The A321neo's & A320neo's fuel burn and operating performance is put to the test and analysed against their precursors from the ceo range, and various competing types from Boeing's 757 and 737 families over a range of four routes between 682nm & 2,165nm.

A321neo & narrowbody fuel burn & operating performance

The fuel burn and operating performance of the A321 new engine option (neo), with both available engine selections, and a suite of comparable aircraft with different airframe-engine combinations is analysed and compared. Aircraft include examples of the older-generation A320 and A321 current engine option (ceo), the 737-800 and 737-900ER, the current-generation A320neo and A321neo, and the 737 MAX 8 (737-8). To put the efficiency gains of modern types in perspective, Boeing's venerable 757-200, the aircraft that has ruled the 200-seat mid-to-long range market for so long, has also been included.

Overall, 12 aircraft variants are included in the analysis *(see table, page 28)*. The four US domestic routes chosen are typical missions for these 12 aircraft. New York's John F. Kennedy (JFK) was the origin for the four US domestic flights, with destinations Chicago O'Hare (ORD), Kansas City (MCI), Denver (DEN) and Los Angeles (LAX). These routes have tracked airway distances ranging from 682nm up to 2,165nm. When combined with route-specific wind components of 43-47 knots headwind, they have equivalent still air distances (ESADs) of 759-2,399nm.

Aircraft types & variants

The two A320ceo variants are equipped with different engines. The A320-214 is powered by the CFM56-5B4/P, and the A320-232 is powered by V2527-A5 engines *(see table, page 28)*.

The two A320neo variants are equipped with a variant of the two main engine types available. The A320-251N is powered by the CFM LEAP-1A, and the A320-271N is powered by the Pratt & Whitney PW1127G *(see table, page 28)*.

The two A321ceo variants are equipped with CFM56-5B3/3 engines and IAE V2533-A5 engines, resulting in the A321-211 and A321-232 variants respectively *(see table, page 28)*.

The A321neo models come with CFM LEAP-1A32 engines and PW1133G engines, resulting in the A321-251N and A321-271N variants respectively *(see table, page 28)*.

The CFM LEAP-1A and PW1100G families are both high-bypass ratio, axial-flow, dual-rotor turbofan engines. However, they show very different design approaches in achieving the demonstrated efficiencies. Where the CFM LEAP-1A series design is based on optimising conventional turbofan architecture through better thermal efficiency, the PW1000G family is the result of improving propulsive efficiency by having the fan and compressor rotate at their own optimum speeds. Both OEMs have made optimum use of the latest in material science, albeit each with a different focus, and both have succeeded in producing engines that have a far lower footprint on the environment than their predecessors in terms of emissions and noise.

The LEAP-1A has a traditional architecture, with one spool consisting of the fan, a three-stage low-pressure compressor (LPC) and a seven-stage low pressure turbine (LPT) driving the intake fan. The other spool consists of a 10-stage high-pressure compressor (HPC), and a two-stage high-pressure turbine (HPT) to drive the HPC. The LEAP-1A's bypass ratio is 11.0:1 and the fan diameter is 78 inches.

The PW1000G has a less traditional architecture in that the low pressure spool consists of a three-stage LPT driving both a three-stage LPC and a drive-gear speed-reduction system which powers the fan and allows both LPT and fan to spin at their own individual optimum speeds. The eight-stage HPC is driven by a two-stage HPT. Bypass ratio is 12.5:1 and the fan diameter is 81 inches.

For the Boeing aircraft analysed, aircraft-engine combinations that were available in the Lufthansa Systems LIDO/Flight database were selected. The 737-800 is therefore equipped with the CFM56-7B26, the 737-900ER is powered by the CFM56-7B27/3, the 737-8 is powered by the LEAP-1B28, and the 757-200 is powered by the Rolls-Royce RB211-535E4 *(see table, page 28)*.

These aircraft-engine combinations are not the most widely operated combinations around the world, but they will, nevertheless, provide relevant data for the purposes of comparison. For example, the choice of engine sub-types and related thrust ratings for the 737-800 is quite large, with three main types by thrust (24,000lbs, 26,000lbs and 27,000lbs) and a host of finer details related to performance improvement packages, single or double annular combustors and other enhancements related to progressive build standards.

Of the 4,900 or more 737-800s in operation, the most widely used engine is the CFM56-7B26E, equipping 39% of 737-800s. The -7B27/B3 engine powers the second largest group of 737-800s which is 17% of the fleet.

In the case of the 737-900ER, it is the CFM56-7B27E with just over 40%, closely followed by its slightly lower-powered sibling CFM56-7B26E with a share of just under 40%.

The 757-200 configuration featured reflects about 60% of installed combinations with a choice between the RB211-535E4 and PW2000 series variants.

AIRCRAFT SPECIFICATIONS & WEIGHTS

Aircraft Type	A320-214	A320-232	A320-251N	A320-271N	737-800	737-8	737-900ER	A321-211	A321-232	A321-251N	A321-271N	757-236
Fitted winglets	Yes	Yes			Yes		Yes		Yes			Yes
Engine	CFM56-5B4/P	V2527-A5	LEAP-1A26	PW1127G	CFM56-7B26	LEAP-1B28	CFM56-7B27 /3	CFM56-5B3 /3	V2533-A5	LEAP-1A32	PW1133G	RB211-535E4
Engine bypass ratio	5.7	4.8	11.0	12.5	5.1	9.0	5.1	5.4	4.5	11.0	12.5	4.1
MTXW - lbs	170,638	170,638	175,047	175,047	174,900	181,700	188,200	207,014	207,014	207,014	207,014	251,000
MTOW - lbs	169,756	169,756	174,165	174,165	174,200	181,200	187,700	206,132	206,132	206,132	206,132	250,000
MLW - lbs	145,505	145,505	148,592	148,592	146,300	152,798	157,300	171,520	171,520	174,606	174,606	198,000
MZFW - lbs	137,789	137,789	141,757	141,757	138,300	145,399	149,300	162,701	162,701	166,669	166,669	184,000
OEW - lbs	99,000	99,000	101,400	101,400	93,000	99,500	97,200	110,000	109,776	116,161	115,500	137,000
Max payload - lbs	38,789	38,789	40,357	40,357	45,300	45,899	52,100	52,701	52,925	50,508	51,169	47,000
Fuel capacity - USG	6,184	6,184	6,184	6,184	6,745	6,812	6,875	6,353	6,261	6,205	6,205	11,276
Dual-class seat	153	153	161	161	158	158	179	184	184	192	192	192
Passenger payload - lbs	35,343	35,343	37,191	37,191	36,498	36,498	41,349	42,504	42,504	44,352	44,352	44,352
Remaining cargo payload - lbs	3,446	3,446	3,166	3,166	8,802	9,401	10,751	10,197	10,421	6,156	6,817	2,648
Range with full passenger payload - nm	2,325	2,415	2,650	2,680	2,865	3,450	2,565	2,110	2,200	2,710	2,580	3,300
MTOW/seat - lbs	1,110	1,110	1,082	1,082	1,103	1,147	1,049	1,120	1,120	1,074	1,074	1,302
OEW/seat - lbs	647	647	630	630	589	630	543	598	597	605	602	714

A321neo

The A321neo is the main aircraft in this analysis, and this re-engined and tweaked version of the A321ceo series is efficient. It is the best to date in this class of aircraft in terms of carried payload per seat-mile.

With new A321neo variants just entering the market and allowing even longer flights and/or more payload (LR, XLR, and the new Cabin-Flex concept of Airbus), this type is getting serious attention both from operators and leasing companies. The order backlog shows a healthy 2,150 aircraft, with many ordered deliveries no doubt being switched to LR or XLR versions of the A321neo, now that Boeing's MAX programme has hit turbulence. This may well have an impact on the 737 MAX 10 programme.

The A321neo is expected to replace a large number of 757-200s, with the aircraft retiring without a clear successor. Recently, the A321LR test aircraft completed an 11-hour and 4,750nm flight while carrying a payload equivalent of 178 passengers and crew from the Seychelles to Toulouse, France. This has set the stage for it becoming the preferred solution in the long, thin middle of the market segment.

The A321neo variants included in this analysis have a maximum take-off weight (MTOW) of 206,132lbs. A total of nine weight variation options have been certified, and the weight variant used in the analysis (WV065) has the highest MTOW and maximum landing weight (MLW) of these weight variants *(see table, this page)*, apart from weight variants reserved for the additional centre tank (ACF) versions of the aircraft, which take the MTOW up to 213,848lbs or beyond the 100 metric tonnes mark.

A321neos weigh about 4,000lbs more than the earlier A321ceo models due to the new engines (an extra 2,000-2,400lbs per engine, depending on engine model) and the associated airframe modifications (engine pylons, wing structure).

The A321neo variants analysed here are equipped with the PW1133G rated at 33,110lbs thrust, and the LEAP-1A32 rated at 32,160lbs thrust. The two engines have bypass ratios of 12.5:1 and 11.0:1 respectively.

Power-to-weight ratio at MTOW is 3.11-3.20 and a standard fuel capacity of 6,205USG gives the A321neos a range of 2,710nm (A321-251N) to 2,580nm (A321-271N) in these configurations and under our standard conditions with a full payload of 192 passengers *(see table, this page)*.

A321ceo

The two A321ceo versions have the same MTOWs of 206,132lbs as the A321neos, and a MLW of 171,520lbs. This weight variant is one of 12 different available weight specifications.

Power-to-weight ratio at MTOW is 3.12-3.26 and the fuel capacities of 6,353USG (A321-211) and 6,261USG (A321-232) give the A321ceos a range of 2,110nm (A321-211) and 2,200nm (A321-232) in these configurations and under our standard conditions with a full payload of 184 passengers *(see table, this page)*.

The lowest MTOW for the A321ceo is 171,961lbs (WV009), and the highest certified MTOW is 206,132lbs (WV011). The two engine options used in this comparison are the V2533-A5 rated at 31,600lbs, and the CFM56-5B3/3 rated at 33,000lbs.

A320neo

The A320neo variants included in this analysis have an MTOW of 174,165lbs. Of the 14 weight variation options available, the two neos have the highest weight variant (WV055). A320neos have OEWs about 2,650lbs more than the two A320ceo variants. The A320neo variants used in this analysis are equipped with two engine options: the PW1127G rated at 27,075lbs thrust, and the LEAP-1A26 rated at 27,120 lbs thrust *(see table, this page)*. The two engines have bypass ratios of 12.5:1 and 11.0:1.

Power-to-weight ratio at MTOW is 3.21-3.22 and the fuel capacity of 6,184USG gives the A320neo variants a range of 2,650nm (A320-251N) to 2,680nm (A320-271N) in these configurations and under the standard conditions with a full payload of 161 passengers *(see table, this page)*.

A320ceo

The two A320ceo variants analysed have an MTOW of 169,756lbs, an MLW of 145,505lbs and a fuel capacity of 6,184USG *(see table, this page)*. This weight variant is one of 20 different available weight specifications.

The lowest MTOW for the A320ceo is 145,505lbs, and the highest certified MTOW is 171,961bs. The two engine variants used in this comparison are the IAE V2527-A5 rated at 24,800lbs, and the CFM56-5B4/P rated at 27,000 lbs. The V2725-A5 has a bypass ratio of 4.8:1, while the CFM56-5B4/P has a bypass ratio of 5.7:1.

The power-to-weight ratio at MTOW is 3.14-3.42 and the combined average fuel burn per transported passenger is 26.1-26.7USG. The fuel capacity of

6,184USG gives the A320ceos a range of 2,325nm (A320-214) to 2,415nm (A320-232) in these configurations and under the standard conditions with a full payload of 153 passengers.

737 MAX 8

The 737 MAX series is the fourth 737 generation, succeeding the 737 Next Generation (NG) series. The first MAX 8, or 737-8, was delivered May 2017.

Compared to the 737NG, the MAX variants are fitted with more efficient LEAP-1B engines, and have aerodynamic improvements and airframe modifications. These produce operating efficiency improvements of about 15% over the NGs.

For a variety of reasons, the MAX family is heavier than the NG family, with the 737-8 having an operating empty weight (OEW) about 6,500lbs higher than the 737-800 it replaces. The 737-8 variant used comes with an MTOW of 181,200 lbs, an MLW of 152,800lbs, and a standard fuel capacity of 6,812USG *(see table, page 28)*.

The LEAP-1B28 engines have a bypass ratio of 9.0:1, which is the lowest of the new generation engines included in this analysis. The power-to-weight ratio at MTOW is 3.09, and the combined average fuel burn per transported passenger is 25.0USG. Range for the aircraft in this configuration and under the standard conditions used is 3,450nm with a full 158 passenger payload.

737-800

The 737-800 is a well known workhorse, and the most popular of the four NG models. The 4,900 aircraft delivered to date can be found all around the world, making the 737-800 one of the most widely used narrowbody aircraft.

The 158-seat 737-800 variant in this analysis is the heaviest variant with an MTOW of 174,200 lbs, powered by CFM56-7B26 engines and equipped with Aviation Partners Boeing blended winglets. MLW is 146,300lbs and fuel capacity is the standard 6,745USG *(see table, page 28)*. The engines have a bypass ratio of 5.1:1.

The power-to-weight ratio at MTOW is 3.31 and the combined average fuel burn per transported passenger is 26.0USG. Range for this aircraft in this configuration and under standard conditions is about 2,865nm with a full passenger payload.

737-900ER

The youngest and longest variant of Boeing's NG series, the 737-900ER is the preferred model of the -900 series chosen by customers worldwide. There are about 500 -900ERs in operation, compared to about 50 standard -900s.

Designed to replace the 757-200 and go head-to-head with the A321ceo, the 737-900ER has not found the expected larger user base for reasons including geo-economic background, and it no longer being the right aircraft for such missions with the advent of the A320neo family and 737 MAX models.

The 179-seat 737-900ER variant in this analysis has an MTOW of 187,700lbs, is equipped with CFM56-7B27/3 engines, and comes with Aviation Partners Boeing blended winglets.

MLW is 157,300lbs and fuel capacity is the standard 6,875USG *(see table, page 28)*. The engines have a bypass ratio of 5.1:1. The power-to-weight ratio at MTOW is 3.44, and the combined average fuel burn per transported passenger is 25.0USG. Range for this aircraft in this configuration and under standard conditions is around 2,565nm with a full passenger payload.

757-200

The version of the 757-200 used in this comparison is equipped with winglets and is powered by two Rolls-Royce RB211-535E4 engines. MTOW is the highest certified 250,000lbs, making this the heaviest aircraft in this analysis. MLW is 198,000lbs.

ROUTE CHARACTERISTICS

Route	JFK-ORD	JFK-MCI	JFK-DEN	JFK-LAX
Flight times - mins	108-113 min	151-155 min	216-222 min	318-328 min
Taxi out times - mins	20 min	20 min	20 min	20 min
Taxi in times - mins	14 min	10 min	15 min	22 min
Block times - mins	142-147 min	181-185 min	251-257 min	360-370 min
Tracked distances - nm	682nm	979nm	1,436nm	2,165nm
Wind components - kts	-43 to -45	-41 to -43	-45 to -47	-41 to -43
ESAD - nm	759-765nm	1,082-1,090nm	1,598-1,609nm	2,382-2,399nm
Alternate airport & distance - nm	MKE/88nm	MEM/370nm	COS/71nm	ONT/56nm

The -535E4 is rated at 40,100lbs and has a bypass ratio of 4.1:1, the lowest number of the aircraft in the analysis. The power-to-weight ratio at MTOW is 3.12 and the combined average fuel burn per transported passenger is 29.2USG, the highest number in this comparison. The fuel capacity of 11,276USG gives the 757-200 a range of 3,300nm in this configuration and under the standard operating conditions with a full payload of 192 passengers *(see table, page 28)*.

Comparison basis

Using the fundamental metric of passenger-carrying capacity versus fuel burned provides a good indication of flight operational efficiency. To this end the metric used is fuel burn per ASM, and, combined with an industry-average current fuel price, fuel cost per ASM.

ASMs are calculated by multiplying the number of available seats with the actually flown distance, also known as the ESAD. It is important to understand that ASMs are calculated on available seats *(see table, page 34)*. This means that fewer ASMs are generated if some aircraft seats are unavailable for sale due to regulatory, performance or technical reasons, or are seats dedicated for crew rest. This turned out to be the case on two of the longest of four missions in this comparison.

Performance of the aircraft was examined using OEW and zero fuel weight (ZFW) on the basis of operating a typical two-class, full-service operation. Since aircraft cabin and equipment configurations vary from airline to airline, it is difficult to select an OEW or dry operating weight (DOW) that will fit all operators in a comparison like this.

The weights selected may vary significantly from what is found at a specific airline, and as such will have an effect on the resulting fuel burn computations or payload-range capacity. Furthermore, the aircraft were planned to operate with a full payload of passengers, with an allowance of 231lbs per passenger and associated baggage. This resulted in relatively high passenger-related payloads for each type, certainly a bit higher than most scheduled airline operations are likely to experience in this fashion and with today's ancillary revenue-conscious passengers (cargo excluded.

Fuel and operational performance numbers for the 12 aircraft-engine combinations were generated by Lufthansa Systems' Lido/Flight 4D flight planning system. All flight plans were produced using the same assumptions and inputs around fixed-Mach cruise, fixed routes, 0% performance degradation, 85% average winds for June, all-engine taxi and normal SOPs.

Lido/Flight 4D optimises climb, cruise and descent segments of a flight based on the performance specifications of the particular airframe-engine combinations as received from the OEMs, as well as specific operating philosophies (flight level caps, performance degradation factors, amended performance buffers in planning, padding) as requested by customers.

If not creating an optimised route itself, once a route has been decided, Lido/Flight 4D will plan an optimal vertical profile based on parameters applicable to the aircraft and its operator, achieving the overall lowest total cost for the planned flight by balancing the cost of fuel burn, time-related costs and airspace access costs. Climb and descent profiles differed per aircraft type and installed powerplants of course, with the newer-technology aircraft reaching desired cruise level a few minutes ahead of the older generation aircraft.

Cruise speeds for all aircraft types and variants on all routes were driven by the LRC cruise mode selection with TAS values ranging from 449 to 461 knots. An increasing number of operators are moving away from fixed-Mach cruise modes, such as a specific Mach number or Long-Range Cruise (LRC) in favour of Cost Index (CI) flying. This is because CI flying is a more cost-conscious way of balancing flight operational costs. Because CI flying relies heavily on operator internal cost structures and fuel prices, no two operators plan and operate flights using exactly the same CI. This means that a flight-for-flight comparison would not be entirely correct. For this reason, LRC was selected as the speed-mode of choice for all 12 aircraft-engine combinations. This resulted in like-for-like economic losses (not making use of wind-component driven cruise speed optimisations) while using this speed-mode. And last, to create the same atmosphere for all aircraft types to operate in, statistical average winds and temperatures were used.

This comparison is following Federal Aviation Administration (FAA) domestic flight planning rules, which have been applied conservatively. Planning with an alternate was also required *(see table, this page)*. The FAA allows for planning without an alternate in addition under certain conditions. Reserve fuel was the normal FAA domestic amount required to cruise for 45 minutes.

Operationally, it was assumed that, again conservatively, all engines would be used for both taxi-out and taxi-in. Taxi times from departure point and at the five destinations were taken from the Lido database, adding 635-2,111lbs of fuel consumption per trip in auxiliary power unit (APU) burn and taxi fuel burns, depending on aircraft type and city-pair operated.

Assumptions

All aircraft in the comparison have been examined with a typical two-class cabin layout, reflecting typical mainline configurations. All 12 aircraft types show a standard six-abreast economy-class configuration. There is more variety in premium cabins, including: high-end four-abreast seating; standard six-abreast seats with increased seat pitch over economy; and six-abreast seats with the same pitch as economy class but with blocked-off centre seats to provide four-abreast window and aisle seats.

Together with recent OEM-driven cabin re-designs, some airlines have adopted new interior layout options that include repositioned rear toilets, smaller and slimmer galleys, additional seat rows through the use of slimmer seats, and a simplified product and cabin service to allow for more seats. The most commonly observed cabin layouts and seat counts were used to provide seat numbers for the comparison. The

The LEAP-1A-powered A320neos are about 2-3% percent more fuel efficient per ASM than the 737-8. The A320neos are the second most fuel efficient narrowbodies are the A321neo variants.

resulting seat numbers and weights drove payload and operational weight estimates, as well as the calculated ASMs for each aircraft type.

As a result, cabin configurations in this comparison are: 153 seats for the A320ceo models; 161 for the A320neo models; 184 for the A321ceo models; 192 for the A321neo models; 158 for both the 737-800 and the 737-8, 179 for the 737-900ER, and 192 for the 757-200 *(see table, page 32).*

Many factors play a role in across-the-board comparisons. Real-world aircraft weights differ from the assumed weights used here, so they will result in different operational weights and performance. Real-world performance deviations (mostly degradations) from book or build standard, different pilot SOPs and techniques, and different operating environments make it clear that the assumptions and numbers used, and the resulting conclusions, can easily mis-represent a particular operation.

Aircraft performance

The flight plans generated for the 12 aircraft-engine combinations on the four routes are for maximum passenger payloads, as described. All seats are filled where possible and capped by payload where necessary. The resulting performance metrics (block times, fuel burn, ASMs) for each aircraft on each of the four routes have been summarised *(see table, page 34).* The fuel burn per ASM metrics was calculated and these derived values form part of the results shown.

The ESADs for each aircraft-engine combination on each of the four routes are listed *(see table, page 34).* While the tracked distance is the same for each aircraft on the same route, there is a small difference in resulting ESADs between aircraft variants, because flight profiles differ in horizontal and vertical speeds and distances between aircraft types, so the varying wind components at different altitudes have different overall effects over the length of the route. The ESAD on JFK-ORD, for example, varies from 759nm to 765nm. By itself this is not a dramatic difference, but over longer distances this effect becomes noticeable; the ESAD spread on JFK-LAX is 2,382nm to 2,399nm, a difference of 17nm.

Relative fuel burn

Fuel burns are listed in absolute terms in USG, and also in fuel burn per ASM *(see table, page 34).* Because the aircraft have been analysed with full passenger payloads, the obvious comparison is relative difference in fuel burn per ASM between the most fuel-efficient type and the 11 other aircraft-engine combinations.

Longer flights are bound to produce lower fuel cost per ASM than shorter flights, as the average fuel burn per flight hour and nm decreases with increased mission length. Cruise fuel burn per FH and per nm is less than fuel burn rate during the take-off and climb phases. A larger portion of a flight spent in cruise mode and an increase in ASMs per FH will improve aircraft productivity.

A321-251N & -271N

First, the most efficient fuel burn per ASM performance seen in the comparison is produced by the 192-seat A321-251N and -271N on the (longest) JFK-LAX sector, at 0.0104 gallon per ASM and 0.0114USG per ASM on the shortest JFK-ORD route *(see table, page 34).* Overall, the A321-251N and -271N had the lowest burns per ASM on all four routes.

The LEAP-1A32-powered A321-251N shows an absolute lower fuel burn of 1-20 USG than the PW1133G-powered A321-271N on three of the four the four routes *(see table, page 34).* The A321-271N is just 1USG more efficient on the shortest route.

Payload limitation route

Second, the worst-performing aircraft was the A321-211, with a burn of 0.0156USG per ASM or 50.6% more burn per ASM than the A321-271N of JFK-LAX. This only applied to this route, however, and does not fully represent the A321-211's performance. The A321-211 had a reduction in passenger load of 147 passengers, and consequently it generated 88,000 and 20% fewer ASMs than it would have done without a payload restriction.

It should be noted that, unlike the A321-232, the A321-211 was not equipped with sharklets. This partly caused the aircraft to reach tank capacity on the longest route, JFK-LAX, of 2,385nm sector, and forced this flight to leave 37 seats vacant in order to be able to reach its destination.

757-200

Third, the highest fuel burn per ASM of all 12 aircraft was demonstrated by the 192-seat 757-200 across all four routes. It burns 0.0162USG per ASM on the shortest JFK-ORD sector, and 0.0141USG on the longest JFK-LAX route *(see table, page 34).* This is perhaps not surprising given that 757-200 is the oldest type in the analysis.

By comparison, the best-performing A321-251N and -271N both produced only 0.0114USG per ASM on the shortest route, the 757-200 being 41.5% per ASM higher. The 757-200's burn per ASM was 35.6% higher than the A321-251N and -271N on the longest route.

The rest of the aircraft types show relatively poorer fuel burn per ASM performance than the A321neo variants *(see table, page 34)*. In general terms, the other A320neo family aircraft and the 737-8 come closest in efficiency to the A321-251N and -271N.

Neo variants versus ceo variants

To simplify the assessment of relative performance between these aircraft and the other, single, aircraft types presented here, the performance of the four pairs of Airbus aircraft in the comparison (the two A320ceos, the two A320neos, the two A321ceos and the two A321neos) have been averaged.

The results drive several observations. First, on all four routes, the two A320neo variants come closest to the two A321neo variants in fuel burn per ASM efficiency *(see table, page 34)*. There is only a 1.9% difference between these two pairs of aircraft in burn per ASM efficiency on the 6-hour JFK-LAX sector, up to a respectable 3.5% difference on the shortest 2.4 hour JFK-ORD sector.

An important comparison is the improvement of the A321neo variants over the A321ceo variants. On a burn in USG per ASM basis, the A321-211 showed 26.32-50.0% higher fuel burn than the A321-251N, and the A321-232 has a 17.3-21.1% higher fuel burn per ASM.

Compared with the A321-271N, the A321-211 showed 25.2-50.0% higher fuel burn per ASM, while the A321-232 scored 17.0-20.0% higher fuel burn per ASM.

All in all, the two A321ceos showed between 17.0% and 50.0% higher USG fuel burn per sector than the two A321neos.

Similarly, there are comparisons between the A320neos and A320ceos.

In terms of fuel burn per ASM, compared to the more-efficient A320-271N, the A320-214 demonstrated a 24.1-26.7% higher fuel consumption, while the A320-232 scored slightly better with 22.3-24.8% higher fuel burn per ASM.

Compared with the A320-251N, the A320-214 shows 21.9-24.3% higher fuel burn per ASM, while the A320-232 scores 20.2-21.7% higher fuel burn per ASM. All in all, the two A320ceos showed between 20.2% and 26.7% worse trip fuel burn than the two A320neo variants.

It should be noted that the A320-214 reached tank capacity on the longest sector, forcing this flight to leave two seats vacant. This led to slightly fewer ASMs for this flight compared to the A320-232, and so a slightly raised fuel burn per ASM.

Other types

The A320neos are closely followed by the 737-8. Next down the list of decreasing fuel efficiency per ASM is the 737-900ER, followed by the A321ceos, then the 737-800, the A320ceos, and finally the 757-200.

In this, the general ranking is only valid for the first three sectors. Aircraft design capabilities start playing a role on the longest sector, and the A321ceos simply lack the range with this payload.

This means that on the longest sector, the A321ceos and the A320ceos switch place in relative efficiency, which ends with the least efficient aircraft type, the 757-200.

The second most efficient aircraft, with a slightly higher burn per ASM than the A320neo models, is the 737-8 *(see table, page 34)*. Again, going from longest sector to shortest sector, relative

BLOCK FUEL BURN PERFORMANCE OF A320 CEO & NEO, A321 CEO & NEO, 737-800, 737-8,737-900ER, 757-200

City-pair	Aircraft variant	Engine variant	Available seats	Payload carried lbs	ESAD nm	ASMs	Block time min	Block fuel USG	Burn /ASM USG
JFK-ORD	A320-214	CFM56-5B4/P	153	35,343 lbs	761	116,433	144	1,711	0.0147
	A320-232	V2527-A5	153	35,343 lbs	761	116,433	144	1,698	0.0146
	A320-251N	LEAP-1A26	161	37,191 lbs	764	123,004	144	1,470	0.0120
	A320-271N	PW1127G	161	37,191 lbs	764	123,004	144	1,445	0.0117
	737-800 W	CFM56-7B26	158	36,498 lbs	765	120,870	146	1,717	0.0142
	737-8	LEAP-1B28	158	36,498 lbs	765	120,870	146	1,480	0.0122
	737-900ER W	CFM56-7B27/B3	179	41,349 lbs	760	136,040	144	1,862	0.0137
	A321-211	CFM56-5B3/3	184	42,504 lbs	759	139,656	142	2,017	0.0144
	A321-232	IAE V2533-A5	184	42,504 lbs	760	139,840	143	1,925	0,0138
	A321-251N	LEAP-1A32	192	44,352 lbs	760	145,920	143	1,670	0.0114
	A321-271N	PW1133G	192	44,352 lbs	759	145,728	143	1,669	0.0115
	757-236 W	RB211-535E4	192	44,352 lbs	763	146,496	147	2,368	0.0162
JFK-MCI	A320-214	CFM56-5B4/P	153	35,343 lbs	1,088	166,464	183	2,322	0.0139
	A320-232	V2527-A5	153	35,343 lbs	1,089	166,617	183	2,283	0.0137
	A320-251N	LEAP-1A26	161	37,191 lbs	1,089	175,329	183	1,994	0.0114
	A320-271N	PW1127G	161	37,191 lbs	1,089	175,329	183	1,970	0.0112
	737-800 W	CFM56-7B26	158	36,498 lbs	1,089	172,062	184	2,328	0.0135
	737-8	LEAP-1B28	158	36,498 lbs	1,089	172,062	184	1,996	0.0116
	737-900ER W	CFM56-7B27/B3	179	41,349 lbs	1,087	194,573	182	2,534	0.0130
	A321-211	CFM56-5B3/3	184	42,504 lbs	1,082	199,088	181	2,753	0.0138
	A321-232	IAE V2533-A5	184	42,504 lbs	1,088	200,192	182	2,596	0.0130
	A321-251N	LEAP-1A32	192	44,352 lbs	1,088	208,896	182	2,281	0.0109
	A321-271N	PW1133G	192	44,352 lbs	1,087	208,704	181	2,282	0.0109
	757-236 W	RB211-535E4	192	44,352 lbs	1,090	209,280	185	3,184	0.0152
JFK-DEN	A320-214	CFM56-5B4/P	153	35,343 lbs	1,608	246,024	255	3,278	0.0133
	A320-232	V2527-A5	153	35,343 lbs	1,608	246,024	255	3,213	0.0131
	A320-251N	LEAP-1A26	161	37,191 lbs	1,608	258,888	256	2,813	0.0109
	A320-271N	PW1127G	161	37,191 lbs	1,609	259,049	256	2,783	0.0107
	737-800 W	CFM56-7B26	158	36,498 lbs	1,609	254,222	257	3,276	0.0129
	737-8	LEAP-1B28	158	36,498 lbs	1,609	254,222	257	2,821	0.0111
	737-900ER W	CFM65-7B27/B3	179	41,349 lbs	1,598	286,042	251	3,599	0.0126
	A321-211	CFM56-5B3/3	184	42,504 lbs	1,599	294,216	253	3,906	0.0133
	A321-232	IAE V2533-A5	184	42,504 lbs	1,607	295,688	254	3,659	0.0124
	A321-251N	LEAP-1A32	192	44,352 lbs	1,607	308,544	254	3,241	0.0105
	A321-271N	PW1133G	192	44,352 lbs	1,606	308,352	253	3,255	0.0106
	757-236 W	RB211-535E4	192	44,352 lbs	1,598	306,816	256	4,468	0.0146
JFK-LAX	A320-214	CFM56-5B4/P	153	34,881 lbs	2,397	361,947	368	4,801	0.0133
	A320-232	V2527-A5	153	35,343 lbs	2,386	365,058	367	4,701	0.0129
	A320-251N	LEAP-1A26	161	37,191 lbs	2,398	386,078	369	4,118	0.0107
	A320-271N	PW1127G	161	37,191 lbs	2,398	386,078	369	4,073	0.0105
	737-800 W	CFM56-7B26	158	36,498 lbs	2,398	378,884	369	4,786	0.0126
	737-8	LEAP-1B28	158	36,498 lbs	2,399	379,042	370	4,105	0.0108
	737-900ER W	CFM56-7B27/B3	179	41,349 lbs	2,382	426,378	360	5,277	0.0124
	A321-211	CFM56-5B3/3	147	33,942 lbs	2,385	350,595	365	5,481	0.0156
	A321-232	IAE V2533-A5	184	42,504 lbs	2,385	438,840	365	5,351	0.0122
	A321-251N	LEAP-1A32	192	44,352 lbs	2,385	457,920	365	4,755	0.0104
	A321-271N	PW1133G	192	44,352 lbs	2,384	457,728	363	4,775	0.0104
	757-236 W	RB211-535E4	192	44,352 lbs	2,397	460,224	367	6,492	0.0141

Source: Lufthansa Systems' Lido/Flight

Notes: Lufthansa Systems provided block fuel figures in lbs. These have been converted to USG using 1 USG = 6.55lbs.

The A321neo has the highest fuel burn efficiency in terms of fuel burn per ASM of all narrowbody aircraft. The performance of LEAP-1A- and PW1100G-powered aircraft is close.

decreasing efficiency numbers range from 3.8% to 6.6% higher burn per ASM when compared to the average of the A321neo variants, and 1.9% to 3.0% higher burn per ASM when compared to the average of the A320neo models.

It is clear that the 737-8 performs with higher burn than the A320ceo models analysed here. The differences per ASM will be partly influenced by the 737-8's higher thrust rating of the selected engine model and its chosen number of seats and cabin layout.

As expected, the 737-900ER lags behind the A321neos by a wider margin. The 737-900ER's higher burn per ASMs ranges from 19.2% to 19.7% across the four routes.

The relative delta between the 737-900ER and the A321ceo is between 2.0% and 12.1% in the 737-900ER's favour. The last number is related to the JFK-LAX route. The numbers for the first three sectors range from 2.0% to 3.1%.

Next up is the 737-800 with 21.2% to 24.0% lower performance per ASM than the combined average performance of our A321neo models.

When compared with the combined average of the two A320neo variants, the 737-800 has a higher burn of about 18.9-19.8% on all four routes.

Relatively, the 737-800 scores better than the A320ceo models, with the A320ceos are higher per ASM by 2.9% to 3.8% in this comparison.

Also to note is that across all four routes, the A320ceos are the worst performing aircraft after the 757-200. The 737-800 and -900ER are therefore the best performing aircraft of the previous generation group.

Relative fuel cost

Jet fuel prices have been going up and down of late. At the time of preparing this analysis, prices are at about the same level as in spring 2018, and are hovering at around $88 per barrel for crude oil, equal to $2.09 per USG for Jet A-1.

The past 12 months saw these prices climb as high as $100 per barrel for crude oil, and drop to as low as $68. This is quite a spread for a business, where fuel cost directly influences the total cost, and where a difference between $68 per barrel and $100 per barrel may cause a change of 25% of an airline's total cost, to a much larger 37% share. This not only puts pressure on airlines in controlling their operational costs, but also affects the relative cost differences between the aircraft types. A generic fuel price of $2.09 per USG has been used to show real-world dollar values.

When translating these fuel burn numbers to cost values, and based on the prices discussed earlier, the lowest fuel cost per ASM performance seen in this comparison is the 192-seat A321-251N on the longest JFK-LAX sector at 2.16 cents per ASM. Values on this route are 2.2-3.3 cents per ASM for the 12 aircraft types on that route.

Relative operational cost

The three major operational cost items for a flight are fuel, overflight (airspace access) costs and time-related costs.

These costs accumulate and form a significant burden on the operation, in most parts of the world almost doubling the per-ASM cost compared to fuel cost alone. This is not the case in the USA however, where overflight charges are not levied. In this, the cost variables of time-dependent costs and overflight costs do not differ much by aircraft type in the same weight category and generation; the overflight costs are usually based on certified MTOW (cost/tonne) and the time-dependent costs are not so different as well with similar cockpit and cabin crew complements and same order of magnitude maintenance costs related to operating the aircraft types.

It is interesting to see here how small differences in fuel burn are amplified or negated by small differences in generated ASMs. This can be driven by the slightly different flight profiles of these two aircraft-engine combinations. On the shortest JFK-ORD sector, the A321-271N actually burn 8lbs less fuel than the -251N. This is, however, due to 1nm difference in ESAD flown on this route. This is enough to push the A321-251N's fuel burn per ASM result to the lowest of all aircraft. On the longer sectors, the A321-251N's advantage over the -271N increases up to 20USG. In reality, the A321-251N and -271N have virtually identical fuel burn performance.

The two A321neo aircraft-engine variants examined here are identical aircraft, apart from the engines and their associated hardware. Since there is a slight difference in dry engine weight of about 331 lbs, the resulting DOW of the two aircraft differs by 662lbs. This in turn creates a slightly higher fuel burn of 37-110lbs, equal to just over 20lbs per FH on the four sectors.

Based on average aircraft utilisation assumptions (say, 25 years of 3,500FH per year), this fuel burn difference equals an extra 1.78 million lbs of fuel over the life of the aircraft.

In closing

This comparative analysis shows that the A321neo variants are the most efficient narrowbody aircraft used today.

The newer LR variant, that has only been in revenue service for six months, and the upcoming XLR variant, will most certainly produce even lower fuel burn per ASM and will comfortably enter territory previously only accessed by the ageing 757-200. AC