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Regional Electricity Carbon Intensity Changes an Airport Activity Shortlist

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Abstract

Using one national electricity carbon factor leaves only the busiest of ten Great Britain airports on a shortlist based on traffic and carbon intensity. We matched 120 airport-month records from the Civil Aviation Authority to archived National Energy System Operator estimates for 2024. With national intensity weighted by each airport's movement months, the shortlist held Heathrow, Gatwick and Bristol. Keeping those weights and substituting regional intensity retained Heathrow and Gatwick, removed Bristol, and added Manchester and Edinburgh. The change reversed 28 of 45 pairwise intensity rankings. Geography mattered more than seasonal movement weighting for the regional comparison. The results describe observed aviation activity and a grid carbon indicator for early planning.

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A site comparison before a network is designed

A list of busy airports can identify where conventional aviation activity is concentrated. It does little to distinguish the electricity system surrounding each site. Conversely, a list of regional electricity carbon factors contains no evidence about the amount of airport activity a facility might serve. Combining them as separate criteria lets a planning screen display the trade-off without assigning a monetary value or presuming a particular fleet. The questions here are how use of a regional instead of a common national electricity indicator changes the airports that survive a two-criterion shortlist, and how much weighting by their observed monthly activity contributes to that change.

Yao et al. (2026) put electricity network integration alongside site location, capacity and operating decisions in their data-driven model of advanced air mobility (AAM). That integrated problem depends on prospective demand, aircraft energy uncertainty and local power-system conditions. We study a narrower, empirical comparison using already observed airport activity and published regional electricity estimates. The count of commercial aircraft movements indicates the observed scale of a conventional aviation site. It does not quantify demand for AAM, the fraction of passengers who would switch modes, how aircraft would charge, or whether a land parcel could host that service. The point of the comparison is to determine which conclusions follow from the stated early-stage metrics before attempting those additional estimates.

Kan et al. (2024) frame low-carbon microgrid evaluation as the design of a system of indicators. Here that distinction is operationalized through two separately reported quantities. One describes observed activity at the airport. The other describes the carbon intensity of electricity in a modeled area at the months when those movements occurred. Keeping the movements and carbon factor separate avoids increasing or decreasing an assumed electricity consumption quantity as the number of commercial movements changes. It also makes the geographic boundary of the grid input visible. This is relevant to a grid-connected site screen, while the measurement needed to evaluate a particular microgrid would include its local generation, meter boundary, storage and load.

Airports as an activity benchmark

Vertiport siting studies typically measure several forms of accessibility or service opportunity. Lim and Hwang (2019) derive candidate locations by clustering travel activity in Seoul. Ploetner et al. (2020) evaluate how regional air mobility might complement public transport in Upper Bavaria. Rahman et al. (2023) identify candidate locations in relation to the existing transit network. Guo et al. (2025) compare clustering approaches, while Lee et al. (2025) use a staged geospatial suitability analysis. Zhang et al. (2026) and Zhou et al. (2026) consider how multiple urban inputs inform site-selection methods. These projects draw on potential trips, spatial accessibility or constraints that could influence a future service. Their variety motivates treating our conventional aviation count as one readily measured activity indicator. Using an airport as a reference location does not make it a candidate cleared through any of those studies' other criteria.

The distinction is especially important for an airport with a mixture of domestic and international activities. An aircraft movement records an aircraft arrival or departure at the reporting airport. Passenger requests and their trip origins are separate quantities. Garrow et al. (2021) review how air-mobility use cases differ from ground transportation and depend on their competing modes. Coppola et al. (2024) distinguish the airport shuttle case from city-taxi service. Rohrmeier et al. (2025) discuss early-stage site screening and broader community planning, and Bauranov and Rakas (2021) examine the separate constraints associated with airspace integration. Our shortlist has no land-use, access, network routing or airspace constraint. It only distinguishes combinations of the two defined quantities within the observed airport comparison group.

Public records and matched calendars

The aviation data come from Table 05 of the Civil Aviation Authority (CAA) annual and monthly airport publications (CAA, 2024, 2025). We selected the ten Great Britain airports with the highest 2024 published annual totals for air transport movements. The total sums the reported EU international, other international and domestic movements. The comparison excludes Northern Ireland and non-UK reporting airports because the electricity service describes Great Britain. We use the monthly Table 05 totals to summarize activity and derive weights after selecting the airport cohort. These are recorded air transport movements, including arrivals and departures under the release definition. Adding activity across airports does not yield a count of distinct journeys because two airports can record opposite ends of a movement. Private and other non-air-transport categories in the broader all-movements table are outside the activity definition.

The electricity data come from the National Energy System Operator Carbon Intensity API (NESO, n.d.) and the regional methodology of Bruce et al. (2024). For an airport we apply its published outward postcode and use the returned region identifier. The lookup gives a reproducible regional classification. It does not identify the airport's electricity supplier, connection point, or power that would serve a potential new site. For each region and for Great Britain nationally, we extract the historical half-hour field labelled forecast, in grams of CO_2 per kilowatt-hour. We use that field consistently because it is supplied by the regional endpoint. The observations are archived model estimates, including effects of regional generation, imports and losses in the service's accounting framework. The API also supplies a separate national actual field, which is outside this matched comparison.

All half-hour comparisons use interval starts on a common UTC scale. To match the British aviation reporting months we convert the local midnight boundaries to UTC using Europe/London, then retain records with an interval start inside each month. This handles the daylight-saving changes without comparing an extra or missing half-hour at month boundaries. We use the intersection of intervals with

valid observations in every sampled electricity series. We then average the common half-hours within each region and month. The weights in the time-based annual statistic are the actual counts of common half-hours, accommodating the length of each month. Calendar month is the finest common scale of the aviation and electricity observations. We do not assign electricity half-hours to individual aircraft events.

A regional carbon indicator addresses a particular geographic definition of electricity consumption. Staffell (2017) discusses the measurement of power-sector decarbonization in Great Britain, including changing supply and imports. Tranberg et al. (2019) show how flow allocation can affect comparisons across connected power systems, and Schäfer et al. (2024) document methodological differences among grid factors. Risner et al. (2021) examine spatial and temporal choices in UK grid carbon factors. Vuarnoz and Jusselme (2018) illustrate temporal variation in the environmental characteristics of electricity supplied in Switzerland. Zou et al. (2026) document the implications of temporal resolution for emissions accounting using building load observations. These findings motivate matching geographic and calendar domains. Unlike those settings involving measured electricity exposure, our movement weights are used to compare planning summaries for airports and represent no observed facility electricity profile.

Two carbon summaries and a two-criterion shortlist

For airport a in electricity region r, let M(a,m) be the recorded air transport movements in month m and C(r,m) the modeled mean intensity in that region for the month. The activity-weighted indicator averages C(r,m) using each month's share of the airport's annual movement count. It answers what mean grid factor results when calendar months enter in proportion to the recorded airport activity. The time-weighted indicator averages the same series using numbers of half-hours instead. For a uniform stream of activity over time the two metrics would coincide. A different temporal distribution can increase or decrease the activity-weighted value even though both inputs use the same electricity series. Both indicators remain in g CO_2/kWh. Multiplying by the observed total number of movements would not yield an emissions quantity because no conversion from movement to electricity consumption was measured.

We calculated four screens by taking the two weighting options on both the national and regional grid series. The national time-weighted intensity is identical for all airports and isolates the information lost by giving every site the same static grid factor. The national activity-weighted values can vary by airport through monthly weights alone. The regional time-weighted values allow geographic differences while keeping the same time weights across sites. The regional activity-weighted values retain both sources of variation. Pairing the same traffic total with all four estimates lets us compare which source of distinction matters for the shortlist. The difference between the two activity-weighted values isolates the national-to-regional substitution holding each site's traffic weights fixed. The difference between an airport's regional activity- and time-weighted values isolates its reweighting at the same geographic boundary.

For any one screen, we keep an airport if no other candidate has at least as many movements and an intensity no higher, with a strict improvement in at least one of those two quantities. This is the standard Pareto notion of nondominance (Miettinen, 1998). In an explicitly stated finite list we can evaluate it by comparing every pair. Multiobjective algorithms such as that of Deb et al. (2002) address larger decision spaces. Our calculation identifies the trade-offs present on the two metrics. We examine sensitivity to omitting any one month and to using domestic movements for both volume and monthly weighting while keeping the original ten airports fixed.

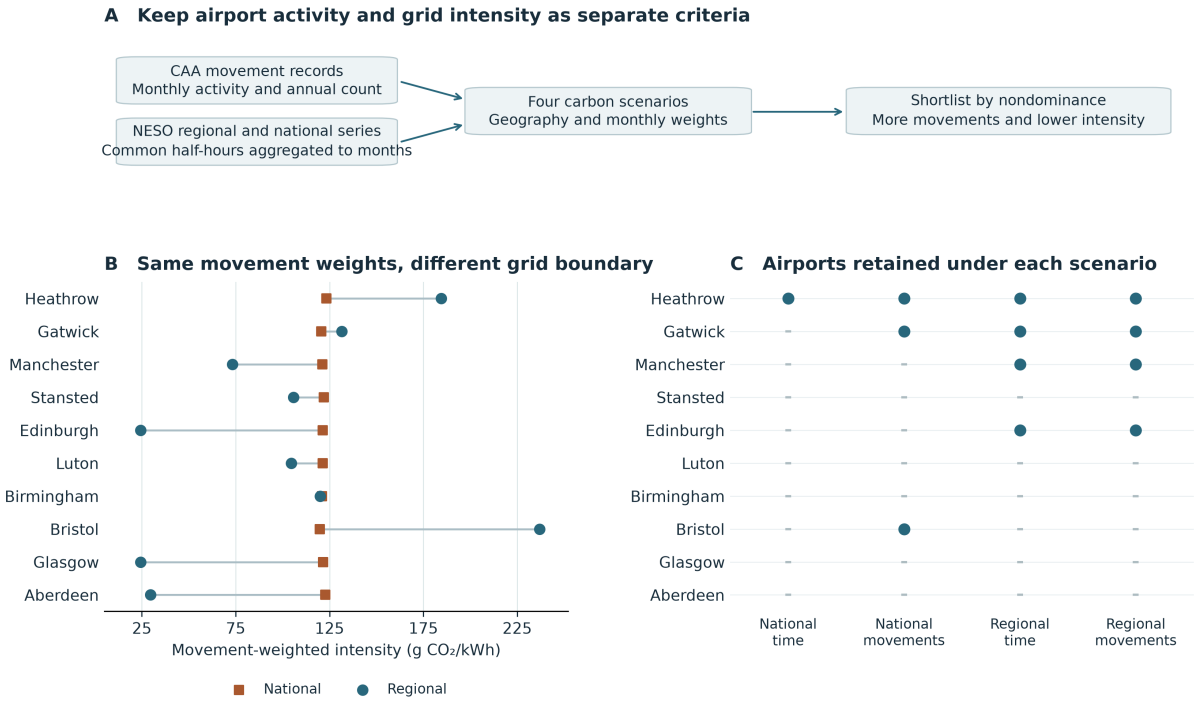


Figure 1. *Panel A describes the comparison design. Panel B compares the modeled intensity of the national and regional grid with identical movement-month weights. Panel C shows the shortlist under all four geographic and weighting choices, with airports ordered by traffic volume.*

Observed results

The ten airports contributed 120 airport-months and 1,633,857 reported movements across the monthly publications. For nine airports their summed monthly counts equal the counts in the annual file. The monthly sum for Heathrow exceeds the annual edition by 147 movements. We report the movements and weights from the monthly edition consistently, and the annual file determines the initial cohort. The ten airports map to eight NESO regions because Glasgow and Edinburgh share South Scotland and Stansted and Luton share East England. Of 17,568 calendar half-hours in 2024, 17,536 have values in all nine electricity series. The common-data filter removed 31 half-hours in June and one in December. We did not reconstruct those estimates and used the same retained timeline for each electricity comparison.

The national time-weighted indicator is 124.01 g CO_2/kWh. With that factor assigned everywhere, Heathrow is the only nondominated site because it has the highest reported activity at the shared intensity. Letting national monthly intensity enter with each airport's actual movement weights produces values from 119.86 to 123.32 and retains Heathrow, Gatwick and Bristol. The range of the regional movement-weighted indicators is substantially wider. Values run from 24.22 for Edinburgh to 236.85 for Bristol. With the regional indicator, Bristol has both fewer movements and a higher intensity than several other airports. Manchester and Edinburgh now enter the shortlist. The same set of four passes when we reweight regions by half-hours in place of traffic, indicating that geographic resolution determines the main shortlist change in these records.

Table 1. *Activity and modeled electricity indicators for the ten-airport cohort. Intensity values use g CO_2/kWh. Movement weights come from the month-level CAA counts. Regional shortlist membership is computed on unrounded values.*

Airport	NESO region	Monthly movement sum	National movement-weighted	Regional time-weighted	Regional movement-weighted	Regional movement shortlist
Heathrow	South England	482,290	123.32	185.67	184.52	Retained
Gatwick	South East England	265,608	120.64	135.29	131.47	Retained
Manchester	North Wales and Merseyside	190,034	121.06	76.57	73.30	Retained
Stansted	East England	188,987	122.02	107.73	105.72	—
Edinburgh	South Scotland	116,693	121.30	24.63	24.22	Retained
Luton	East England	102,597	121.31	107.73	104.64	—
Birmingham	West Midlands	88,203	120.87	124.52	120.03	—
Bristol	South West England	71,134	119.86	241.77	236.85	—
Glasgow	South Scotland	67,634	121.61	24.63	24.25	—
Aberdeen	North Scotland	60,677	122.76	29.91	29.51	—

All 45 site pairs have a strict intensity order under the two movement-weighted grid boundaries. Switching the boundary reverses 28 and retains the order in 17. Bristol moves from the lowest national movement-weighted value to the highest regional value. Edinburgh moves to the opposite end of the regional scale while retaining a midrange value in the national comparison. The widest absolute boundary change with identical movement weights is Bristol's increase of 116.99 g CO_2/kWh. The largest absolute change when replacing regional time with regional movement weights is 4.92, also for Bristol. All ten regional movement-weighted intensity values are lower than their regional time-weighted counterparts, by between 0.38 and 4.92. The order of distinct regions is unchanged in all 43 strictly comparable pairs. The two remaining pairs share a region and the same time-weighted value. Different month weights break those ties without altering the shared electricity estimates.

The four members of the full regional shortlist remain nondominated in every leave-one-month-out comparison. Omitting a month adds Stansted in three cases and Glasgow in two. The change can be important near the frontier. Manchester and Stansted differ by only 1,047 movements over the full year, and their relative movement ranking can change when a busy month is removed. Monthly weighting also makes it possible for two airports with the same regional time series to exchange their intensity order. Using domestic movements for the traffic dimension and its calendar weights instead gives a regional shortlist of Edinburgh and Glasgow. Edinburgh has the most domestic movements within the sample, while Glasgow has a slightly lower domestic-weighted grid value, 24.31 against 24.44. That narrow gap under the proxy is smaller than a gram and should be read as a numerical ordering in the data rather than independent evidence for a material emissions advantage.

What the screen can contribute to planning

This comparison uses recorded activity to retain some calendar structure while introducing a carbon indicator that can differ across model regions. Kasliwal et al. (2019) calculate environmental outcomes for aircraft journeys using flight and occupancy scenarios. Taye et al. (2024) examine the charging-demand implications of simulated operations. The Federal Aviation Administration electrical infrastructure study addresses local connection availability, charging demands and facility choices (Solanki et al., 2023). A low regional modeled factor could coexist with a constrained connection at an airport. The carbon intensity, actual electric capacity and operating requirements therefore belong as distinct inputs to any subsequent planning model.

An attributional electricity factor also does not establish what generating resources would respond to a new or rescheduled load. Hawkes (2010) estimates marginal emissions rates by a different approach. Riepin and Brown (2024) model procurement and operational choices under hourly carbon-free energy matching. These are distinct questions from the ordering of mean grid intensity in an archive. Before considering hypothetical emissions savings, a network model would need both additional electricity demand and an appropriate response or procurement counterfactual. A regional historical indicator remains useful as a documented environmental context for a comparison among airport areas, and its ranking can be tested independently of those more demanding assumptions.

Selection on observed annual traffic restricts the comparison to busy airports whose activity profiles may be different from those of local airfields. Monthly totals preserve broad variation across seasons but cannot show whether movement times fall in hours when the local intensity is lower or higher than the regional monthly mean. They also cannot distinguish possible future travel segments that would use a different part of the day. The airport postcode approximation captures a stable official regional lookup for this comparison. A candidate premise within an airport estate could require its own connection inquiry. The data cover a single year, during which the underlying British generating mix and aviation schedules were specific to the period. Sensitivity to leaving out a month characterizes that year's result and does not establish stability under later market or grid changes.

Conclusion

An airport comparison that combines conventional movement counts with regional grid carbon context retains a different set from the same comparison based on a national grid factor. In this sample the regional boundary changed 28 pairwise intensity rankings. The four airports on the regional shortlist stayed there when movement weights were exchanged for time weights and when individual months were omitted. Using domestic movements as the traffic proxy changed that set. A planning screen can report these sensitivities explicitly before using airport activity as evidence about a prospective network.

Data and code availability

The input sources are the public Civil Aviation Authority airport tables and the NESO Carbon Intensity API. The acquisition receipt records the source URLs and archive checksums. The acquisition script and analysis script generate the airport-month input table, airport scores and summary. The figure script reproduces Figure 1. Author declarations and publication approval are pending author review.

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