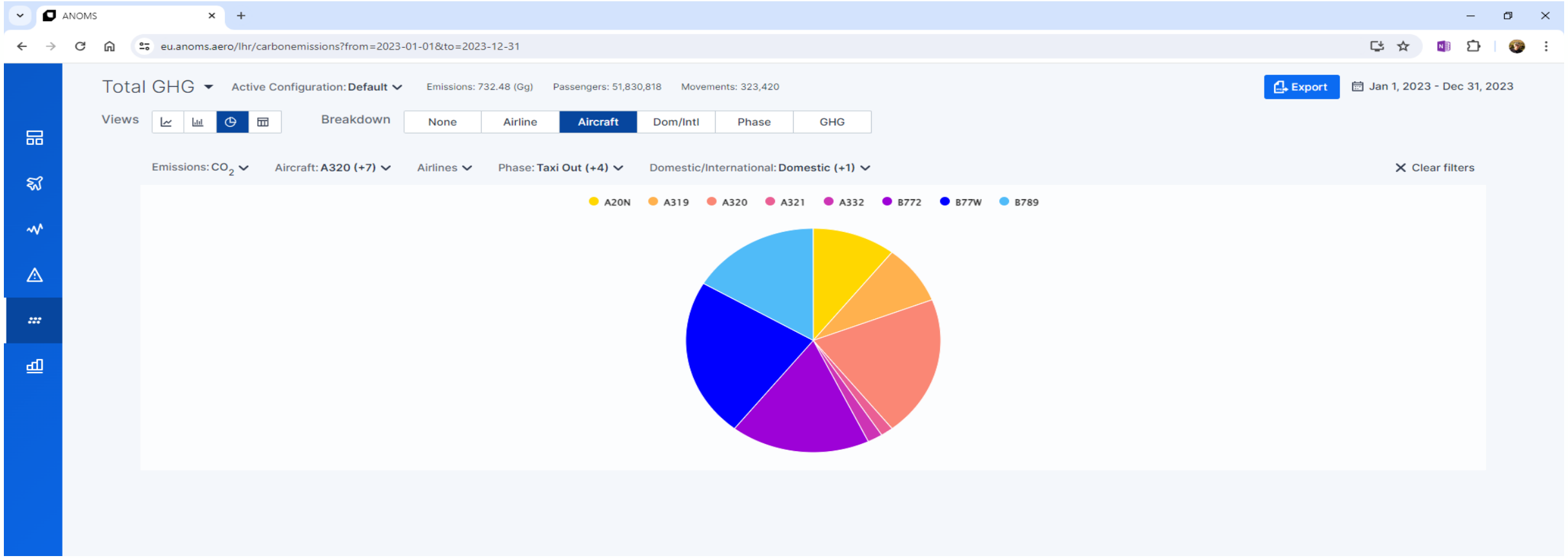
CO_2 Emissions for aircraft operations



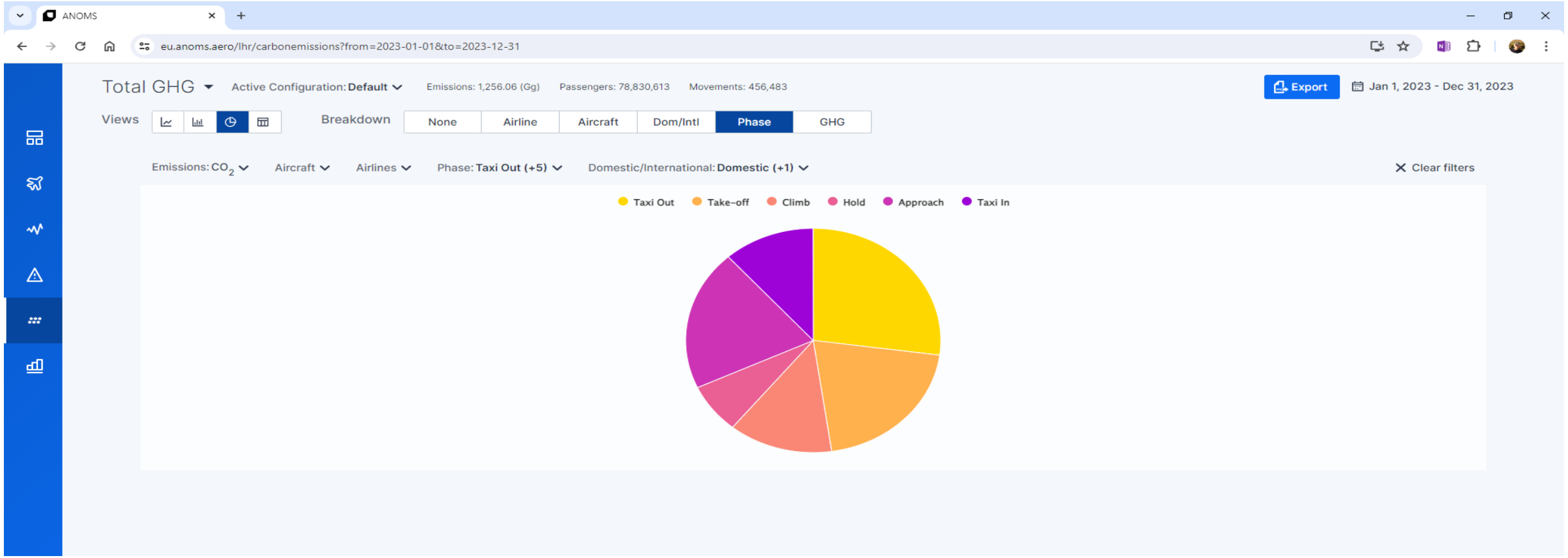
CO_2 Emissions by airline



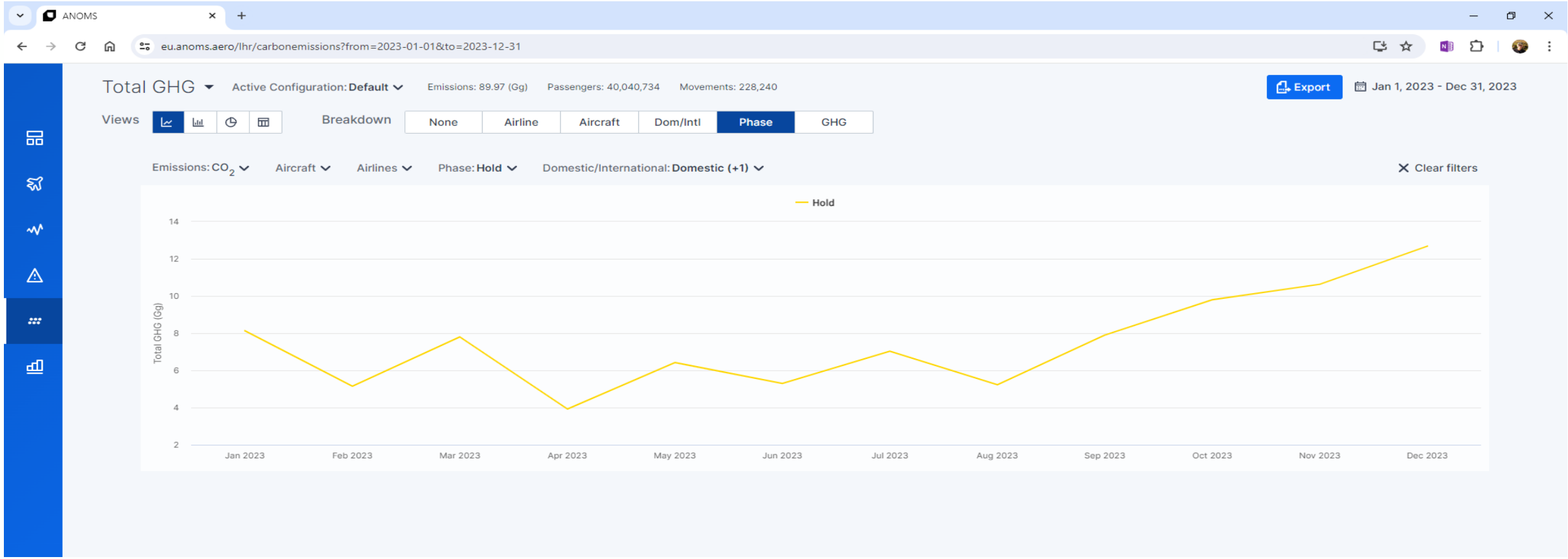
CO_2 Emissions by aircraft type



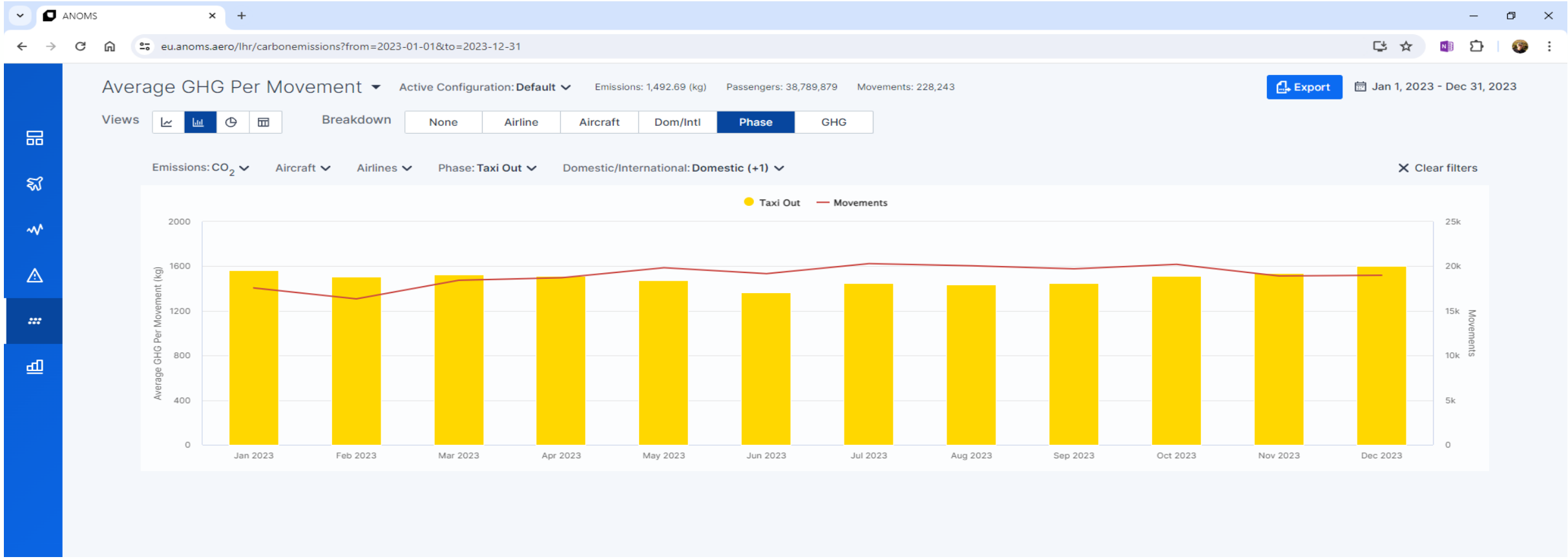
CO_2 Emissions by LTO phase



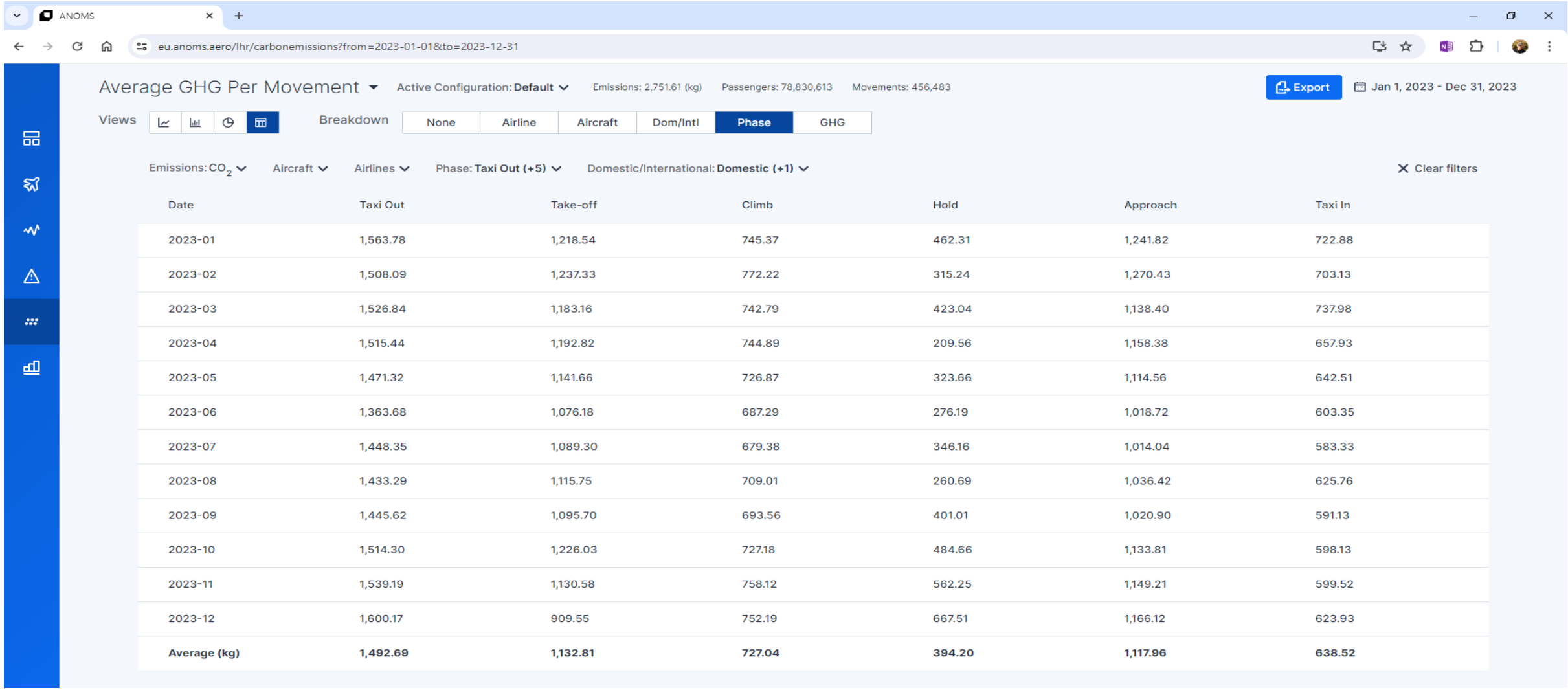
CO_2 Emission trends



CO_2 Emission trends normalized by movement



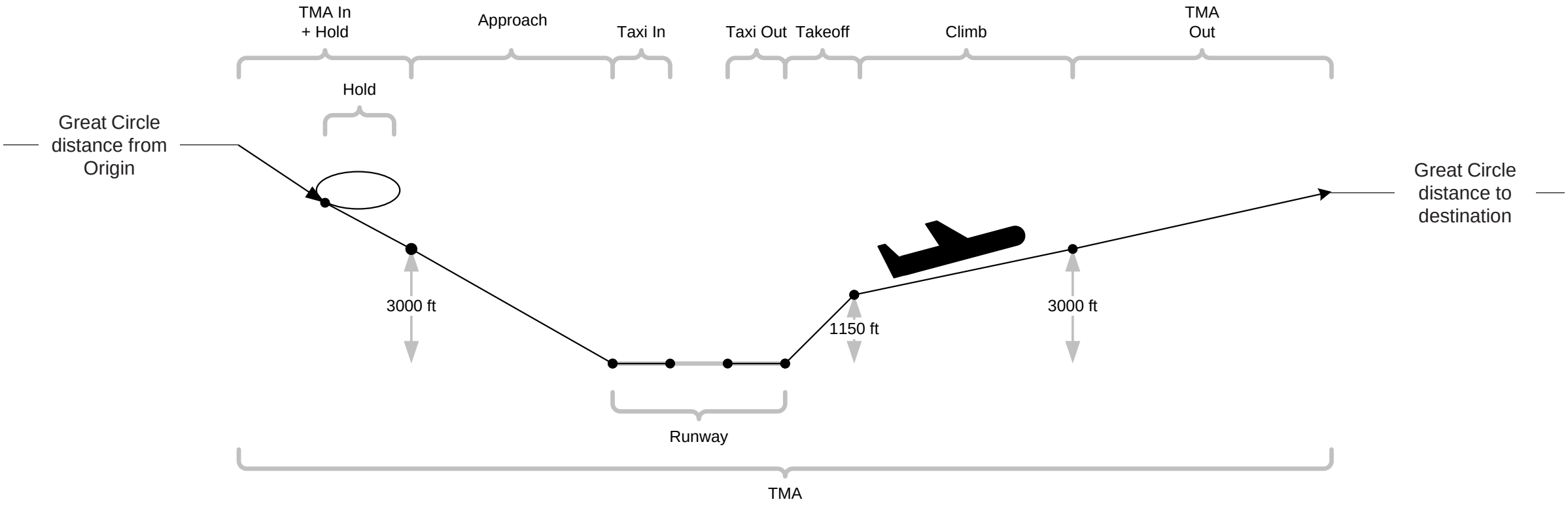
CO_2 Emission detailed data



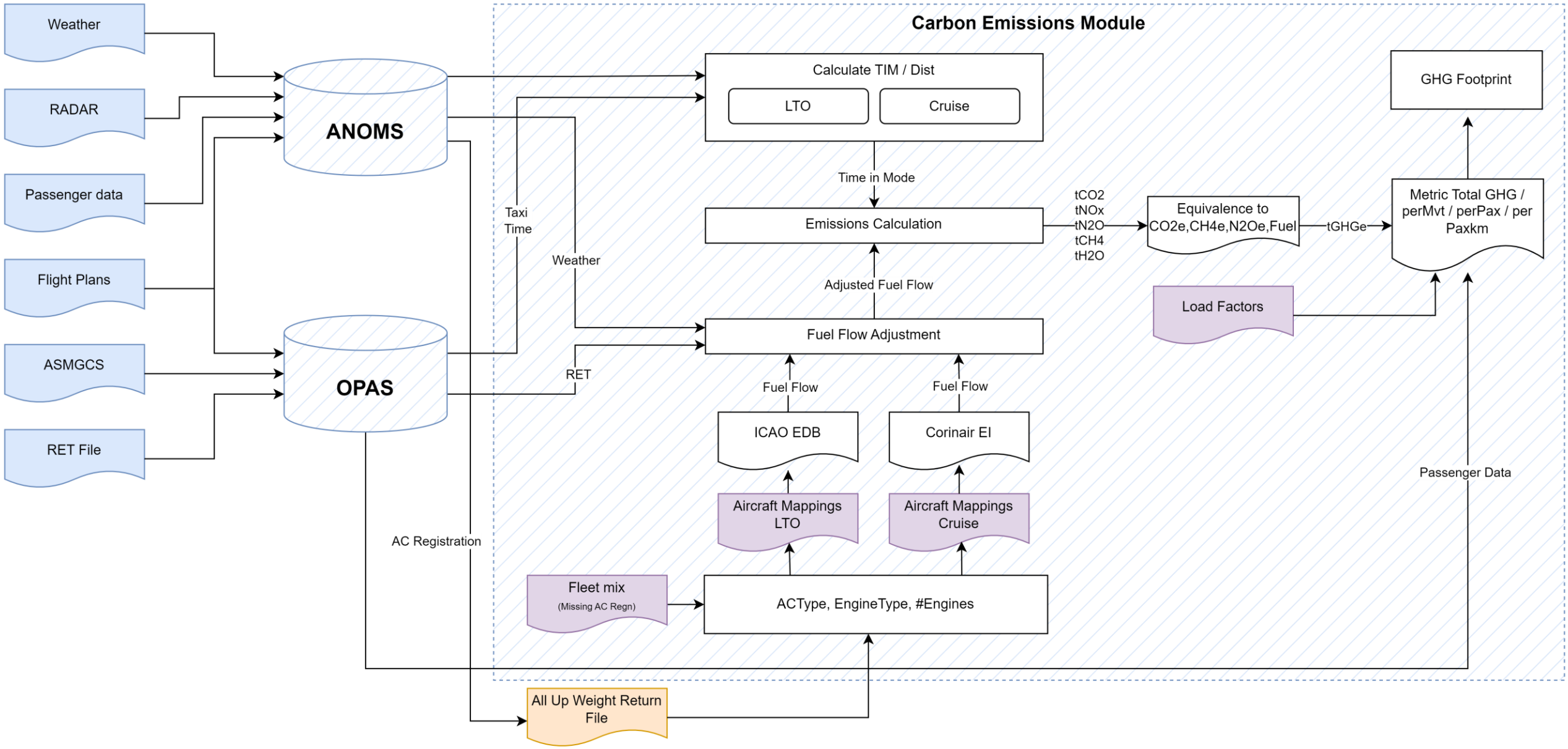
Date	Taxi Out	Take-off	Climb	Hold	Approach	Taxi In
2023-01	1,563.78	1,218.54	745.37	462.31	1,241.82	722.88
2023-02	1,508.09	1,237.33	772.22	315.24	1,270.43	703.13
2023-03	1,526.84	1,183.16	742.79	423.04	1,138.40	737.98
2023-04	1,515.44	1,192.82	744.89	209.56	1,158.38	657.93
2023-05	1,471.32	1,141.66	726.87	323.66	1,114.56	642.51
2023-06	1,363.68	1,076.18	687.29	276.19	1,018.72	603.35
2023-07	1,448.35	1,089.30	679.38	346.16	1,014.04	583.33
2023-08	1,433.29	1,115.75	709.01	260.69	1,036.42	625.76
2023-09	1,445.62	1,095.70	693.56	401.01	1,020.90	591.13
2023-10	1,514.30	1,226.03	727.18	484.66	1,133.81	598.13
2023-11	1,539.19	1,130.58	758.12	562.25	1,149.21	599.52
2023-12	1,600.17	909.55	752.19	667.51	1,166.12	623.93
Average (kg)	**1,492.69**	**1,132.81**	**727.04**	**394.20**	**1,117.96**	**638.52**

Data Sources

Identifies phase of flight from track data (taxiing, arrival, departure, etc) for fuel burned ratios.



Carbon Emissions Block Diagram



Why do airports need CE?

Why do airports need CE?

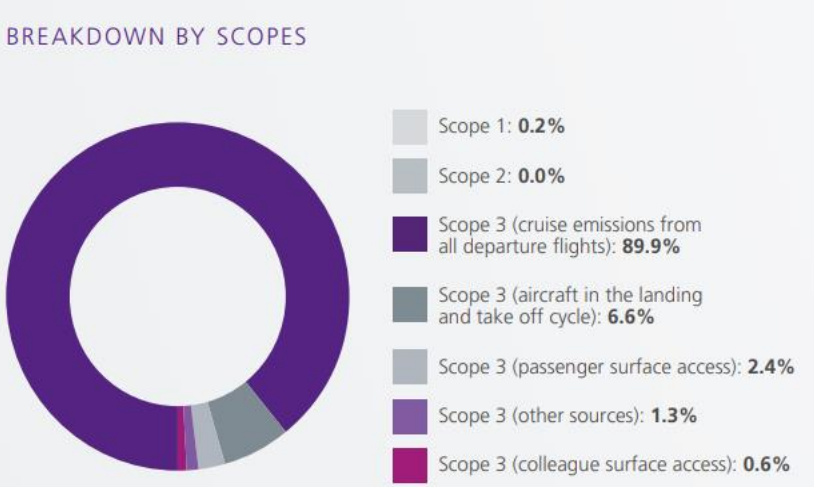
Pre-emptive, pro-active assessment

- **Easy Greenhouse Gas assessment**: Totally automatic, web-based and utilises the airport's ANOMS infrastructure, resulting in minimum overhead on resources
- **Continuous measurement**: Carbon Emissions Manager delivers a steady stream of emission data for every movement in and out of the airport
- **Accuracy**: Carbon Emissions Manager measures carbon emissions from the *actual* flight track, specific flight by specific flight, rather than using averages or approximations – that ignore your situation and your efficiency initiatives
- **Detail**: Carbon Emissions Manager measures carbon emissions at each stage of the flight, especially stages that can be directly influenced, such as taxiing and holding. This means airports can implement changes and measure the impact of those changes
- **Certified results**: Consistent with International Standards and best practice.

Airport Carbon Accreditation and CE

Level 1 Mapping	Level 2 Reduction	Level 3 Optimisation	Level 3+ Neutrality	Level 4 Transformation	Level 4+ Transition	Level 5
• Aéroport Trois-Rivières • Comox Valley • Edmonton • Fredericton • London • Regina • Region of Waterloo • Saint John • Calgary • Greater Moncton Romeo LeBlanc • Thunder Bay • John C. Munro Hamilton	• City of Kelowna • Fort McMurray • Nanaimo • Saskatoon • Victoria	• Aéroport de Québec • Charlottetown • Halifax • Winnipeg	• Ottawa	• Montréal • GTAA	• Vancouver	

- Aircraft emissions are more than 90% of an airport's Scope 3 emissions
- Assessment is required for ACA level 4+ & 5
- Before that it's important to get informed
- CE provides a simple, accurate and detailed assessment and shows regular progress towards targets



Heathrow Sustainability Report 2023

The Heathrow Sustainability Linked bond

- Issued Sep 2023, the bond performance depends on achievement of 2 sustainability KPIs
- First bond to include in the air emissions from aircraft – determined by CE
- KPI's are defined, continuously monitored and published annually
- Attractive for ESG investors
- Allows the airport access to preferential financing

SCHEDULE 1: DESCRIPTION OF HEATHROW'S KEY PERFORMANCE INDICATORS (KPIs) AND SUSTAINABILITY PERFORMANCE TARGETS (SPTs)

KEY PERFORMANCE INDICATORS	SUSTAINABILITY PERFORMANCE TARGETS			SDG ALIGNMENT
KPI 1 Reduction of 'in the air' carbon emissions: Absolute 'in the air' carbon emissions expressed in tonnes of CO2 equivalent *. **** Includes Scope 3 emissions of all aircraft operating at Heathrow Airport during i) cruise phase (for departing flights only), ii) landing, and iii) take off.***	**Financial Year**	**Absolute 'in the air' carbon emissions (millions tCO2e)**	**Reduction of absolute 'in the air' carbon emissions (%)[17]**	7 AFFORDABLE AND CLEAN ENERGY 13 CLIMATE ACTION
	2019 (Baseline)	20.0	0%	
	2026	18.0	10% reduction from 2019	
	2030	17.0	15% reduction from 2019	
KPI 2 Reduction of 'on the ground' carbon emissions: Absolute 'on the ground' carbon emissions expressed in tonnes of CO2 equivalent **. ***** Includes i) Scope 1, 2 & 3 emissions relating to buildings and infrastructure, ii) Scope 1 & 3 emissions relating to airport vehicles, iii) Scope 3 emissions relating to supply chain, and iv) Scope 3 emissions relating to surface access to the airport (incl. passengers and colleagues).***	**Financial Year**	**Absolute 'on the ground' carbon emissions (thousands tCO2e)**	**Reduction of absolute 'on the ground' carbon emissions (%)[17]**	
	2019 (Baseline)	1,048	0%	
	2026	774	26% reduction from 2019	
	2030	564	46.2% reduction from 2019	

Source: Second Party Opinion on Heathrow Airport Sustainability-Linked Bond Framework

Directly links environmental performance with company strategy – If targets are missed the cost of debt increases

Our Purpose

We believe environmental intelligence is the key to improving the wellbeing of people and the planet.

Photo courtesy of NASA

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Reverse Thrust Detection

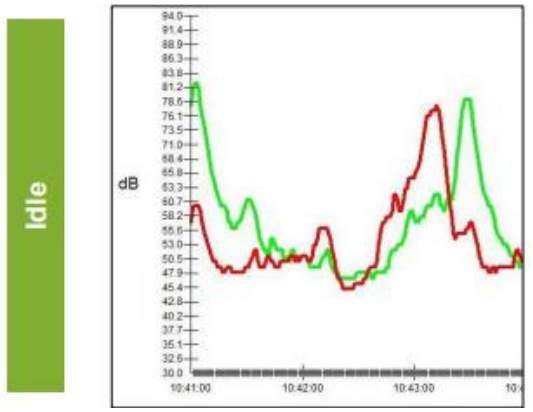
Work in progress…

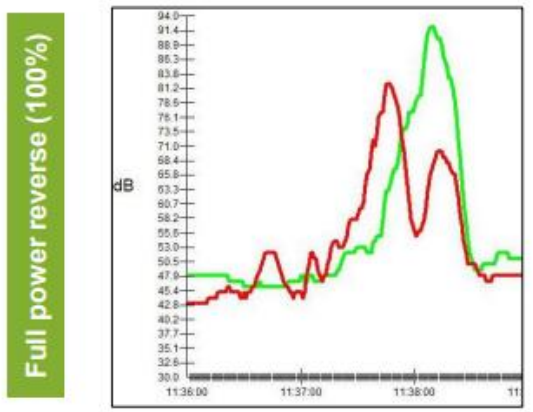
Why is detection useful?

- Many airports discourage use of reverse thrust
- Particularly at night due to significant community noise nuisance
- Some (most?) allow idle reverse thrust
- No established methodology to understand compliance

Detection is challenging

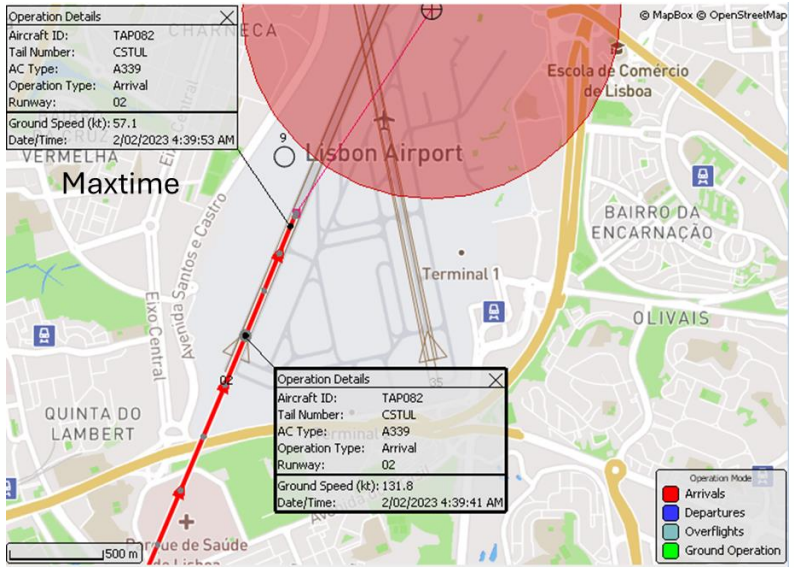
- Measure aircraft deceleration from the flight track
  - Doesn’t correlate well with RT usage
  - Depends additionally on aircraft type, weight, load factor, weather conditions, wheel or aero brake application
- Measure noise levels
  - Expensive, need to measure at two points to capture reverse thrust noise down the runway
  - Frankfurt study used 2 NMTs per runway end.
  - Can be difficult to distinguish between RT noise and other sources of ground noise on the airfield



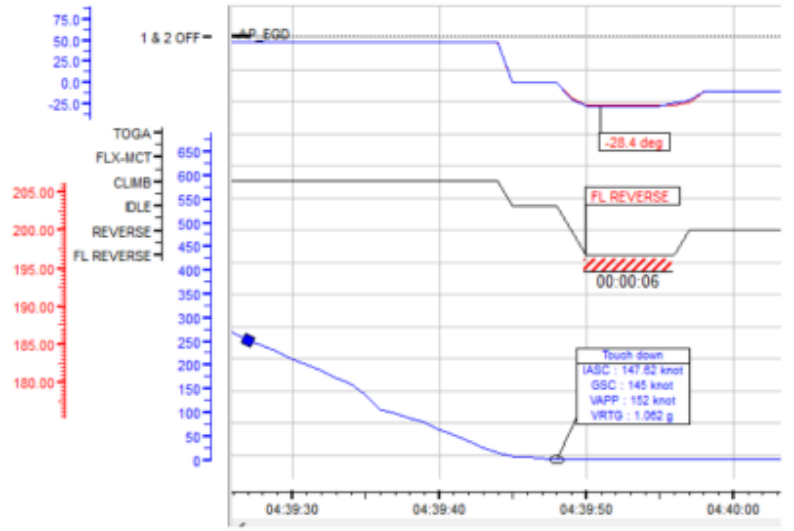


What we’re doing

- Working with a European airport and its airlines to collect data which will lead to a methodology we can apply across airports
- Capturing
  - Noise Signature, flight track, ac info, met data
  - Throttle vs altitude, RT application, braking method
  - Use of early exits or long landing roll
- Develop a practical method to determine compliance with reverse thrust usage policies at airports.



Na sequência do pedido infra, informamos que foi utilizado Full Reverse durante 6s no seu voo TP82 de 01/fev.



Preliminary ideas

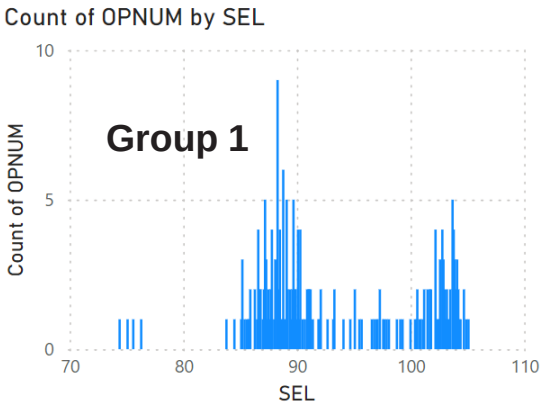
- Frequency spectrum can distinguish between full or idle reverse thrust
- A single measurement point produces 2 population distributions when grouped by Max Landing Weight
- More work to do……wait for Aviation Forum 25

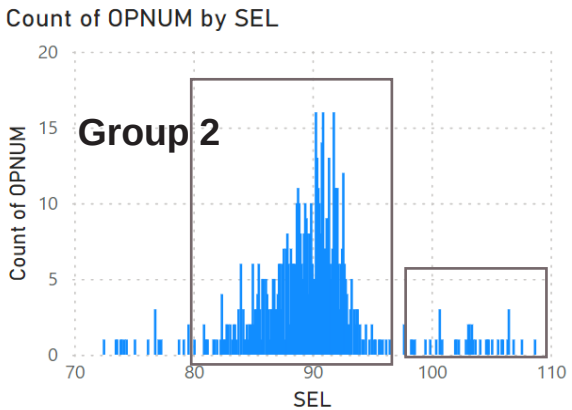
HZ16	HZ20	HZ25	HZ31	HZ40	HZ50	HZ63	HZ80	HZ100	HZ125	HZ160	HZ200	HZ250	HZ315	HZ400	HZ500	HZ630	HZ800	KHZ1	KHZ1_2	KHZ1_6	KHZ2	KHZ2_5	KHZ3_1	KHZ4	KHZ5	KHZ6_3	KHZ8	KHZ10	KHZ12	KHZ16
641	623	659	700	694	726	712	733	698	600	492	475	512	511	516	534	568	615	608	546	532	560	508	482	437	345	235	126	89	117	172
722	731	741	748	778	816	768	792	785	703	579	497	525	575	582	605	641	670	678	634	599	630	568	544	507	456	362	264	129	116	171
722	789	792	762	820	836	814	814	791	739	683	551	578	616	640	671	698	737	745	710	691	708	662	644	610	564	503	420	290	142	173
744	803	817	789	868	891	889	857	861	831	780	665	627	684	727	759	778	804	818	811	772	760	743	732	703	668	617	551	444	284	183
764	808	790	830	840	876	863	882	880	865	820	748	622	653	707	752	775	797	810	807	780	749	745	732	710	668	633	570	473	325	193
761	800	790	822	821	863	842	849	881	874	838	777	690	684	707	748	775	793	804	806	782	759	746	718	713	663	633	582	480	331	197
761	800	770	805	848	873	838	849	879	873	830	761	669	656	695	724	756	794	803	800	775	745	735	721	709	667	630	576	460	306	189
727	748	786	796	810	873	866	869	845	839	800	724	613	630	679	708	729	762	777	766	733	705	695	677	657	613	568	507	382	228	174
710	750	761	808	842	822	864	876	855	821	752	654	562	615	672	705	737	757	754	732	712	711	697	668	642	592	531	456	314	158	172
714	738	714	753	797	855	828	836	822	797	724	609	541	582	646	684	701	732	729	687	683	688	650	632	602	548	480	396	242	126	171
695	693	763	774	806	810	805	830	808	780	682	565	556	587	625	631	660	687	675	630	632	630	601	578	540	480	407	305	151	116	172
715	732	770	766	772	813	837	826	803	741	659	513	572	614	646	663	695	695	670	652	639	626	596	567	527	462	374	268	119	116	171
722	716	715	744	730	803	819	807	768	722	604	488	535	576	625	659	692	694	646	661	644	631	611	577	536	468	374	255	108	116	172
682	733	702	740	786	811	812	802	769	704	568	462	528	579	608	656	688	686	626	645	611	596	572	535	492	418	318	192	94	116	172
690	692	739	744	769	801	791	788	755	688	543	487	509	537	585	634	662	643	622	629	582	585	545	505	459	381	265	143	89	116	171
665	694	710	744	777	781	785	775	749	678	539	483	542	525	553	597	632	607	608	606	567	563	532	492	438	354	233	115	90	118	172
622	687	701	723	766	788	799	766	747	673	526	471	524	549	577	604	604	576	578	569	537	530	497	457	399	308	188	97	90	117	171
654	687	722	753	743	785	782	753	720	644	518	489	539	560	566	607	604	564	567	549	521	510	488	442	389	296	173	93	88	116	170
608	647	687	686	729	771	754	731	710	631	501	474	519	536	558	577	594	549	564	543	514	496	468	420	362	272	154	91	88	116	172

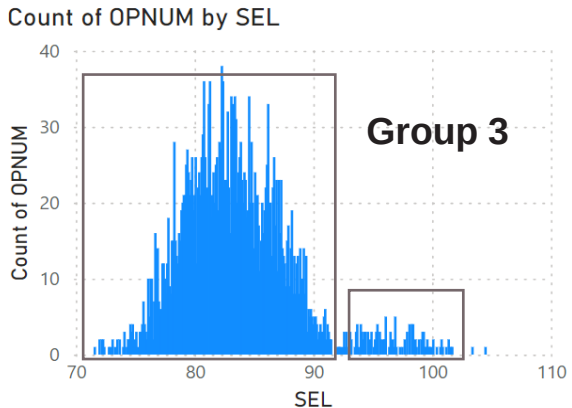
Full Reverse thrust

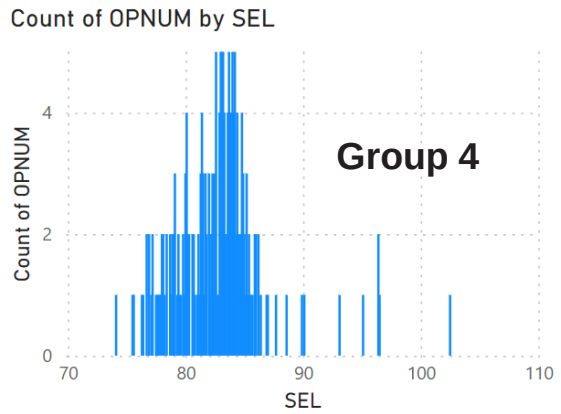
HZ16	HZ20	HZ25	HZ31	HZ40	HZ50	HZ63	HZ80	HZ100	HZ125	HZ160	HZ200	HZ250	HZ315	HZ400	HZ500	HZ630	HZ800	KHZ1	KHZ1_2	KHZ1_6	KHZ2	KHZ2_5	KHZ3_1	KHZ4	KHZ5	KHZ6_3	KHZ8	KHZ10	KHZ12	KHZ16
662	715	723	708	726	748	745	761	766	761	721	664	569	559	518	524	554	577	586	583	587	578	563	557	530	482	420	337	210	123	174
720	744	734	751	768	778	789	798	797	774	768	734	636	619	591	581	591	606	612	604	594	582	564	559	542	516	464	394	285	148	173
780	780	771	770	803	866	818	845	843	842	821	794	746	704	666	634	630	638	637	627	629	630	614	603	595	560	533	497	400	256	177
750	736	785	793	812	855	848	850	845	864	862	843	781	728	650	650	665	689	692	688	696	697	687	681	666	634	610	576	475	350	207
726	786	781	801	806	848	847	819	836	847	831	824	810	771	689	627	647	660	664	669	666	663	663	660	648	624	612	570	462	338	205
706	721	725	725	810	843	810	784	830	820	806	787	755	723	659	628	636	661	667	655	649	637	632	624	609	585	583	501	413	289	186
702	688	693	737	761	779	762	764	783	790	778	765	708	669	573	567	602	623	634	638	635	622	621	610	594	575	526	459	369	234	177
663	647	664	731	751	754	763	745	753	768	755	734	675	611	548	544	559	579	577	588	587	578	575	567	551	537	465	395	291	160	172
648	637	670	672	746	750	724	736	741	731	721	671	628	577	504	519	537	553	556	577	574	569	559	535	513	483	414	340	227	128	174
617	633	659	709	715	744	733	743	728	704	703	661	615	571	495	491	503	517	505	510	511	498	478	461	439	400	331	259	140	119	172

Idle Reverse thrust









Our Purpose

We believe environmental intelligence is the key to improving the wellbeing of people and the planet.

Photo courtesy of NASA

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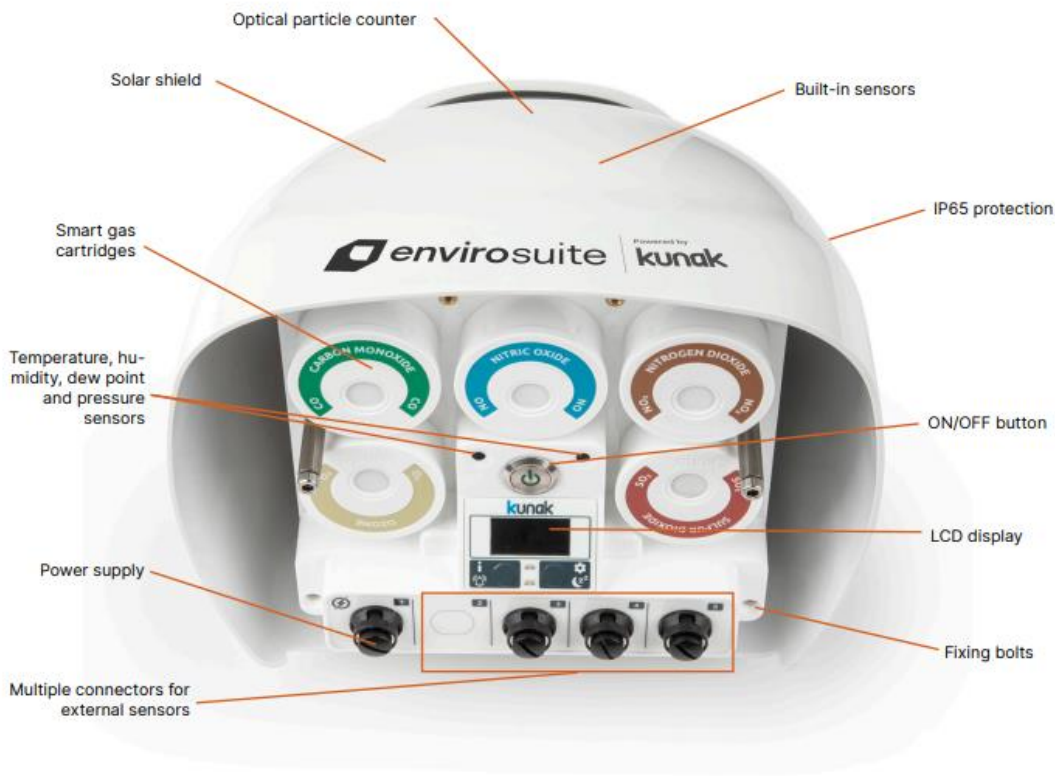
Envirosuite and Aviation Air Quality

EVS is uniquely positioned to help with Aviation AQ

- EVS is an established provider technology to reduce air quality impact and optimise operations in Mining, Wastewater, Landfill and other industries
- Our technology combines hyper local weather forecasts with continuous measurement of gas, particulates and Odour to
  - Understand impact
  - Forecast impact up to 5 days ahead
  - Optimise operations to avoid breach
  - Understand source of AQ to respond to complainers and mitigate issues
- We are now combining our meteorologists, environmental engineers and data scientists with our aviation expertise to devise a compelling, effective and unique technology solution to help you manage airport air quality issues
- Community impact / concern, Occupational Health, Indoor

Monitoring

- Cost effective indicative sensors
- Continuous 1-minute measurements
- CO,NO,NO2,O3,H2S,SO2,NH3,VOC,PM10,PM2.5,PM1
- Ultrafine particles – coming soon….



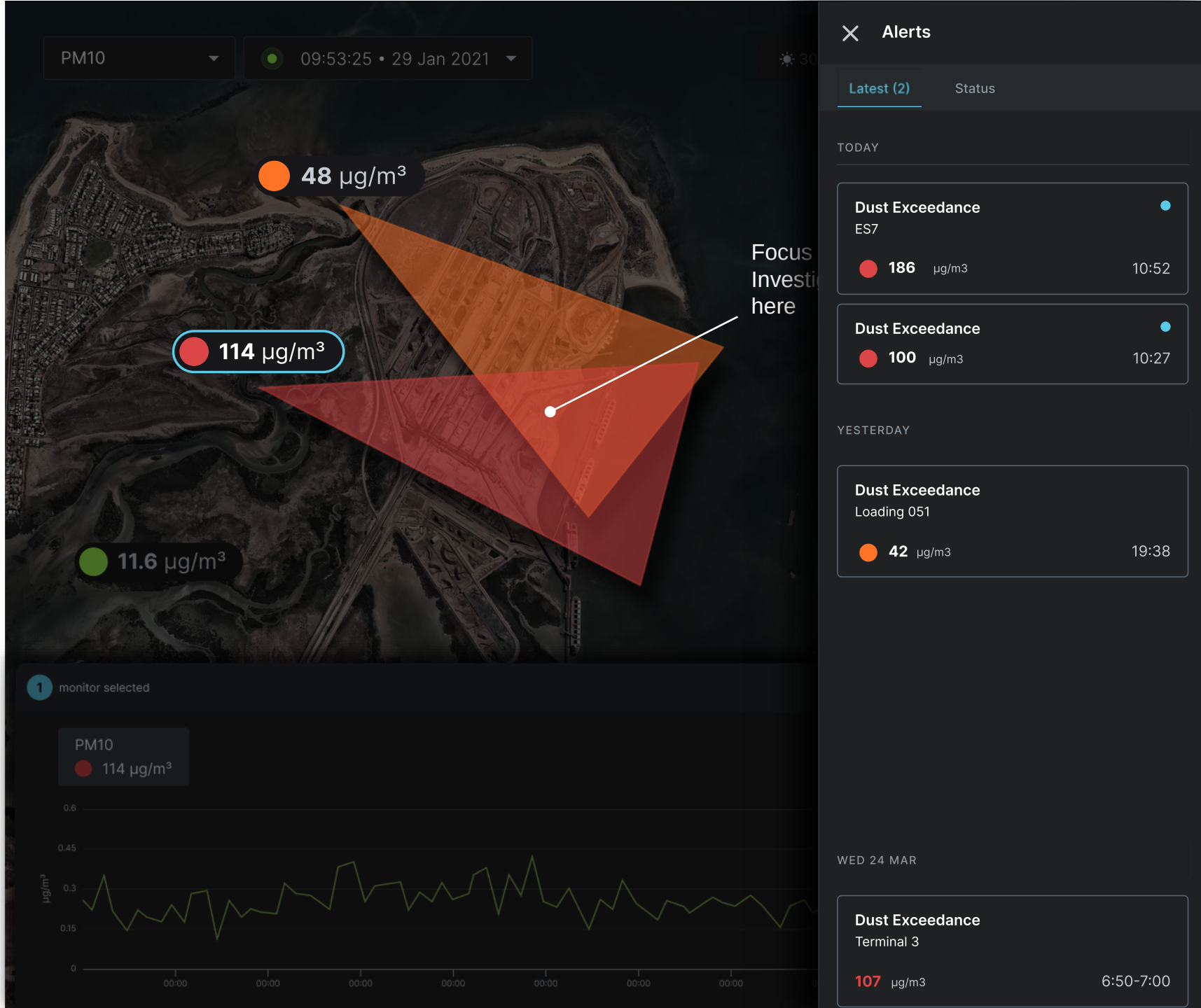
Know when you are at risk and understand sources in real-time

Anyone can quickly understand:

- Is there a problem?
- Where is it coming from?

So they can:

- Respond rapidly
- Prevent incidents



Plan operations around high-risk periods to avoid community impact

- Schedule operations for optimum conditions
- Protect the health of community
- Understand risk in advance and avoid downtime
- Reduce costs of resource mitigation when unnecessary

Rapid and effective response

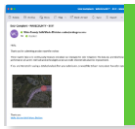
Complaint received

Ticket generated

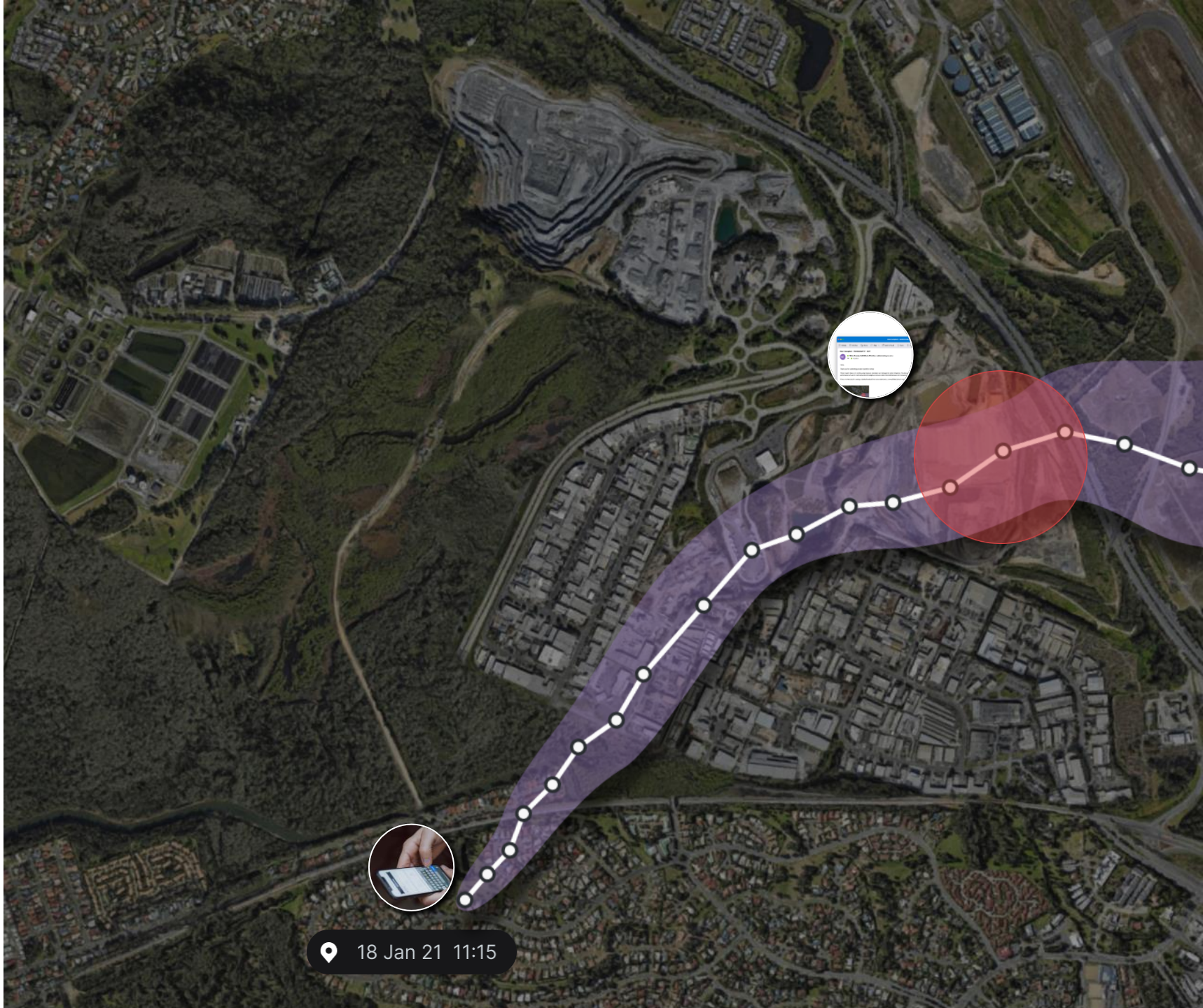
Reverse trajectory

Likely source identified

Deploy crew?

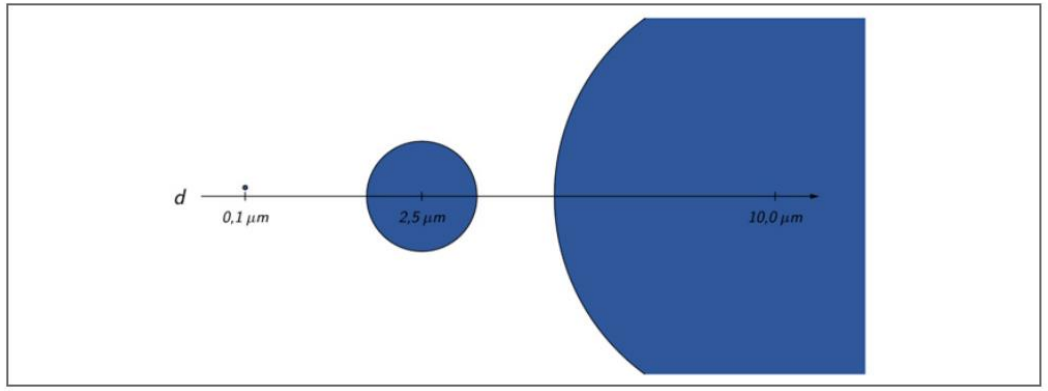


Informed response



UFPs - Ultrafine Particles

- Dust particles of size < 100nm (PM0.1)
- Concerns over health effects - may lead to an increased risk of respiratory and cardiovascular disease
- Multiple sources of UFPs around airports
- Particle sizes vary leading to possibility to identify sources
- Challenges
  - Currently not regulated
  - Due to small size, established dust measurement techniques are not valid
  - Measurement is dependent on location, weather conditions and a developing practice
  - Only long-term measurement campaigns can produce meaningful results



At an airport, the most typical particle sources come from the following sources:

- Aircraft: Particles from main engines, auxiliary power units, brakes and tires.
- Aircraft handling: Particles from ground support equipment, vehicles combustion and tires.
- Infrastructure operation: Diesel and oil smoke from combustion processes, paint pigments from maintenance and pollen from green-field maintenance,
- Landside traffic access: Particles from vehicles combustion and tires and particles from rail services (brakes and rails).

Ultrafine particles at Airports, 2018 – ACI Europe

UFP Reference level measurements

- Condensation Particle Counters – CPC's
- Require samples to be at defined temperature and humidity
- Absorb particles in Butanol to expand their size then measure them
- Require butanol replacement weekly / monthly – high operating costs

TSI Instruments
7nm ~ £18,000
2.5nm ~ £35,000
1nm ??

GRIMM
~ £40,000

UFP Indicative measurements

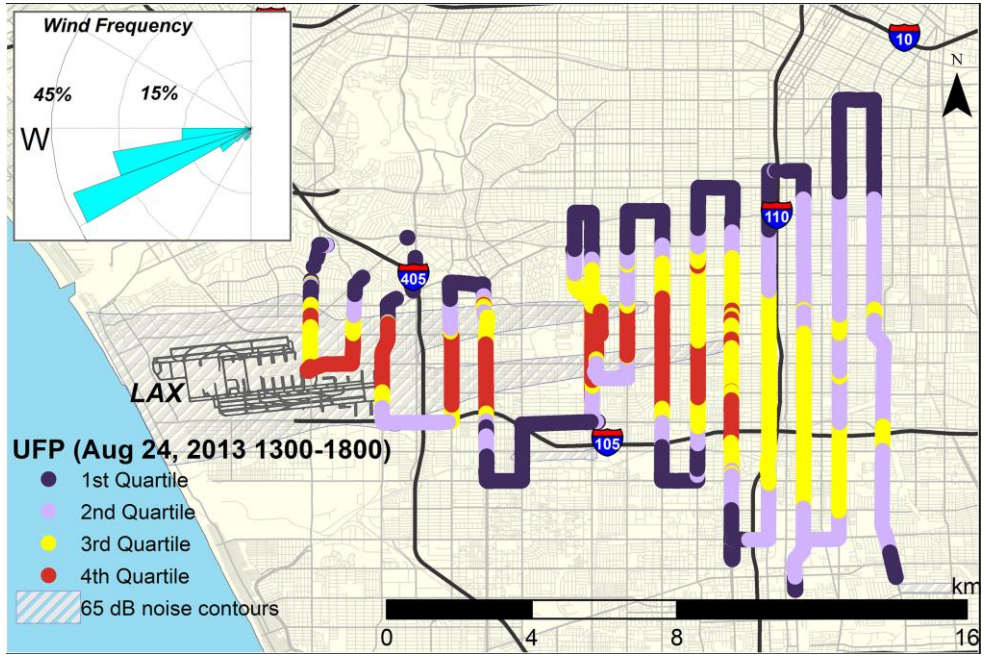
- LSDA – Lung deposited surface area methodology
- Lower purchase and operating costs
- New technology is being worked on

Oxility NanoTracer
~£25,000

Naneos Partecter
~£14,000

Existing UFP studies and information

- Individual airport studies at Heathrow, Zurich, Copenhagen, Eindhoven, Schiphol, Seattle, Los Angeles - others
- ACI Europe Env. Strategy committee
- TSI Instruments



What else could we do….

- Understand sources
  - –Analytics to combine aircraft movements with AQ assessment to determine the airports contribution
- Show reduction trends and set targets to demonstrate achievements
- Engage communities and regulators
  - Present real time data
  - Present meaningful information about air quality impact, the airport’s contribution

Discussion

What are your air quality issues?