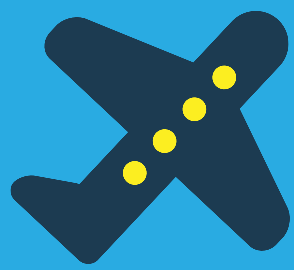
jet, set, go
technical report

UK Business Aviation Market Analysis:
Potential for Electrification



november 2019

about

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Fellow Travellers is a not-for-profit, unincorporated association campaigning for fair and equitable solutions to the growing environmental damage caused by air travel. We aim to protect access to reasonable levels of flying for the less well-off, whilst maintaining aviation emissions within safe limits for the climate.
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This paper was first published in November 2019.
See related policy paper, **Jet, Set, GO: electric-only UK private jet flights from 2025**

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introduction

This analysis attempts to quantify the potential for the UK business aviation market to switch to electric propulsion.

Detailed data on the business aviation market is not readily available so establishing definitive numbers is challenging. HMRC have refused to even publish figures for Air Passenger Duty revenues from UK private jet passengers. However, information published by the European Business Aviation Association (EBAA) and Eurocontrol has allowed an initial estimate to be made.

The business aviation market is dominated by private jet use (but also includes turboprops) and by two categories of operations: commercial and non-commercial. Commercial operations represent businesses which rent out turboprops and private jets to individuals and businesses. Non-commercial operations represents businesses and individuals who own their own jets. While the sector's name implies that the aircraft are operated for business purposes, a lot of the time these aircraft are used by wealthy owners and renters for leisure purposes. This is borne out by the fact that Mediterranean and Alpine airports feature prominently in the traffic data.

uk business aviation market

A picture of business aviation operations within the UK and between the UK and Europe was developed using data given in the EBAA's Economic Value & Business Benefits publication from March 2018[1] and supplemented by Eurocontrol's STATFOR dashboard[2].

Eurocontrol data goes back to January 2005 and shows a picture of rapid, double digit growth in the run up to the financial crisis followed by two years of similarly rapid contraction, subsequently followed by more modest growth rates averaging 2% since 2010.

business aviation movements to, from and within the uk

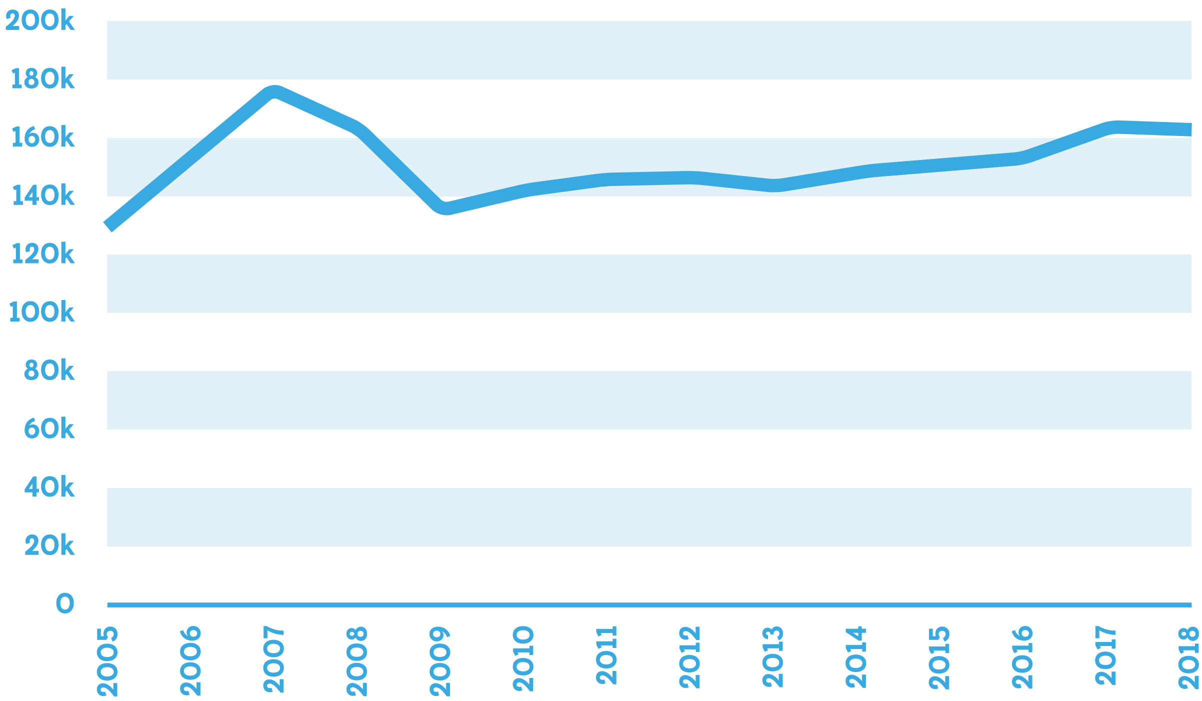


figure 1

Business aviation fleet composition by aircraft category July 2018[3]

Category	Aircraft	%
Bizliners	15	3%
Heavy Jets	146	29%
Midsize Jets	76	15%
Light Jets	105	21%
Multi Engine Turboprops	106	21%
Single Engine Turboprops	56	11%
Total	504	

table 1

UK aviation market share by number of departures 2018[4]

Category of Flight	%
Business Aviation	6%
Traditional Airlines	45%
Low Cost Airlines	43%
Charter	2%
Cargo	3%
Other	2%

table 2

Business Aviation departures by type of operation 2017[5]

Operation	% Departures
Commercial	57%
Non-commercial	39%
Medical	1%
Government/military	2%
Training	1%
Total	

table 3

Commercial operation refers to aircraft being used to transport passengers for remuneration or hire, while non-commercial operation refers to private aircraft operated by businesses or individuals.

Top 5 European markets for UK business aviation in 2018

Market	Flights To/From
United Kingdom	41,041
France	23,881
Germany	10,362
Switzerland	10,168
Spain	9,219

table 4

Top airports in 2017

Airport	Departures
London Luton	14,593
Farnborough	12,207
Biggin Hill	7,225
London Stansted	5,385
Northolt	5,195

table 5

These five airports around London account for 45% of UK business aviation departures.

network analysis

Both the EBAA publication and Eurocontrol data were used for the analysis. While there are some differences between the two data sources, the results for the European market as a whole were very similar. The numbers presented below are based on data extracted from Eurocontrol's STATFOR database.

For each country for which there is data on flight movements to and from the UK, a representative route distance was calculated:

Country	Representative Route	Great Circle Distance km
Austria	Luton-Vienna	1,281
Belgium	Luton-Brussels	354
Croatia	Luton-Zagreb	1,382

Country	Representative Route	Great Circle Distance km
Cyprus	Luton-Larnaca	3,280
Czech Republic	Luton-Prague	1,451
Denmark	Luton-Copenhagen	951
Finland	Luton-Helsinki	1820
France	Luton-Paris/Nice	724
Germany	Luton-Munich	950
Greece	Luton-Athens	2,430
Hungary	Luton-Budapest	1,490
Iceland	Luton-Reykjavik	1,850
Ireland	Luton-Dublin	433
Italy	Luton-Milan/Rome	1,234
Latvia	Luton-Riga	1,670
Luxembourg	Luton-Luxembourg	525
Malta	Luton-Luqa	2,120
Netherlands	Luton-Amsterdam	354
Norway	Luton-Oslo	1,130
Poland	Luton-Warsaw	1,450
Portugal	Luton-Lisbon	1,610
Spain	Luton-Palma	1,390
Sweden	Luton-Stockholm	1,430
Switzerland	Luton-Zurich	806
United Kingdom		450

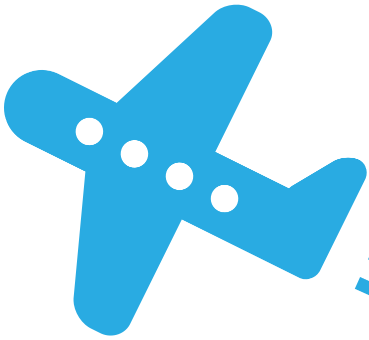
table 6

The route distances were then uplifted by 5% to account for indirect routing[6] and the vehicle-km for each route was calculated. When ranked by route distance it is then possible to calculate the cumulative proportion of total flights and vehicle-km by distance:

Country	Route Distance km	Trips	% Trips	Cumulative % Trips	vkm	% vkm	Cumulative % vkm
Netherlands	372	4,291	3%	3%	1,594,965	2%	2%
Ireland	455	5,093	4%	7%	2,315,532	2%	4%
Belgium/ Luxembourg	461	3,780	3%	10%	1,742,580	2%	5%
United Kingdom	473	41,288	32%	43%	19,508,580	19%	24%
France	760	24,145	19%	61%	18,355,029	18%	42%
Switzerland	846	10,658	8%	70%	9,019,865	9%	51%
Germany	998	10,274	8%	78%	10,248,315	10%	60%
Denmark	999	1,264	1%	79%	1,262,167	1%	62%
Norway	1,187	967	1%	79%	1,147,346	1%	63%
Austria	1281	2,066	2%	81%	2,646,546	3%	65%
Italy	1,296	8,359	7%	88%	10,830,756	10%	76%
Croatia	1,382	296	0%	88%	409,072	0%	76%
Czech Republic	1,451	821	1%	88%	1,191,271	1%	77%
Spain	1,460	9,057	7%	96%	13,218,692	13%	90%
Sweden	1,502	1,496	1%	97%	2,246,244	2%	92%
Poland	1,523	507	0%	97%	771,908	1%	93%
Portugal	1,691	1,642	1%	98%	2,775,801	3%	95%
Iceland	1,943	1,010	1%	99%	1,961,925	2%	97%
Greece	2,552	1,065	1%	100%	2,717,348	3%	100%

table 7

The above table shows that of around 128,000 business aviation flights which were undertaken within the UK and between the UK and Europe in 2018, the average distance flown was around 810km per flight and around 100 million vehicle-km were flown by business aircraft.



uk business aviation climate impact

While reasonable quality data is available on the number of business aviation movements between different countries in Europe, there is little information publicly available defining what types of aircraft are flown on each route. This makes estimating the climate impact of UK business aviation challenging and the numbers presented below should be considered an approximate guide to the scale of the industry's contribution.

Further research will require more granular data, not only covering movements between airport pairs (as opposed to the country pair analysis described here), but also covering the mix of types which operate on different routes. This data is captured by organisations such as Eurocontrol, although it is unfortunately not readily available via their STATFOR dashboard.

The EBAA publishes a monthly Fleet Tracker[7] which as at July 2018 gave the following figures for business aircraft based in the UK and Europe:

	Single Engine Turboprop	Twin Engine Turboprop	Light Jet	Midsize Jet	Heavy Jet	Bizliners	Total
UK	56	106	105	76	146	15	504
	11%	21%	21%	15%	29%	3%	100%
Europe	570	668	930	445	939	88	3,640
	16%	18%	26%	12%	26%	2%	100%

table 8

This does not tell us the extent to which each category of aircraft is used on flights within Europe, however it is possible to make some broad estimates in order to establish a range of emissions which UK business aviation might generate.

Using Aviation Week's Business & Commercial Aviation Purchase Planning Handbook estimates of aircraft CO_2 emission factors in $kgCO_2$/vkm (excluding non-CO_2 effects) were derived for each category of aircraft and for different ranges of mission:

Mission Range	Single Engine Turboprop	Twin Engine Turboprop	<20,000lb MTOW Jet	>20,000lb MTOW Jet	Ultra-Long Range Jet
300nm	1.5	2.1	2.2	4.5	
600nm	1.4	1.9	1.8	3.7	
1,000nm	1.3	1.6	1.7	3.4	4.6
3,000nm					4.3
6,000nm					4.5

table 9

As part of the network analysis, the average distance travelled on business aviation flights within the UK and between the UK and the rest of Europe was calculated to be around 810km (437nm) and the total distance travelled by business aircraft on these routes was estimated to be slightly over 100 million vehicle-km.

Using the emission factors given in the table above, emissions from this activity are therefore estimated to be somewhere between 200,000tCO_2 and 400,000tCO_2 per year.

According to Eurocontrol's Statfor dashboard there were a further 14,000 business aviation flights between the UK and non-EU regions, the most significant of which (covering 94% of these additional movements) are:

Region	Flights	Representative Distance km	vkm
North America	7,549	5,550	42m
Middle East	2,544	5,525	14m
Russian Federation	2,285	2,490	6m
Turkey	937	2,525	2m

table 10

Total distance travelled between these four regions and the UK amount to around 64m vehicle-km. The longer ranges of these routes mean that the largest, ultra-long range aircraft will dominate, leading to an estimate of between around 250,000tCO_2 and 300,000tCO_2 for these operations between the UK and these four non-EU regions.

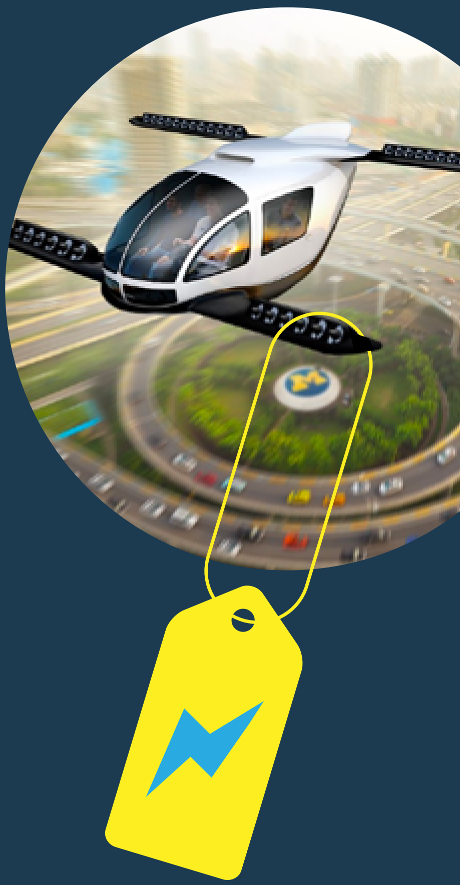
The total emissions associated with all business aviation operating to and from the UK is therefore estimated to be in the region of 450,000tCO_2 to 650,000tCO_2. As such business aviation accounts for around 1% of UK aviation emissions. Taking into account the non-CO_2 effects of aviation means that the total impact of business aviation operations to and from the UK could be between 0.85MtCO_2e and 1.25MtCO_2e.

electrification of business aviation

Electric Aircraft Development

The electric aircraft designs which are being announced fall into two broad categories, vertical take-off and landing aircraft and regional aircraft, with battery-electric, hybrid-electric and hydrogen powertrains. Aircraft development is happening across the globe, with the majority of activity in the US and Europe.

The focus of the first wave of electric aircraft designers is on small, short haul aircraft. This is partly driven by the limitations of battery technology but also makes pragmatic sense as the cost of developing modern airliners is prohibitively large. Business aviation, with its comparatively small aircraft, short stage lengths and affluent users, will therefore be a good early market for the nascent electric aviation sector.



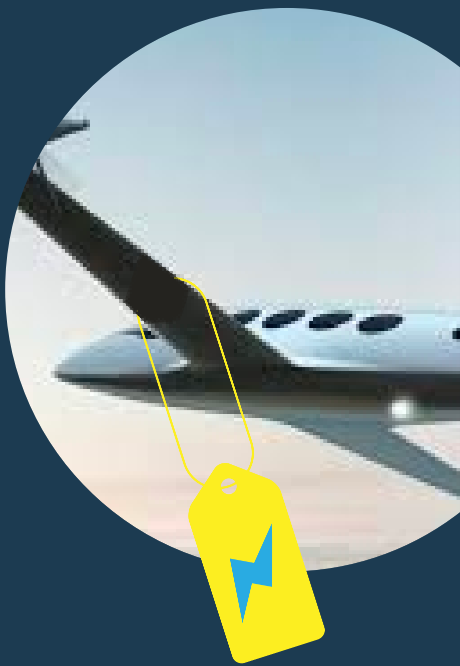
eVTOL

Most of the electric vertical take-off and landing (eVTOL) aircraft currently being proposed are either battery-electric (for intracity and commuting operations, typically capable of ranges up to 100 miles, some as much as 200 miles) or hybrid-electric (intercity operations of hundreds of miles).

The companies developing these vehicles envisage large fleets operating autonomously out of city centre 'vertiports' and hope to offer rapid point-to-point journeys using booking systems similar to ride hailing services such as Uber (indeed Uber is one of the main promoters of this technology via the Elevate platform).

The timescale for the first trials of this technology in cities is in the early 2020s (Uber Elevate is targeting a 2023 launch date) and the first services will be piloted rather than autonomous.

There is considerable scepticism that the regulatory and operational challenges associated with this kind of technology can be overcome, but if the technology can be made to work and is publicly acceptable, hybrid eVTOL aircraft may be capable of capturing some business aviation market share on shorter routes, and journeys currently undertaken by helicopter. If the networks become sufficiently well developed then it may be possible to undertake longer trips using a series of hops.



Battery-Electric Aircraft

Eviation Alice

The Eviation Alice is an Israeli electric aircraft design which has caught a lot of attention in 2019, having been formally unveiled at the Paris Air Show. It is an unconventional design capable of carrying 9 passengers with a maximum range of 650 miles (nearly 1,050km) at 260 knots.

The Alice's battery pack is expected to have an energy density of 260Wh/kg and the company will achieve this industry-leading range by having the batteries take up 60% of the aircraft's maximum take-off weight.

The Alice's first flight is expected to take place later in 2019 or early 2020 and Eviation is hoping to receive certification around 2021. The company has secured a launch customer in the form of Cape Air, a US regional commuter airline, and hopes to commence deliveries from 2022.

Wright Electric

The US manufacturer Wright Electric has teamed up with low cost operator Easyjet to promote their concept for a 150-seat battery-electric aircraft. Wright Electric's design is so far the only attempt at developing an electric aircraft that is similar in terms of capacity to existing regional aircraft.

Aspects of its design will be familiar to current air travellers although its propulsion system is made up of a number of distributed motors mounted in the wing and at the rear of the fuselage and V-tail. It is expected to have a 500km range but the company is one of the few intending to make use of swappable battery packs which could make longer distance trips feasible. The company hopes to have aircraft flying operationally in the late 2020s.

Heart Aerospace

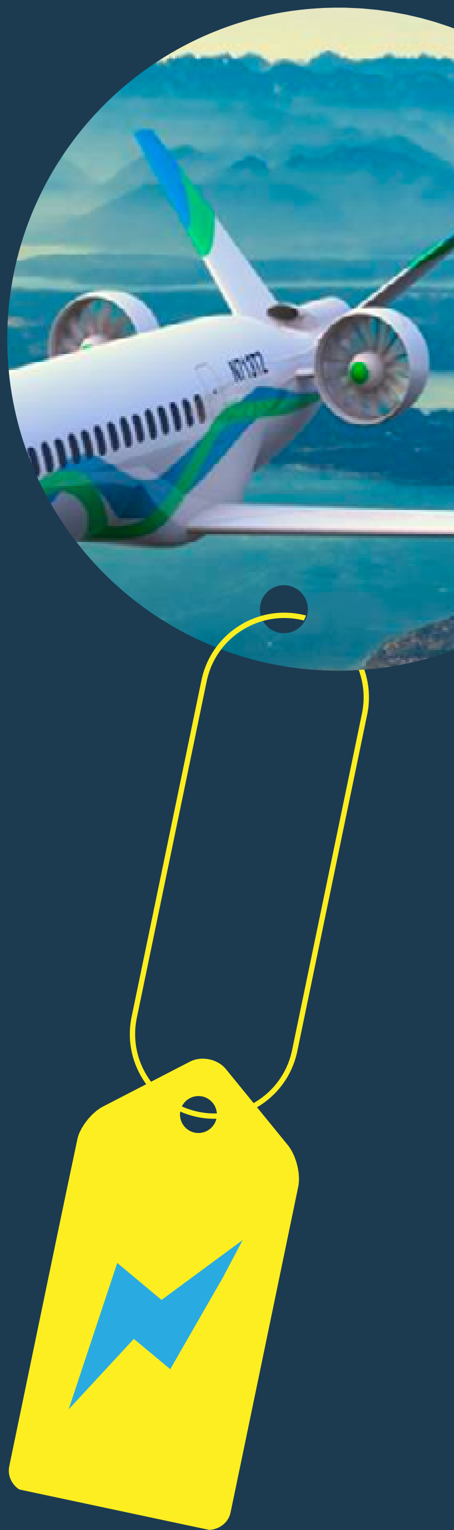
Sweden's Heart Aerospace[8] recently announced plans to develop a 19-seat electric aircraft with a 400km (250 mile) range for point-to-point operation between Scandinavian cities. It will also be offered as a business aircraft and the company is targeting 2025 as the date for certification for commercial operations.

Some of the high volume business aviation routes (for example London to Paris, Brussels or the Amsterdam) are very short haul and within the capabilities of this aircraft, however it is likely that better performance than this will be needed in order to give operators the flexibility they need.

The 400km range quoted by Heart Aerospace is based on battery pack energy densities of 250Wh/kg, with just 25% of the aircraft's maximum take-off weight (MTOW) taken up by batteries. It is likely that by the 2030s the aircraft would be capable of flying substantially further thanks to improvements in battery energy density.

Scylax

Scylax[9] is a newly announced venture from Germany designing a 6-seat and 10-seat battery-electric aircraft. Little information is available in the public domain but the initial target range of their design is 400km and this is expected to increase as battery performance improves. One of the companies behind Scylax, Elektra Solar, is developing high efficiency electric light aircraft with integrated solar cells.



Hybrid-Electric Aircraft

Zunum Aero

Zunum Aero[10] has put forward a design for a hybrid-electric aircraft carrying up to 12 passengers and capable of flying a total range (using both battery and fuel) of 700 miles (1,100km).

The design looks familiar and similar to business jet designs, with two electric ducted fans mounted on the rear fuselage, and a v-tail in place of the more traditional combination of horizontal and vertical stabilisers. The proposed powertrain is a series hybrid with a battery taking up 20% of the total weight of the aircraft, supplemented by a 500kW turbogenerator burning liquid fuel to extend the range. The company hopes also to develop a larger 48-seat regional aircraft.

Zunum Aero is one of the higher profile electric aircraft companies, having originally received investment from large, established aviation companies Boeing and JetBlue however these two backers have withdrawn their support in the last year and the company is now facing challenges raising capital to continue development of their aircraft.

Faradair[11]

UK company Faradair has proposed an unconventional box-wing design of aircraft aimed at both the military and regional aircraft market. The company describes it as a “Bio Electric Hybrid Aircraft” as they expect to make use of biofuels, and plans initially to develop a hybrid version first, with an unmanned air vehicle and battery-electric version following.

Hydrogen-Electric Aircraft

ZeroAvia

ZeroAvia[12] is a US-based company developing hydrogen-electric powertrains for small business aircraft. The company envisages their technology decarbonising short haul commuter and business flights by using low carbon electricity to electrolyse hydrogen which would be used to power fuel cells on the aircraft.

The company is currently targeting 300 to 500-mile missions in existing 10 to 20-seat aircraft which the company will convert to hydrogen. The company has already converted a 6-seat single engine Piper aircraft for testing purposes.

Retrofit of Existing Aircraft

There is currently considerable interest in the potential for retrofitting existing aircraft types with electric motors and batteries.

In the UK, Cranfield University is working with Loganair on Project Fresson, a programme to retrofit 9-seat Britten-Norman Islanders used on short island-hopping flights around Orkney off the North coast of Scotland.[13] Meanwhile in Canada, electric motor manufacturer MagniX has teamed up with seaplane operator Harbour Air to retrofit a de Havilland Canada DHC-2 Beaver.[14]

In both cases the routes flown are very short and the aircraft are expected to have very limited range. This is imposed by the aircraft which are being retrofitted, which were designed with rugged, backcountry operations, not efficiency, in mind.

Apart from airframe efficiency, one of the key limitations imposed by existing airframes is the weight of batteries that can be carried and in the case of private jets, this is at most around 45% of the maximum take-off weight in the case of the ultra-long range aircraft, and closer to 35% in the smaller and more common private jets.

The reason why the Eviation Alice is expected to achieve its expected range of 1,000km is that it has a very efficient airframe design and the batteries will take up around 60% of the maximum take-off weight. This combination is necessary for ranges approaching 1,000km and for this reason we believe that retrofits of private jets could only produce relatively short range aircraft using current battery technology. If there is a breakthrough in battery energy density then a retrofit market may develop but there is no sign of this happening in the near term.

business aviation electrification potential

It is early days in the development of electric aviation. Many of the proposed designs are little more than renders with outline technical specifications, but first flights will be starting in 2020 with others following. There are likely to be more companies currently operating in stealth mode so more designs are likely to appear in the coming years.

As such the technology remains unproven and there are significant regulatory hurdles to overcome (not least associated with the use of batteries as a primary source of power). The aerospace industry has traditionally been a conservative one, especially when it comes to safety-critical systems, so the regulatory aspects of electrification may take some time to resolve.

A key benefit of the adoption of batteries to power aircraft is that battery technology is expected to improve (potentially considerably) during this time period and electric aviation will be able to take advantage of this. New battery chemistries such as lithium-sulfur and lithium-metal with energy densities 50% greater than lithium-ion already exist so the performance figures quoted by electric aircraft companies now will certainly be bettered by electric aircraft in production in the 2030s.

One consideration is that the development of long haul battery electric aircraft will be very challenging and may not emerge at all, absent a truly revolutionary breakthrough in battery energy density. The focus is therefore expected to initially be on aircraft capable of flying routes of up to around 1,000 km in the 2020s, with routes extending to 1,500km, potentially further, likely to become technically feasible in the 2030s.

UK business aviation flights and vehicle-km by route distance within Europe break down as follows:

Route Distance[15]	Cumulative % of Flights	Cumulative % of Vehicle-km
Up to 500km	43%	24%
Up to 1,000km	79%	62%
Up to 1,500km	96%	90%
Up to 2,000km	99%	97%
Up to 2,500km	99%	97%
Up to 3,000km	100%	100%

table 11

The implication of the above table is that electric aircraft currently in commercial development for market entry in the mid-2020s could be capable of covering around 80% of business aviation departures and 60% of business aviation km between the UK and Europe in the coming decade, and around 95% of departures and 90% of km in the 2030s.

In addition to this short haul European business aviation activity, longer haul flights to North America, the Middle East, Turkey and the Russian Federation represent around 10% of all UK business aviation flights. Barring a revolution in battery technology, these routes are likely to remain beyond the capabilities of battery-electric aviation for many decades.

Around 1% of UK business aviation movements are air ambulances, repatriating or relocating critically ill people who need urgent treatment at specialist hospitals. Most air ambulances are operated by charter companies and are dedicated aircraft with specialist equipment and crews. As such they represent a distinct market category which could potentially be exempted from future requirements to decarbonise, as the flexibility offered by conventional fuels will be important for this type of operation.

business jet emissions comparisons

Two example business aviation routes (New York to London and London to Zurich) are described below, with estimates of the emission factors and total emissions associated with each.

New York to London

Estimates of the emissions of business aviation flying the transatlantic route from New York to London are presented below.

The following aircraft in the Ultra-Long Range category were selected for this estimate:

- Gulfstream G550
- Gulfstream G600
- Gulfstream G650
- Dassault Falcon 8X

The data was gathered from Aviation Week's Business & Commercial Aviation Purchase Planning Handbook 2017 (BCA PPH), which contains specification data for a wide range of business jets and turboprops. This data includes estimates of actual fuel burn over three different mission stage lengths and for the Ultra-Long Range aircraft category these are 1,000nm, 3,000nm and 6,000nm assuming an occupancy of 8 passengers.

The great circle distance from LTN to JFK is 2,989nm (3,440 statute miles or 5,540km) and this figure was uplifted by a standard 8%[16] factor to account for indirect routing, bringing the stage length to 3,228nm. The BAC PPH fuel consumption figures for a 3,000nm mission were adjusted up to account for this slightly greater distance.

According to the BAC PPH all four of these aircraft have very similar fuel consumption and so an average of the four types was taken. Another aircraft in the same class, the Bombardier Global 6000, was excluded from the analysis but has fuel consumption around 22% higher than these aircraft and the Airbus ACJ and Boeing BBJ were also excluded as they are considerably bigger aircraft (with considerably higher fuel consumption).

Average fuel consumption for the four types was about 7.8t of aviation turbine fuel which would generate around 24.6tCO_2 when combusted (using an emission factor of 3.15kgCO_2/kg for aviation turbine fuel[17]). The non-CO_2 impacts were accounted for by applying a standard multiplier of 1.9[18], leading to a final figure of 46.8tCO_2e for the trip.

This figure was then divided by the passenger load (these four aircraft types can carry 12 or 16 passengers in a typical executive layout) to obtain an emission factor per passenger-km which varies substantially depending on the number of passengers carried.

It should be noted that the fuel burn estimate is based on an occupancy of 8 passengers so at lower occupancy rates the calculated emission factor will likely be a slight overestimate and at higher occupancy rates the calculated emission factor will likely be a slight underestimate.

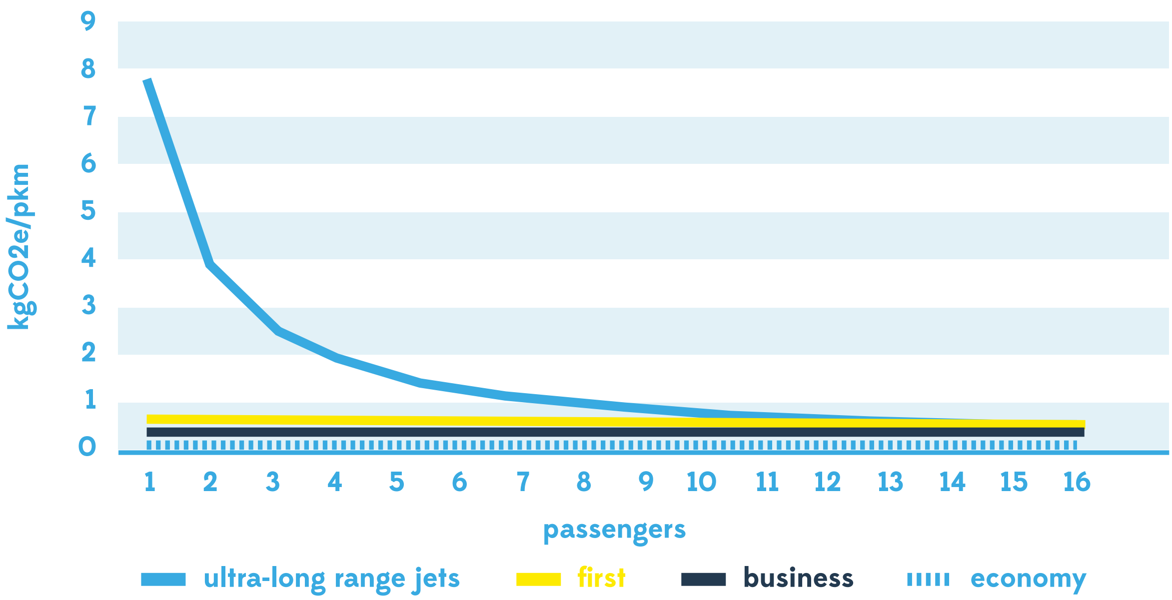


figure 2

For comparison, the emission factors for long haul aviation out of the UK by class are also included in the graph. The emission factor for this class of business jet on this trip only drops below that of First Class at occupancy rates of 14 or more and exceeds Business Class at all occupancy rates.

Average occupancy rates for transatlantic flights are not publicly available, however a National Business Aviation Association (the US equivalent of the EBAA) publication from 2016[19], assumes an average occupancy of 4.7. Using this occupancy rate would imply an emission factor and greenhouse gas emissions (including non-CO_2 effects) of:

Type	Emission Factor $kgCO_2e/pkm$	Emissions per passenger tCO_2e
Business Jet	1.66	10.0
First Class	0.60	3.6
Business Class	0.43	2.6
Economy Class	0.15	0.9

table 12

A business jet with an occupancy of 4.7 therefore has emissions around 3 times greater than First Class, 4 times greater than Business Class and 11 times greater than Economy Class.

The NBAA publication also cites EBAA data that “indicating that 41% of all Business Aviation flights in 2014 were empty leg flights”. Empty leg flights are flights which take place with no passengers in order to reposition the aircraft to where it is needed by the customer. If this figure is correct then the above emission factor would need to be increased by more than 50% in order to account for these repositioning flights.

London to Davos

Business Aviation flights to the annual meeting of the World Economic Forum in Davos have been attracting attention lately as the focus of the meeting has turned towards environmental concerns.

Business jets flying to the event predominantly use Dübendorf Air Base close to Zurich in Switzerland with connections to Davos made by surface transport or helicopter. Estimates of the emissions of business aviation flying from London Luton (LTN) to Zurich are presented below.

Emissions from two aircraft categories (light jets with less than 20,000lb MTOW and mid-size and super mid-size jets with greater greater than 20,000lb MTOW) were calculated with data again sourced from BCA PPH.

For these two aircraft categories estimates of fuel burn over 300nm, 600nm and 1,000nm missions are available assuming an occupancy of 4 passengers.

The great circle distance from LTN to ZRH is 435nm (501 statute miles or 806km) and this figure was uplifted by 8% to account for indirect routing, bringing the stage length to 470nm. The BAC PPH fuel consumption figures for a 600nm mission were adjusted down to account for this reduced distance.

The aircraft with a MTOW of less than 20,000lb were subdivided into 5 seaters and 7-8 seaters while the aircraft with a MTOW of greater than 20,000lb were subdivided into 6-9 seaters and 10-13 seaters. Averages were taken of the fuel consumption of each of the four groups of aircraft.

Average fuel consumption and CO_2e emissions (including non-CO_2effects) were:

<20,000 MTOW			>20,000lb MTOW		
Seats	Fuel Consumption (t)	Emissions (tCO_2e)	Seats	Fuel Consumption (t)	Emissions (tCO_2e)
5 seats	0.4	2.6	6-9 seats	1.1	6.4
7-8 seats	0.6	3.3	10-13 seats	1.6	9.3

table 13

The fuel burn estimate is based on an occupancy of 4 passengers so at lower occupancy rates the calculated emission factor will likely be a slight overestimate and at higher occupancy rates the calculated emission factor will likely be a slight underestimate.

LTN-ZRH <20,000lb Jet Emission Factors by Occupancy

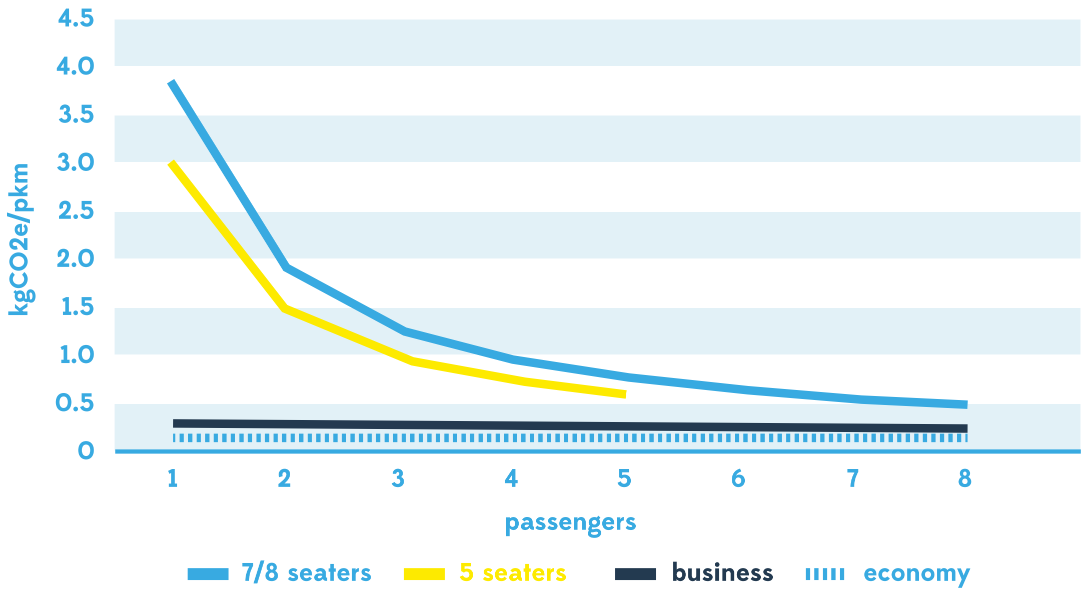


figure 3

LTN-ZRH >20,000lb Jet Emission Factors by Occupancy

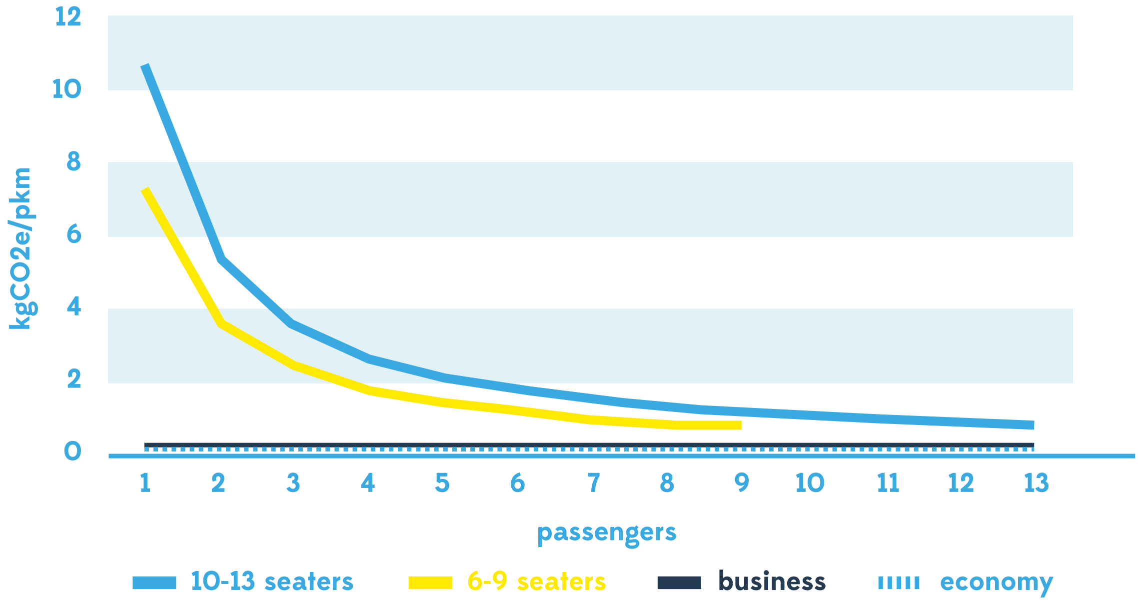


figure 4

For comparison, the emission factors for short haul aviation out of the UK by class (economy and business) are also included in the graph. The emission factor for these classes of business jet on this trip exceed airline emissions in all cases.

Assuming an average occupancy of 4.7, the emission factors and multiples of conventional aviation short haul Business and Economy class flights are:

Aircraft Category	Seats	Emission Factor $kgCO_2e/pkm$	Emissions per passenger tCO_2e
<20,000 MTOW	5 seat	0.6	0.6
	7-8 seat	0.8	0.7
>20,000lb MTOW	6-9 seat	1.6	1.4
	10-13 seat	2.3	2.0
Airlines	Economy	0.16	0.14
	Business	0.23	0.20
Rail	Average	0.01	0.01

table 14

Flying a business jet on this route would be around 3 to 10 times the emissions associated with flying business class and between 4 and 15 times the emissions associated with flying economy class. Compared to high speed rail between London and Zurich, flying in a business jet would generate between 75 and 250 times as much CO2. It is not unheard of for business jets to be operated with much lower numbers of passengers, even solo passengers, which would increase emissions to 50 or even 70 times the emissions associated with a typical UK citizen flying economy class in a conventional aircraft.

Similar to the transatlantic estimates in the previous section, emissions associated with repositioning flights mean that these estimates are likely to substantially underestimate the true impact of this category of aviation.

endnotes

1. https://www.ebaa.org/app/uploads/2018/01/EBAA-Economic-report-2017_compressed.pdf
2. https://www.eurocontrol.int/forecasting
3. https://www.ebaa.org/publications/fleet-tracker/
4. Eurocontrol STATFOR
5. https://www.ebaa.org/app/uploads/2018/01/EBAA-Economic-report-2017_compressed.pdf
6. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/781281/uk-aviation-forecasts-2017.pdf
7. https://www.ebaa.org/publications/fleet-tracker/
8. https://heartaerospace.com
9. https://www.scylax.eu
10. https://zunum.aero/
11. http://faradair.com
12. https://www.zeroavia.com/
13. https://www.cranfield.ac.uk/~/media/files/brochure/aircraft-electrification-brochure-2019.ashx
14. https://www.harbourair.com/harbour-air-and-magnix-partner-to-build-worlds-first-all-electric-airline/
15. As a single representative route distance for each country has been used in this analysis, these cumulative percentages may vary under a more granular analysis considering all airport pairs, however the broad trends are not expected to vary greatly.
16. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/829336/2019_Green-house-gas-reporting-methodology.pdf
17. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019
18. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/829336/2019_Green-house-gas-reporting-methodology.pdf
19. https://nbaa.org/wp-content/uploads/aircraft-operations/international/region-v-europe/boozallenhamilton-bizav-impact-on-Europe.pdf