The A220-100 and -300 series have impressed industry observers with their cabin appeal and operating efficiency. The fuel burn and operating performance of the A220-100 and -300 are analysed and compared with competing types on routes between 200nm and 900nm.

A220-100/-300 fuel burn & operating performance

The A220-100 and -300 have impressed many with their quiet and comfortable cabin, and reputation for efficiency and low cash operating costs. A main contributing factor is the A220's fuel burn performance, aided by the ultra-high bypass ratio of its Pratt & Whitney PW1524G engines. The CAE Flight Plan Manager has been used to assess the fuel burn and operating performance of the A220-100 and -300 against six of their closest competitors on nine routes with tracked distances between 218 nautical miles (nm) and 889nm over an annual period. CAE used the flight planning system that was acquired as the Sabre Flight Planning System in this analysis.

Aircraft types

The A220-100 falls between large regional jets (RJs) and the smallest narrowbodies, while the larger A220-300 is similar in size and capacity to the smallest narrowbody jetliner.

The A220-300's seating configuration for most operators makes it closest to the 737-300, 737-700 and A319. Seating configurations and passenger cabin layouts for many short-haul operations have changed in recent years. In Europe and the Asia Pacific narrowbodies are generally configured with three to six rows of business-class seats and an economy cabin. Many US carriers configure their aircraft with two or three rows of first-class seats, and an economy cabin.

Some airlines have changed to an all-economy-class layout, while others have a three-class layout. American, Delta Airlines and United Airlines have split the economy cabin into traditional economy and economy plus with increased seat pitch. Other airlines have a single-class arrangement to maximise seat numbers.

Each aircraft type in this analysis has been examined with an 85% passenger load factor when operated in a two-class arrangement that is representative of most operators. This makes it difficult to clearly compare seat capacities between the two main A220 variants and other types.

The A220 has a standard five-abreast arrangement and a wider aisle and seat width than the A320 and 737 families, which have six-abreast seating in economy.

A220-100 & competitors

Only two operators have the shorter A220-100 in service with a two-class arrangement: Swiss and Air Vanuatu. Both have a total of 117 seats, although Swiss has 12 in business class with four rows of three abreast, with two of the five-abreast seats closed off; and Air Vanuatu has eight, with two rows of four abreast. A seat count of 117 has been used in this analysis.

The A220-100 comes closest to the Embraer E-190 and -195 types. These are operated by mainline carriers, secondary airlines and regional subsidiaries.

The E-190/-195 has a narrower fuselage with a standard four-abreast cabin, which makes it harder for airlines to vary cabin layouts and seating arrangements. The only difference that can be made in business class is having a three-abreast design.

The E-190's and -195's fuselages are longer than the A220-100's, so the E-190 has two more seat rows and the E-195 four more seat rows than the A220-100. This means the E-190 overall would have 16-20 fewer seats than the A220-100, while the E-195 would have seven to eight fewer.

The E-190 is examined here with a seat count of 100, which is close to an average for most of its operators, which have a business cabin with six to 16 seats, and an average of 10-12. The E-190 E2 has been included with the same number of seats to analyse the fuel burn performance of younger generation aircraft.

The E-195 has been examined with a 111-seat configuration. This is an average of its main operators, whose business class averages 12 seats.

A220-300 & competitors

The A220-300 is 3.71 metres or just over 12 feet longer than the -100 series, so the A220-300 can be configured with three or four more rows of seats, giving it up to 15-20 more seats.

The A220-300 will always be operated in a mainline service, with a suitably-sized premium cabin. In some cases this could be configured in four-abreast seating.

The A220-300 is now operated by more than eight airlines, and its six largest operators are Breeze Airways, Air Austral, Air Vanuatu, Air France, Air Canada and Swiss. Average seat numbers are 133, with 18 in business class and 114 in economy. This is close to Swiss Airlines' arrangement, which has 18 business- and 115 economy-class seats.

The A220-300 is closest in size to the A319 current engine option (ceo) and new engine option (neo), the two having the same fuselage length, and the 737-700. The A319 and 737-700 are almost identical in fuselage and cabin length. While they are both about five metres shorter than the A220-300, the A319 and 737-600 have one more seat per row, so the overall seating configurations of the A220-300, A319ceo/neo and 737-700 should be similar. Few airlines have placed orders for the A319neo, so it is not included in this analysis.

Average seat counts for A319 operators are 131, just two fewer than the A220-100, with 16 seats in business class and 115 in economy.

The 737-700 is operated by only four carriers, with just WestJet operating in a two-class layout with 12 business-class

AIRCRAFT SPECIFICATIONS & WEIGHTS

Aircraft types	E-190LR	E-190 E2	E-195	A220-100	737-700	A319ceo	A319ceo	A220-300
Engine	CF34-10E5	PW1919G	CF34-10E7	PW15194G/ PW1524G-3	CFM56-7B24	CFM56-5B6	-V2524-A5	PW1521G/ PW1524G
Engine bypass ratio	5.4:1	12:1	5.4:1	12:1				12:1
Take-off thrust rating - lbs	18,820	20,860	20,360	19,775/ 24,400	24,200	23,500	24,480	21,970/ 24,400
MTXW - lbs	111,245	124,700	112,326	141,500	154,998	167,331	167,331	150,000
MTOW - lbs	114,199	124,300	111,973	140,500	154,500	166,450	166,450	149,000
MLW - lbs	97,003	108,140	99,208	120,500	127,998	137,789	137,789	129,500
MZFW - lbs	90,169	102,960	93,696	116,000	120,500	128,970	128,970	123,000
OEW/DOW - lbs	63,459	74,490	64,900	81,151	87,956	92,951	92,379	84,306
Max payload - lbs	26,710	28,470	28,796	34,849	32,544	36,019	36,591	38,694
Fuel capacity - USG	4,234	5,000	4,234	5,756	6,875	6,303	6,303	5,901
Dual-class seat configuration	100	100	111	117	129	131	131	133
Passengers carried	85	85	94	99	110	111	111	113
Passenger payload - lbs	19,635	19,635	21,795	22,973	25,410	25,722	25,722	26,115
Range with full passenger payload - nm	2,400	2,850	2,000	2,250	2,400	3,000	3,000	2,800

ROUTE CHARACTERISTICS FOR ANALYSIS OF AIRCRAFT PERFORMANCE

Route	ORD-DTW	ORD-CLE	ORD-PIT	ORD-YYZ	ORD-ATL	ORD-PHL	ORD-BDL	ORD-BOS	ORD-MCO
Tracked distance - nm	218	310	400	433	551	612	723	799	889
Average wind component - kts	22-27	30-32	31-33	27-29	4-6	40-42	39-41	41-43	11-13
ESAD - nm	200-202	282-285	363-366	398-401	543-551	547-548	647-655	718-723	860-863
Average flight time - mins	40-45	50-56	62-71	68-77	84-93	90-99	103-114	110-120	129-140
Alternate airport	CMH	PIT	CLE	SYR	BHM	BWI	BOS	BDL	TPA

seats in three rows of four abreast, and 118 economy-class seats, totalling 129. As the 737-700 may have marginally less cabin floor area than the A319, the 737-700 would have two seats fewer than the A319 for both to provide an equal amount of space for toilets, wardrobes, and galleys.

Passenger payloads

The aircraft types have been analysed with a number of passengers equal to an 85% load factor. The weight of each passenger includes an assumed baggage weight, and a weight of 231lbs. This is a conservative assumption, which allows for hand luggage and checked luggage for every passenger.

This affects payload carried, and therefore trip fuel burn.

The A220-100 at 117 seats is analysed with 99 passengers *(see table, this page)*. The E-190 and -190 E2 have 100 seats, and 85 carried passengers. The larger E-195 is examined with 111 seats and 94 passengers *(see table, this page)*.

The A220-300 is analysed with 133 seats, and 113 passengers carried, and the A319 and 737-700 with total seats of 131 and 129 respectively, and 111 and 110 passengers carried *(see table, this page)*.

Aircraft specifications

The important specifications for the aircraft examined are those with the biggest effect on aircraft performance: weights, fuel capacity and engine type. These are summarised *(see table, this page)*.

Each of the seven main types has a range of weight specifications available. Engine variant, maximum take-off weight (MTOW), and fuel capacity are the three main criteria that affect fuel burn. Variants with higher gross weights and larger fuel capacities have fewer performance restrictions. The aircraft have been analysed on nine city-pairs in the US, originating from Chicago O'Hare (ORD). These have tracked distances of 204nm to 873nm *(see table, this page)*, representative of typical route lengths across the network.

The payload carried by the A220-100 is therefore 22,973lbs *(see table, this page)*. The payload used for the E-190/-190 E2 is 19,635lbs, and 21,795lbs for the E-195.

The larger A220-300 has a passenger payload of 26,115lbs *(see table, this page)*, while the A319ceo's is 25,772lbs, and the 737-700's is 25,410lbs.

The aircraft have also been analysed with a typical operating empty weight (OEW) that represents an aircraft prepared for service (APS) weight. This is the basic empty weight of the aircraft, plus the weight of two flightcrew; and three cabin crew for the E-190 and E-195, or four cabin crew for the five larger types. Crew weights used are 187lbs for each flightcrew and 165lbs for each cabin crew member.

There is also a standard weight of 200lbs for on-board catering to provide a simple service level for all types. The OEW for each aircraft is summarised *(see table, this page)*. The OEW is highly dependent on the basic empty weight of the aircraft.

The aircraft's available gross payload is the difference between MZFW and OEW. This will be higher than the payload of a full load of passengers and weight of

The A220-100's fuel burn per seat is 30-34% lower than the E-190, and 22-37% per seat lower than the E-195. Comparing the A220-100 and E-190 E2 shows the two to be closer in performance, although the A220-100 still has a 6-8% lower fuel burn per seat.

carried passengers, and so provides some capacity for additional freight payload.

A220-100

The A220-100 examined here has an MTOW of 140,500lbs; the highest of all the different weight variants. This is with the PW1524G engine, rated at 24,400lbs *(see table, page 12)*. The aircraft has an MZFW of 116,000lbs and OEW of 81,151lbs. This allows a gross payload of 34,849lbs *(see table, page 12)*.

The aircraft has a fuel capacity of 5,756 US Gallons (USG). With this specification, a full load of passengers at 231lbs each would utilise all of its payload capacity. Range would be about 2,250nm *(see table, page 12)*.

E-190 & E-190 E2

The E-190 variant used in this analysis is the -190LR, which has long-range performance.

The -190LR has an MTOW of 114,199lbs, maximum landing weight (MLW) of 97,003lbs, and a MZFW of 90,169lbs. It is equipped with the CF34-10E5 engine rated at 18,820lbs. Fuel capacity used is 4,234USG. With this specification, the aircraft could carry a full passenger payload up to 2,400nm.

The OEW of 63,459lbs allows a gross payload of 26,710lbs *(see table, page 12)*. A passenger payload of 100 and 23,100lbs leaves a remaining payload of 3,610lbs.

The E-190 E2 used in this analysis has an MTOW of 124,300lbs, and is equipped with the PW1519G engine rated at 20,860lbs *(see table, page 12)*. The aircraft also has an MLW of 108,140lbs, and an MZFW of 102,960lbs.

Fuel capacity is 5,000USG, and the OEW used is 74,490lbs. This allows a gross available payload of 28,470lbs. The aircraft is capable of carrying a full passenger payload of 100 up to 2,850nm.

E-195

The E-195 variant used in the analysis is the LR version that has a longer-range performance than the standard E-195. The -195LR is therefore less likely to experience take-off weight and payload restrictions on typical route networks.

The E-195 LR has an MTOW of 111,973lbs, and is powered by the CF34-10E7 engine rated at 20,360lbs *(see table, page 12)*. Other weights are MLW at 99,208lbs, MZFW at 93,695lbs and OEW at 64,900lbs. This allows a gross payload of 28,796lbs *(see table, page 12)*.

The aircraft has a fuel capacity of 4,234USG, the same as the -190LR. This allows the aircraft to carry a full passenger payload of 111 up to 2,000nm.

A220-300

The A220-300 is lighter than the 737-700 and A319ceo, and this is expected to give the A220-300 a further advantage in fuel burn performance.

The A220-300 variant used here has an MTOW of 149,000lbs, and is powered with a PW1524G-3 engine rated at 24,400lbs thrust *(see table, page 12)*.

The aircraft's MLW and MZFW are 129,500lbs and 123,000lbs. It has a fuel capacity of 5,901USG, and can carry a full passenger load of 133 about 2,800nm.

The OEW used is 84,306lbs, so the aircraft has a gross payload of 38,694lbs.

A319ceo

The A319ceo has a large number of weight variants, and also has two main engine choices: the CFM56-5B and V2500-A5. There are several modification or build standards for both these engine types.

The variant used in this analysis has the second highest possible MTOW of 166,450lbs, the highest possible MLW of 137,789lbs, and the highest possible MZFW of 128,970lbs *(see table, page 12)*. The aircraft has a standard fuel capacity of 6,303USG for all weight variants.

The CFM56-5B6 or -5B7 used is rated at 23,500lbs and 27,000lbs, and the V2524-A5 is rated at 24,400lbs.

The OEW for the two variants differs by 572lbs, with the CFM56-5B-powered aircraft being the heavier type. The aircraft with the CFM56-5B engines therefore has an OEW of 92,951lbs, while that with the V2524-A5 has an OEW of 92,379lbs.

This leaves a gross payload of 36,019lbs for the CFM56-equipped aircraft, and a gross payload of 36,591lbs for the V2500-equipped aircraft.

A full passenger payload would be 30,261lbs, which would give the two variants a range of 3,000nm.

737-700

Like the A319, the 737-700 has several weight specification variants. The variant used has a MTOW of 154,500lbs, and a fuel capacity of 6,875USG. The aircraft is equipped with the CFM56-7B24 rated at 24,200lbs.

The MZFW of 120,500lbs and the used OEW of 87,956lbs allows a gross payload of 32,544lbs. A full passenger payload of 29,799lbs would allow the aircraft to operate up to 2,400nm.

Evaluation route networks

The eight aircraft types analysed here, in two groups of four, have been tested across nine US routes from ORD. These routes have been chosen to reflect a range of typical route lengths.

The nine US routes operated from ORD include the shortest with a tracked distance of 218nm to Detroit (DTW), and the longest to Orlando (MCO) at 889nm. The other seven routes are to Cleveland (CLE), Pittsburgh (PI), Toronto (YYZ), Atlanta (ATL), Philadelphia (PHL), Bradley (BDL) and Boston (BOS) *(see table, page 12)*. A suitable alternate is used on each route.

BLOCK FUEL PERFORMANCE OF

City-pair	Aircraft variant	Engine variant	Seats	Payload carried - lbs	ESAD - nm	Flight time - mins	Trip fuel - USG	USG per seat	Diff USG	% diff USG	Trip fuel/ ASM
ORD-DTW	E-190	CF34-10E6	100	19,635	200	45	468	4.68	1.18	33.6%	0.021
	E-190 E2	PW1919G	100	19,635	202	45	377	3.77	0.27	7.6%	0.017
	E-195	CF34-10E7	111	21,795	200	45	486	4.38	0.87	24.9%	0.020
	A220-100	PW1524G	117	22,973	200	43	410	3.50			0.016
ORD-CLE	E-190	CF34-10E6	100	19,635	283	56	570	5.70	1.34	30.8%	0.018
	E-190 E2	PW1919G	100	19,635	283	56	595	5.95	1.59	36.5%	0.019
	E-195	CF34-10E7	111	21,795	282	54	460	4.14	-0.021	-4.9%	0.013
	A220-100	PW1524G	117	22,973	283	53	510	4.36			0.014
ORD-PIT	E-190	CF34-10E6	100	19,635	365	71	703	7.03	1.60	29.5%	0.018
	E-190 E2	PW1919G	100	19,635	365	69	576	5.76	0.33	6.1%	0.014
	E-195	CF34-10E7	111	21,795	365	71	736	6.63	1.20	22.2%	0.017
	A220-100	PW1524G	117	22,973	363	68	635	5.43			0.014
ORD-YYZ	E-190	CF34-10E6	100	19,635	400	77	769	7.69	1.77	29.8%	0.018
	E-190 E2	PW1919G	100	19,635	399	75	631	6.31	0.39	6.5%	0.015
	E-195	CF34-10E7	111	21,795	399	77	803	7.23	1.31	22.1%	0.017
	A220-100	PW1524G	117	22,973	398	74	693	5.92			0.014
ORD-ATL	E-190	CF34-10E6	100	19,635	544	92	917	9.17	2.20	31.5%	0.017
	E-190 E2	PW1919G	100	19,635	544	90	751	7.51	0.54	7.7%	0.014
	E-195	CF34-10E7	111	21,795	544	93	961	8.66	1.68	24.1%	0.016
	A220-100	PW1524G	117	22,973	543	90	816	6.97			0.013
ORD-PHL	E-190	CF34-10E6	100	19,635	548	99	966	9.66	2.29	31.1%	0.016
	E-190 E2	PW1919G	100	19,635	547	97	795	7.95	0.58	7.9%	0.013
	E-195	CF34-10E7	111	21,795	548	99	1,011	10.11	2.74	37.2%	0.017
	A220-100	PW1524G	117	22,973	547	96	862	7.37			0.012
ORD-BDL	E-190	CF34-10E6	100	19,635	650	114	1,091	10.91	2.64	31.9%	0.015
	E-190 E2	PW1919G	100	19,635	649	111	890	8.90	0.63	7.6%	0.012
	E-195	CF34-10E7	111	21,795	655	108	1,161	10.46	2.19	26.4%	0.014
	A220-100	PW1524G	117	22,973	647	111	968	8.27			0.011
ORD-BOS	E-190	CF34-10E6	100	19,635	719	119	1,165	11.65	2.86	32.6%	0.015
	E-190 E2	PW1919G	100	19,635	719	117	950	9.50	0.71	8.1%	0.012
	E-195	CF34-10E7	111	21,795	720	120	1,228	11.06	2.28	25.9%	0.014
	A220-100	PW1524G	117	22,973	718	117	1,028	8.79			0.011
ORD-MCO	E-190	CF34-10E6	100	19,635	861	139	1,349	13.49	3.24	31.6%	0.015
	E-190 E2	PW1919G	100	19,635	863	137	1,102	11.02	0.77	7.5%	0.012
	E-195	CF34-10E7	111	21,795	862	140	1,421	12.80	2.55	24.9%	0.014
	A220-100	PW1524G	117	22,973	860	138	1,199	10.25			0.012

Source: CAE Flight Plan Manager

A main issue affecting aircraft performance is the wind component en route. This is generally from a westerly direction. All eight routes generally operate in an easterly and south-easterly direction from ORD, and so will experience a tailwind component. This will make the equivalent still air distance (ESAD) shorter that the tracked distance.

To representatively demonstrate each aircraft's performance, flight plans were generated by the CAE Flight Plan Manager on the same day for 52 weeks. This provides an average wind component, and therefore the ESAD and subsequent flight time and fuel burn, across a full year of operations for each aircraft type. From this a reliable average can be extracted.

The average wind component for each route resulted in an average ESAD across the year. These averages were all a tailwind component, and in the case of most routes were 22-40 knots of tailwind *(see table, page 12)*. This made the ESAD shorter than the tracked distance. A 50-knot tailwind will reduce the tracked distance by about 12.4% in the case of jetliners operating typical flight profiles.

The variances in aircraft speed and operating performance factors, including rate of climb, affect the flight profile of each aircraft, which leads to differences in flight times between each type.

The eight routes with their tracked distances, average wind components, ESADs, and average flight times are summarised *(see table, page 12)*.

All nine routes are within the range capability of the eight aircraft types when carrying a maximum passenger payload in standard temperature conditions. That is, the longest tracked distance is 889nm.

All eight types are capable of carrying an 85% passenger payload on all nine routes throughout the year, without any payload limitations.

Operating assumptions

The analysis of the eight types on these nine routes evaluates several factors. The first is the actual average fuel burn over 52 flight plans over an annual period for each aircraft on each of the nine routes. From this fuel burn per available seat, per passenger carried, and per available seat-mile can all be examined. The cost per seat can also be examined if a representative fuel price per USG is applied.

Operating assumptions affect the fuel

BLOCK FUEL PERFORMANCE OF

City-pair	Aircraft variant	Engine variant	Seats	Payload carried - lbs	ESAD - nm	Flight time - mins	Trip fuel - USG	USG per seat	Diff USG	% diff USG	Trip fuel/ ASM
ORD-DTW	737-700	CFM56-7B24	129	25,410	201	40	505	3.91	0.58	17.3%	0.018
	A319	CFM56-5B7	131	25,722	201	40	517	3.95	0.61	18.2%	0.018
	A319	V2524-A5	131	25,722	201	41	496	3.79	0.45	13.4%	0.017
	A220-300	PW1524G-3	133	26,115	200	42	444	3.34			0.015
ORD-CLE	737-700	CFM56-7B24	129	25,410	284	51	634	4.91	0.76	18.4%	0.016
	A319	CFM56-5B7	131	25,722	285	50	647	4.94	0.79	19.0%	0.016
	A319	V2524-A5	131	25,722	284	53	619	4.73	0.57	13.8%	0.015
	A220-300	PW1524G-3	133	26,115	283	52	552	4.15			0.013
ORD-PIT	737-700	CFM56-7B24	129	25,410	366	62	780	6.05	0.93	18.3%	0.015
	A319	CFM56-5B7	131	25,722	366	63	804	6.14	1.02	20.0%	0.015
	A319	V2524-A5	131	25,722	365	65	775	5.92	0.80	15.7%	0.015
	A220-300	PW1524G-3	133	26,115	364	65	680	5.11			0.013
ORD-YYZ	737-700	CFM56-7B24	129	25,410	400	68	857	6.64	0.95	16.7%	0.015
	A319	CFM56-5B7	131	25,722	401	70	885	6.76	1.06	18.7%	0.016
	A319	V2524-A5	131	25,722	401	71	857	6.54	0.85	14.9%	0.015
	A220-300	PW1524G-3	133	26,115	399	73	757	5.69			0.013
ORD-ATL	737-700	CFM56-7B24	129	25,410	545	85	1,028	7.97	1.30	19.5%	0.014
	A319	CFM56-5B7	131	25,722	543	84	1,059	8.08	1.41	21.2%	0.015
	A319	V2524-A5	131	25,722	544	87	1,031	7.87	1.20	18.0%	0.014
	A220-300	PW1524G-3	133	26,115	543	87	887	6.67			0.012
ORD-PHL	737-700	CFM56-7B24	129	25,410	550	91	1,081	8.38	1.37	19.6%	0.014
	A319	CFM56-5B7	131	25,722	551	90	1,108	8.46	1.45	20.7%	0.014
	A319	V2524-A5	131	25,722	549	92	1,079	8.24	1.23	17.5%	0.013
	A220-300	PW1524G-3	133	26,115	548	92	932	7.01			0.011
ORD-BDL	737-700	CFM56-7B24	129	25,410	652	104	1,205	9.34	1.39	17.5%	0.013
	A319	CFM56-5B7	131	25,722	652	103	1,247	9.52	1.57	19.8%	0.013
	A319	V2524-A5	131	25,722	652	106	1,216	9.28	1.34	16.8%	0.013
	A220-300	PW1524G-3	133	26,115	649	108	1,057	7.95			0.011
ORD-BOS	737-700	CFM56-7B24	129	25,410	723	111	1,305	10.12	1.66	19.6%	0.013
	A319	CFM56-5B7	131	25,722	723	110	1,348	10.29	1.83	21.7%	0.013
	A319	V2524-A5	131	25,722	722	113	1,320	10.08	1.62	19.1%	0.013
	A220-300	PW1524G-3	133	26,115	719	114	1,125	8.46			0.011
ORD-MCO	737-700	CFM56-7B24	129	25,410	862	131	1,504	11.66	1.79	18.1%	0.013
	A319	CFM56-5B7	131	25,722	861	129	1,557	11.89	2.01	20.4%	0.013
	A319	V2524-A5	131	25,722	861	130	1,530	11.68	1.81	18.3%	0.013
	A220-300	PW1524G-3	133	26,115	861	133	1,313	9.87			0.011

Source: CAE Flight Plan Manager

burn of each aircraft. In addition to the tracked distance and ESAD described, the main factors are the flight rules used, cruise speed, and altitude or flight level. These have been determined by the CAE Flight Plan Manager.

There is also the reserve fuel policy, the taxi-in and -out times, and any time spent in holding patterns, delays or diversions.

The flight rules used are IFR, US domestic rules for route optimisation. The flight profile was optimised by the CAE Flight Plan Manager, and included an altitude or FL for the shortest ORD-DTW route of 250, or 25,000 feet. This avoids a ballistic flight profile being used, and allows a cruise portion for the flight. The FL for the other eight routes was optimised as part of the flight profile for the route being optimised by the Flight Plan Manager.

The speed used was a minimum range cruise (MRC) Mach number, according to the FL flown, to achieve the best fuel economy.

The taxi times used were 15 minutes for taxi-out and eight minutes for taxi-in. This would affect total fuel carried.

Reserve fuel policy was 5%, and it was assumed that no diversions or in-flight delays were experienced. Sufficient fuel for diversion to the alternate was also carried.

Fuel consumption was produced in lbs, and a fuel density of 6.7lbs per US Gallon (USG) was used to convert fuel burn in to volume.

Fuel burn performance

The eight aircraft types were split into two groups: the A220-100 plus three Embraer large RJs; and the A220-300 and three A320 and 737NG family members. The results for these two groups are shown *(see tables, pages 14 & 15)*.

The main parameter is fuel burn per seat, since this is an element of fuel cost per seat. This cost can be adjusted by passenger load factor to show the contribution that fuel makes to total operating cost per fare paying passenger, and what is the difference between aircraft types on this basis if required.

A220-100 & large RJs

This analysis shows the A220-100 to be significantly more fuel-efficient than the first generation Embraer E-190 and E-195 E Jets *(see table, page 14)*.

Fuel burn per seat reduces as route and mission length increase, and with increased aircraft size and seat numbers. Despite the

The A220-300 has a 17-18% lower fuel burn per seat than the older generation and similarly-sized 737-700 and A319ceo. At a fuel cost of $2..50 per USG, this can translate into a cost advantage of $1-5 per seat for the A220-300.

increasing route lengths, the A220-100's fuel consumption per seat is 29.5-33.6% lower than the E-190's. While the E-195 is 11 seats larger than the -190 and only six seats smaller than the A220-100, the A220-100 still has a burn rate per seat that is 22.1-37.2% lower than the E-195.

These percentage differences translate to the E-190 having a higher fuel burn per seat of 1.18USG for the shortest ORD-DTW route of 200nm, and up to 3.24USG per seat on the longest ORD-MCO route of 861nm *(see table, page 14)*.

The E-195's fuel burn per seat is 0.87-2.55USG higher than the A220-100's on the nine routes.

The cost of fuel has varied widely over the past year, from $1.75 per USG in July 2021, to a peak of $4.10 per USG in June 2022. A median fuel price of $2.50 per USG translates into a higher fuel cost per seat difference of $2.95-8.10 for the E-190 compared to the A220-100. The E-195's higher fuel cost per seat is $2.18-6.38 on the same basis. These differences are high when typical profit margins per seat or per carried passenger are taken into consideration.

The main factor in the A220-100's fuel efficiency compared to the E-190 and E-195 is the difference in bypass ratios of the PW1524G and the CF34-10E5/7. The PW1524G has a bypass ratio of 12.0:1, while the CF34-10E's ratio is considerably smaller at 5.4:1.

The next generation E-190 E2 is much closer to the A220-100, as would be expected. The E-190 E2 is powered by the PW1919G, which has the same bypass ratio as the PW1524G of 12.0:1.

The E-190 E2 has the same number of seats as the first generation E-190, so it is 14% smaller than the A220-100 and thus has a higher fuel consumption per seat on the same routes and missions.

Across the nine routes of 200-862nm, the A220-100 has a 6.1-8.1% lower burn per seat than the E-190 E2 *(see table, page 14)*. This is from actual fuel consumption per seat for the E-190 E2 being 0.27-0.77 USG higher than the A220-100. This translates to a higher cost per seat of $0.67-1.93 for the E-190 E2, when using the median fuel price. This is considerably closer to the A220-100 than the first generation E-Jets.

The E-195 E2 is 10 feet longer than the first generation E-195. The E-195 E2 can therefore accommodate about four rows of economy-class seats. This would add 16 seats over the E-195, giving the -195 E2 a seat capacity of about 127, making it nine or 10 seats larger than the A220-100. The E-195 E2 is therefore likely to have a lower fuel burn per seat than the A220-100. Unfortunately the E-195 E2 was not available for this analysis.

A220-300 versus 737-700 & A319

The A220-300 has a significantly lower fuel burn than the 737-700 and A319ceo.

The A220-300 has 17-18% lower burn per seat than the 737-700 across the nine routes *(see table, page 15)*. This translates to 0.58-1.79USG per seat more for the 737-700 than the A220-300. At a median fuel price of $2.50 per USG, the A220-300 has a fuel cost per seat advantage of $1.45-$4.50 across the route lengths of 200-862nm.

The CFM56-powered A319ceo has 2-4% higher burn than the V2524-powered version. The difference in the A220-300's fuel burn per seat performance compared to the A319ceo is similar to the 737-700.

Compared to the CFM56-powered A319ceo, the A220-200 has 18.2-20.4% lower burn per seat on the nine routes, equal to a difference of 0.61-2.01USG per seat *(see table, page 15)*. This translates to an advantage of $1.52-5.02 per seat for the A220-300.

When looking at the V2524-powered A319ceo, the A220-300 has a smaller advantage of 0.45-1.81USG per seat *(see table, page 15)*. This translates to a difference in fuel cost per seat of $1.12-4.52.

The differences in fuel cost per seat between the A220-300 and its older generation alternatives are significant when typical profit margins per available seat are considered. The cost per seat differences can be changed to cost per passenger by adjusting for passenger load factor.

The A220-300 is a new generation aircraft that is a direct replacement candidate for the 737-700 and A319ceo. The other two replacement candidates are the A319 new engine option (neo) and the 737 MAX 7.

The A319neo has the same fuselage size as the A319ceo, and the 737 MAX 7 has the same fuselage size as the 737-700. The A319neo and 737 MAX 7 would therefore have the same seat numbers when their cabins are configured in the same way as the A319ceo and 737-700.

The A319neo can be powered by either the CFM LEAP-1A26 or the PW1127G. These engines have bypass ratios of 11:1 and 12:1, and so should have a fuel burn efficiency similar to the PW1524G powering the A220-300. To date, Airbus has secured fewer than 100 orders for the A319neo, and only three aircraft are in airline service. The A319neo has therefore not been included in this analysis.

The 737 MAX 7 is equipped with the CFM LEAP-1B25. The aircraft has secured more than 280 firm orders from airlines, including 234 from Southwest and 22 from WestJet. To date, more than 60 have been delivered to Southwest and WestJet. The 737 MAX 7 has, however, been in service for only a short period, so it has not been possible to include it in this analysis.

On a weight-for-weight basis, the A220-300 has both a lower MTOW and OEW than the A319neo and 737 MAX 7. The A220-300 may therefore have a small fuel burn per seat advantage. AC