The 787 and A350 families both promised significant fuel burn reductions over similar-sized, older generation aircraft. Examples of the potential efficiency gains are analysed here across four typical transatlantic sectors between about 3,500nm and 5,500nm.

Fuel burn & operating performance of the 787-8, 787-9 and A350-900

Over the past five years a number of new generation twin-engine, long-haul aircraft have entered service. The 787-8 began operations in 2011, and was followed into service by the 787-9 in 2014, and the A350-900 in 2015. All three aircraft were designed to reduce fuel burn by 20% or more compared to older generation types.

The fuel burn and operating performance of the 787-8, 787-9 and A350-900 are analysed here. They are compared to older generation aircraft with similar capacities, including the 767-300ER, A330-200, A330-300 and 777-200ER. These aircraft are analysed on four north transatlantic routes.

Assumptions

The following fuel burn and operating performance analysis is based on simulated flight plan data provided by Lufthansa Systems' LIDO/Flight solution. The results generated by these flight plans and additional calculations performed by *Aircraft Commerce*, should only be considered within the context of specific assumptions.

Operational assumptions

The flight plans were generated using a number of operating assumptions. The simulated performance assumes the aircraft are operating under international flight rules. The reserve, diversion and contingency fuel requirements were based on European Aviation Safety Agency (EASA) standards.

The aircraft were operated at their long-range cruise (LRC) speeds to optimise fuel economy. Weather assumptions included average temperatures for the month of June, with 85% reliability winds.

The routes and flight levels flown were optimised to achieve minimum cost, while complying with airways rules and restrictions. The minimum cost track (MCT) is based on the optimum routeing for each aircraft variant, taking account of fuel, navigation and operational time costs.

Aircraft flying transatlantic services generally operate via the North Atlantic track (NAT) system. This is a series of official airways established between Europe and North America that are updated twice daily to take advantage of favourable weather (or wind) conditions. Since these NATs change on a daily basis it was not possible to predict a precise NAT route for this analysis. If the routes were flown via the NAT system, aircraft may not have been able to operate at optimum LRC speeds due to airway separation requirements and the need to operate at fixed mach numbers. Operating via the NAT system could also lead to longer tracked distances than the MCTs used in this analysis.

The block time for each sector is the sum of the trip and taxi times. The taxi out and taxi in times are based on realistic averages for each airport. The block fuel is the sum of the trip and taxi fuel burn. In this analysis it is assumed that the aircraft had both engines running while taxiing.

The cost of fuel is assumed to be $1.32 per US Gallon (USG). This is taken from data from Lufthansa Systems' LIDO/Flight and is based on the fuel price at London Heathrow (LHR) airport during the first week of November 2016. This analysis assumes that one USG is equal to 6.7lbs.

The 787-8 is about 20 seats larger than the 767-300ER, while the 787-9 has about 20 seats more capacity than the A330-200. The 787 was originally pitched to offer fuel burns up to 20% lower than similar-sized previous generation aircraft.

AIRCRAFT SPECIFICATIONS & WEIGHTS USE IN FUEL BURN SIMULATIONS

Aircraft	767-300ER	A330-200	787-8	787-8
Engine	CF6-80C2B6	Trent 772C	Trent 1000-J	GEnx-1B-70
MTXW-lbs	413,000	515,661	503,498	503,498
MTOW-lbs	412,000	513,677	502,500	502,500
MLW-lbs	319,999	401,241	380,000	380,000
MZFW-lbs	294,998	374,786	354,999	354,999
OEW-lbs	204,148	273,373	264,500	264,500
Max payload-lbs	90,850	101,413	90,499	90,499
Fuel capacity-USG	24,140	35,927	33,340	33,340
Fuselage length	180ft 3-inches	191ft 6-inches	186ft 1-inch	186ft 1-inch
Cabin width	15ft 6-inches	17ft 4-inches	18ft	18ft
Economy config	2+3+2	2+4+2	3+3+3	3+3+3
Typical capacity	210	248	228	228

Aircraft	A330-300	777-200ER	787-9	787-9	A350-900
Engine	Trent 772B	GE90-94B	Trent 1000-J	GEnx-1B-74/75	Trent XWB-84
MTXW-lbs	515,661	658,000	561,500	561,500	592,824
MTOW-lbs	513,677	656,000	559,998	559,998	590,839
MLW-lbs	412,264	470,000	424,998	424,998	451,948
MZFW-lbs	385,809	440,000	399,998	399,998	423,288
OEW-lbs	284,396	321,875	284,000	284,000	308,647
Max payload-lbs	101,413	118,125	115,998	115,998	114,641
Fuel capacity-USG	25,192	56,317	33,384	33,384	35,646
Fuselage length	208 ft 11-inches	209ft1-inch	206ft 1-inch	206ft 1-inch	219ft 2-inches
Cabin width	17ft 4-inches	19ft 3-inches	18ft	18ft	18ft 5-inches
Economy config	2+4+2	3+3+3 or 3+4+3	3+3+3	3+3+3	3+3+3
Typical Capacity	274	278	268	268	293

Notes:
1). Fuel capacity figures are converted from lbs using 1 USG = 6.7lbs.

The flight plans were generated to show the maximum available payload that could be carried by each aircraft on each sector. The maximum payloads were extrapolated from certain aircraft specification assumptions.

Aircraft weights and engines

There are multiple certified weight options available for most of aircraft in this analysis. With the exception of the A350-900, the aircraft also have multiple engine options. The aircraft specifications chosen here should reflect realistic and common in-service examples. Both engine families are considered for the 787s, while one specific variant was selected for the 767-300ER, 777-200ER, A330-200 and A330-300.

The number of potential alternative aircraft weight and engine specification combinations means that this analysis can only offer a rough guide to potential performance. In some cases higher or lower weight specifications and engine ratings might be available and these will invariably influence performance.

The dry operating weights (DOWs) or operating empty weights (OEWs) used in this analysis should only be treated as a rough guide. Although they should all fit within a realistic in-service range, OEW will vary by individual aircraft. OEW is influenced by a number of factors including the cabin configuration, engine variant, crew numbers and associated belongings, catering and cabin service items.

It should be noted that manufacturers often find ways to reduce OEW for later production line numbers of a particular aircraft variant. It is not uncommon for early production and delivery aircraft to have higher OEWs than later-build examples. Since they are still in the relatively early stages of production, the OEWs for some 787 and A350 airframes may still be on the high side, and it is possible that future examples might offer more payload.

Aircraft capacity

This analysis took the raw flight plan data provided by Lufthansa Systems' LIDO/Flight, and extrapolated it further to provide a guide to the potential fuel costs per available seat mile (ASM) and the potential payload available for cargo *(see table, page 22)*.

To achieve this, *Aircraft Commerce* made its own independent assumptions regarding aircraft capacity.

For reasons of commercial sensitivity, it was not possible to identify the cabin configurations or capacities that resulted in the OEWs used in the simulated flight plans. The capacities used here would in all likelihood result in different OEWs resulting in a subsequent impact on the performance figures. The resulting ASM and fuel cost per ASM calculations should only be considered in this context.

Widebody cabin configurations can vary significantly for the same aircraft type. This is often due to product differentiation between airlines, which view the cabin layout of their long-haul flagships as key product differentiators. On transatlantic services for example, some airlines have a four-class cabin, while others may only have a two-class configuration. In some cases a single operator may have separate sub-fleets of the same aircraft type configured with different seats numbers, depending on the routes they are used to serve.

This variation in possible configurations means that it is difficult to identify a typical capacity for each aircraft variant. With the exception of the A350-900, this analysis identified average capacities for each type by taking into consideration typical transatlantic operators. As an example, six airlines were identified as having the potential to operate the 787-9 on transatlantic services. The capacity of these aircraft varied from British Airways (BA) with 216 seats in a four-class arrangement, to Air Canada with 298 seats in a three-class configuration. The average capacity for 787-9 transatlantic services was therefore established as 268 seats. It was

The A350-900 has about 15-20 more seats than a 777-200/-200ER in typical intercontinental configurations. Despite the larger seat capacity, the A350-900 has a 10% lower gross weight and 37% smaller fuel capacity than the 777-200ER.

not possible to use the same method for the A350-900, since the operational fleet still numbers fewer than 50 aircraft and there are relatively few, if any, currently being operated on transatlantic services. This analysis therefore used Lufthansa's proposed 293-seat configuration for the A350-900, since the airline is likely to be one of the first to deploy the type on transatlantic sectors when it takes delivery of its first aircraft in early 2017.

The analysis also attempts to demonstrate the potential payload remaining for cargo for all aircraft types, once passengers and their baggage have been accounted for. The use of available widebody belly freight capacity has been a growing trend in the air cargo market since the introduction of new widebodies, such as the 777, which offer more lower deck capacity *(see The belly freight capacity of widebody passenger aircraft, Aircraft Commerce, December 2014/January 2015, page 52)*.

In this analysis the potential payload available for cargo is calculated by removing the assumed weight of passengers and their bags from the maximum available payload. The available cargo payloads do not account for the tare weights of unit load devices (ULDs). These would also need to be subtracted to identify the net payload that is available for the freight itself.

It is assumed that each passenger will have one carry-on bag and will check in an average of 1.2 hold bags. The assumed weights are 187lbs for a single passenger and carry-on bag and 57lbs per hold bag. The number of hold bags on each flight is rounded up to the nearest whole number. Taking these assumptions into account, a 268-seat 787-9 would carry 322 hold bags.

Aircraft

The precise specifications used for each aircraft variant in this analysis are summarised here *(see table, page 17)*.

The different types can be broadly categorised into two groups according to size. The 787-8 will be compared to the 767-300ER and A330-200, while the 787-9 and A350-900 will be compared to each other and against the A330-300 and 777-200ER.

787-8, 767-300ER & A330-200

The 787-8 was analysed with both engine family options. In this case one aircraft was equipped with Rolls-Royce (RR) Trent 1000-J engines and the other with General Electric (GE) GEnx-1B-70 engines. Both examples had a maximum take-off weight (MTOW) of 502,500lbs, an OEW of 264,500lbs, and a fuel capacity of 33,340 USG *(see table, page 17)*. In reality there is likely to be a minor difference in OEW between aircraft with different engine families, but a realistic average is applied to both variants on this occasion. It was assumed that the 787s are configured with 228 seats.

The 767-300ER is equipped with CF6-80C2B6 engines and has an MTOW of 412,000lbs. It has a fuel capacity of 24,140 USG, and an assumed capacity of 210 seats *(see table, page 17)*.

The A330-200 is equipped with Trent 772C engines. It has an MTOW of 513,677lbs and a fuel capacity of 35,927 USG. The A330-200's assumed capacity was 248 seats.

The 767-300ER is the smallest aircraft in this size category with a length of 180ft and three inches (180ft 3-inches) and a cabin width of 15ft 6-inches. It typically seats seven-abreast in economy in a 2+3+2 configuration.

At 186ft 1-inch, the 787-8 is nearly six feet longer than the 767-300ER. It is also two-and-a-half feet wider, allowing it to accommodate eight- or nine-abreast seating in economy class. This results in a higher seating capacity.

The A330-200 is nearly five feet, six-inches longer than the 787-8, but about eight inches narrower. The A330-200 has eight-abreast seating in economy, and is configured with 20 more seats than the 787-8 in this analysis. The difference in capacity can vary by layout, but the 787-8 is capable of accommodating similar seat numbers in some scenarios.

787-9, A330-300, A350-900, 777-200ER

The 787-9 is analysed with Trent 1000-J and GEnx-1B-74/75 engines. Both variants have an MTOW of 559,998lbs, an OEW of 284,000lbs and a fuel capacity of 33,384 USG *(see table, page 17)*. The two 787-9s have an assumed passenger capacity of 268 seats.

The A350-900 is equipped with Trent XWB-84 engines. It has an MTOW of 590,839lbs and a fuel capacity of 35,646 USG. The capacity is assumed to be 293 seats.

The A330-300 is equipped with Trent 772B engines. It has an MTOW of 513,677lbs and a fuel capacity of 25,192 USG. It is assumed that the A330-300 is configured with 274 seats *(see table, page 17)*.

The 777-200ER is equipped with GE90-94B engines. It has an MTOW of 656,000lbs and a fuel capacity of 56,317 USG. In this analysis the 777-200ER has an assumed passenger capacity of 278 seats.

The 787-9 is the shortest aircraft in this size category at 206ft 1-inch in length. It is nearly three feet shorter, but eight inches wider than the A330-300. The 787-9 is often configured with nine-abreast seating in economy, to the A330-300's eight-abreast. In this analysis the A330-300 is configured with six more seats than the 787-9, but the two types offer similar potential capacities depending on the cabin layout.

The A350-900 is the longest aircraft in this analysis at 219ft 2-inches, making it 13 feet longer than the 787-9, and 10 feet longer than the 777-200ER. The A350-900 is five inches wider than the

FUEL BURN PERFORMANCE OF WIDEBODY AIRCRAFT ON TRANSATLANTIC ROUTES

City-pair	Aircraft variant	Engine variant	PLNTOW (lbs)	PLNLW (lbs)	PLNZFW (lbs)	Available payload (lbs)	ESAD (nm)	Block time (hr:min)	Block fuel (USG)
LHR-BWI	787-8	Trent-1000-J	451,372	367,302	354,999	90,499	3,594	08:01	12,707
	787-8	GEnx-1B-70	453,322	367,673	354,999	90,499	3,574	07:55	12,943
	767-300ER	CF6-80C2B6	402,429	308,219	294,998	90,850	3,686	08:35	14,250
	A330-200	Trent 772C	491,652	389,261	374,786	101,413	3,623	08:17	15,378
	787-9	GEnx-1B-74/75	506,074	413,346	399,998	115,998	3,621	07:59	13,999
	787-9	Trent-1000-J	508,942	413,739	399,998	115,998	3,625	08:03	14,369
	A350-900	Trent XWB-84	536,541	437,553	423,288	114,641	3,589	07:55	14,894
	A330-300	Trent 772B	506,690	400,657	385,809	101,413	3,641	08:20	15,945
	777-200ER	GE90-94B	574,546	456,468	440,000	118,125	3,644	08:08	17,781
LHR-ATL	787-8	Trent-1000-J	469,236	370,605	354,999	90,499	4,152	09:19	14,930
	787-8	GEnx-1B-70	471,927	371,193	354,999	90,499	4,131	09:14	15,244
	767-300ER	CF6-80C2B6	412,000	303,604	287,487	83,339	4,235	09:53	16,427
	A330-200	Trent 772C	513,677	392,828	374,308	100,935	4,187	09:39	18,163
	787-9	GEnx-1B-74/75	525,929	417,051	399,998	115,998	4,183	09:17	16,459
	787-9	Trent-1000-J	529,347	417,445	399,998	115,998	4,188	09:21	16,911
	A350-900	Trent XWB-84	558,021	441,602	423,288	114,641	4,147	09:14	17,533
	A330-300	Trent 772B	513,677	392,402	373,916	89,520	4,188	09:39	18,257
	777-200ER	GE90-94B	599,983	461,143	440,000	118,125	4,210	09:27	20,929
LHR-AUS	787-8	Trent-1000-J	486,713	371,429	354,999	90,499	4,770	10:22	17,361
	787-8	GEnx-1B-70	489,835	372,068	354,999	90,499	4,756	10:16	17,731
	767-300ER	CF6-80C2B6	412,000	290,944	274,239	70,091	4,846	11:00	18,251
	A330-200	Trent 772C	513,677	378,552	359,685	86,312	4,794	10:43	20,260
	787-9	GEnx-1B-74/75	544,398	417,885	399,998	115,998	4,797	10:19	19,037
	787-9	Trent-1000-J	548,510	418,369	399,998	115,998	4,787	10:23	19,578
	A350-900	Trent XWB-84	577,982	442,579	423,388	114,641	4,763	10:17	20,325
	A330-300	Trent 772B	513,677	378,081	359,204	74,808	4,782	10:43	20,354
	777-200ER	GE90-94B	623,307	462,225	440,000	118,125	4,802	10:29	24,195
LHR-SAN	787-8	Trent 1000-J	500,360	370,787	354,999	90,499	5,276	11:26	19,499
	787-8	GEnx-1B-70	502,500	370,359	354,104	89,604	5,275	11:29	19,882
	767-300ER	CF6-80C2B6	412,000	280,005	264,349	60,201	5,382	12:09	19,890
	A330-200	Trent 772C	513,677	366,488	348,921	75,548	5,312	11:48	22,064
	787-9	GEnx-1B-74/75	559,264	417,136	399,998	115,998	5,342	11:25	21,372
	787-9	Trent-1000-J	559,998	414,610	397,052	113,052	5,322	11:26	21,859
	A330-300	Trent 772B	513,677	365,981	348,388	63,992	5,312	11:48	22,164
	A350-900	Trent XWB-84	590,839	439,703	421,397	112,750	5,293	11:20	22,677
	777-200ER	GE90-94B	642,020	461,262	440,000	118,125	5,331	11:35	27,136

Source: Lufthansa Systems' LIDO/Flight

Notes:
1). Lufthansa Systems provided block fuel figures in lbs. These have been converted to USG using 1 USG = 6.7lbs.

787-9, but nearly one foot narrower than the 777-200ER. The A350-900 is configured with nine-abreast seating in economy, whereas the 777-200ER could be configured in a nine- or 10-abreast layout.

In this analysis the A350-900 is configured with 15 more seats than the 777-200ER, but both types could be configured with very similar capacities, depending on the scenario.

Routes

Four transatlantic sectors were chosen for this analysis. LHR is the origin point for all four and the destinations are Baltimore (BWI), Atlanta (ATL), Austin (AUS) and San Diego (SAN). These airport-pairs were chosen since they include examples of hub-to-hub and hub to secondary city sectors; and the 787-8, 787-9 and A350-900 can be expected to serve both markets. The selection of routes also provides a good spread of sector lengths and allows an analysis of payload-range performance over longer distances.

The sector length for each airport-pair is stated in terms of the tracked distance and the equivalent still air distance. (ESAD). The tracked distance is governed by compliance with airway rules and restrictions. It can vary slightly by aircraft type depending on individual climb, cruise and descent profiles.

The ESAD is based on the tracked distance, but also takes into account the effect of en-route winds in extending or shortening the effective distance flown. It therefore considers the aircraft's airspeed, rather than ground speed, throughout the mission. If an aircraft experiences a headwind the ESAD will be longer than the tracked distance. If there is a tailwind the ESAD is shorter than the tracked distance. The available seat-miles (ASM) generated by each aircraft used in this analysis are based on the ESAD for each aircraft on each route.

All the aircraft operate a tracked distance of 3,200nm on LHR-BWI. They each experience a headwind on this sector. The average headwind component

FUEL BURN PERFORMANCE OF WIDEBODY AIRCRAFT ON TRANSATLANTIC ROUTES

City-pair	Aircraft variant	Engine variant	Available payload lbs	Available payload %	Pax capacity	Available cargo (lbs)	ASMs	Fuel burn USG per ASM	Fuel cost per ASM (cents)
LHR-BWI	787-8	Trent-1000-J	90,499	100%	228	32,245	819,432	0.0155	2.05
	787-8	GEnx-1B-70	90,499	100%	228	32,245	814,872	0.0159	2.10
	A330-200	Trent 772C	101,413	100%	248	38,051	898,504	0.0171	2.26
	767-300ER	CF6-80C2B6	90,850	100%	210	37,216	774,060	0.0184	2.43
	A350-900	Trent XWB-84	114,641	100%	293	39,786	1,051,577	0.0142	1.87
	787-9	GEnx-1B-74/75	115,998	100%	268	47,528	970,428	0.0144	1.90
	787-9	Trent-1000-J	115,998	100%	268	47,528	971,500	0.0148	1.95
	A330-300	Trent 772B	101,413	100%	274	31,422	997,634	0.0160	2.11
	777-200ER	GE90-94B	118,125	100%	278	47,101	1,013,032	0.0176	2.32
LHR-ATL	787-8	Trent-1000-J	90,499	100%	228	32,245	946,656	0.0158	2.08
	787-8	GEnx-1B-70	90,499	100%	228	32,245	941,868	0.0162	2.14
	A330-200	Trent 772C	100,935	100%*	248	37,573	1,038,376	0.0175	2.31
	767-300ER	CF6-80C2B6	83,339	92%	210	29,705	889,350	0.0185	2.44
	A350-900	Trent XWB-84	114,641	100%	293	39,786	1,215,071	0.0144	1.90
	787-9	GEnx-1B-74/75	115,998	100%	268	47,528	1,121,044	0.0147	1.94
	787-9	Trent-1000-J	115,998	100%	268	47,528	1,122,384	0.0151	1.99
	A330-300	Trent 772B	89,520	88%	274	19,529	1,147,512	0.0159	2.10
	777-200ER	GE90-94B	118,125	100%	278	47,101	1,170,380	0.0179	2.36
LHR-AUS	787-8	Trent-1000-J	90,499	100%	228	32,245	1,087,560	0.0160	2.11
	787-8	GEnx-1B-70	90,499	100%	228	32,245	1,084,368	0.0164	2.16
	A330-200	Trent 772C	86,312	85%	248	22,950	1,188,912	0.0170	2.25
	767-300ER	CF6-80C2B6	70,091	77%	210	16,457	1,017,660	0.0179	2.37
	A350-900	Trent XWB-84	114,641	100%	293	39,786	1,395,559	0.0146	1.92
	787-9	GEnx-1B-74/75	115,998	100%	268	47,528	1,285,596	0.0148	1.95
	787-9	Trent-1000-J	115,998	100%	268	47,528	1,282,916	0.0153	2.01
	A330-300	Trent 772B	74,808	74%	274	4,817	1,310,268	0.0155	2.05
	777-200ER	GE90-94B	118,125	100%	278	47,101	1,334,956	0.0181	2.39
LHR-SAN	787-8	Trent-1000-J	90,499	100%	228	32,245	1,202,928	0.0162	2.14
	787-8	GEnx-1B-70	89,604	99%	228	31,350	1,202,700	0.0165	2.18
	A330-200	Trent 772C	75,548	74%	248	12,186	1,317,376	0.0167	2.21
	767-300ER	CF6-80C2B6	60,201	66%	210	6,567	1,130,220	0.0176	2.32
	A350-900	Trent XWB-84	112,750	98%	293	37,895	1,550,849	0.0146	1.93
	787-9	GEnx-1B-74/75	115,998	100%	268	47,528	1,431,656	0.0149	1.97
	787-9	Trent-1000-J	113,052	97%	268	44,582	1,426,296	0.0153	2.02
	A330-300	Trent 772B	63,992	63%	250*	142	1,328,000	0.0167	2.20
	777-200ER	GE90-94B	118,125	100%	278	47,101	1,482,018	0.0183	2.42

Notes:
1). Remaining cargo payload excludes tare weight of lower deck containers/pallets.
3). A330-200 has minor payload restriction of less than 1% on LHR-ATL.
2). A330-300 limited to 250 passengers on LHR-SAN.

varies from 51 knots (kts) to 60 kts.

The ESAD ranges from 3,574nm for the GE-powered 787-8 to 3,686nm for the 767-300ER. The total taxi time on this sector is 32 minutes for each aircraft, based on an estimated taxi-out time of 20 minutes and a taxi-in time of 12 minutes. The alternate airport is Washington Dulles (IAD).

On LHR-ATL, the tracked distance is 3,699nm for all types. All of the aircraft experience headwinds. The average wind component varies from 51 to 58kts. The ESAD ranges from 4,131nm for the GE-powered 787-8, to 4,235nm for the 767-300ER. The total taxi time is 42 minutes, assuming a taxi-out time of 20 minutes and a taxi-in time of 22 minutes. The alternate airport is Birmingham, Alabama (BHM).

The tracked distance flown on LHR-AUS varies slightly between aircraft types. The shortest tracked distance is 4,320nm and the longest is 4,345nm. There is a headwind and the average wind component varies from 43kts to 49kts. The ESAD ranges from 4,756nm for the GE-powered 787-8, to 4,846nm for the 767-300ER. The total taxi time is 31 minutes, based on assumed taxi-in and taxi-out times of 20 minutes and 11 minutes. The alternate airport is Houston (IAH).

LHR-SAN is the longest sector with tracked distances of 4,808-4,817nm. Once again all aircraft experience a headwind with an average wind component of 43-49kts. The ESAD ranges from 5,275nm for the GE-powered 787-8, to 5,382nm for the 767-300ER. The total taxi time is 32 minutes, with a taxi-out allowance of 20 minutes and a taxi-in assumption of 12 minutes. The alternate airport is Ontario, California (ONT).

Performance

The block time and block fuel performance of each aircraft variant is summarised here across all four sectors *(see table, page 20)*. These data were extrapolated directly from the simulated flight plans. The analysis also summarises the payload-range performance and estimates each aircraft's fuel cost per ASM *(see table, page 22). Aircraft Commerce* has estimated the ASMs based on the assumed capacity figures used in this analysis. Different capacity assumptions will clearly influence the cost per ASM result.

The two 787-8s variants burn the least block fuel across the four transatlantic sectors, but the A350-900 demonstrates the lowest fuel cost per ASM on each route, due to the larger capacity of the A350-900, which allows it to generate more ASMs.

The 777-200ER burns the most block fuel on each sector, but has lower fuel costs per ASM than the smaller 767-300ER on the two shortest routes due its higher capacity.

A more thorough analysis was carried out to show comparable performance within the two size categories.

787-8, 767-300ER & A330-200

The two 787-8 variants burn the least block fuel in this category across all four sectors *(see table, page 20)*. They also demonstrate the lowest fuel burn per ASM, and therefore the lowest fuel costs per ASM *(see table, page 22)*.

The A330-200 burns the most block fuel across all four sectors. This is unsurprising given that the Airbus aircraft has the highest weight specifications in this category. Despite this, the A330-200 has lower fuel costs per ASM than the 767-300ER on each route due to its higher seat numbers.

On each of the four sectors the RR-powered 787-8 burns 2% less block fuel than the variant with GE engines.

The RR-equipped 787-8 uses 12-18% less block fuel than the A330-200, and 2-11% less than the 767-300ER across all four sectors. The GE-powered 787-8 uses 10-16% less block fuel than the A330-200. It also uses 3-9% less block fuel than the 767-300ER on the shortest three sectors but burns a similar amount of fuel on the LHR-SAN route. In both cases the 787-8's block fuel burn advantage decreases on the longest sectors of LHR-AUS and LHR-SAN.

The 787-8 with RR engines has the lowest trip costs in this category. These range from $16,773 on LHR-BWI, to $25,738 on LHR-SAN. The RR-powered 787-8's fuel trip costs are $311-506 lower than those of the GE-powered variant. The 767-300ERs trip fuel costs are $517-2,037 higher than those of the RR-powered 787-8. The trip fuel costs of the A330-200 are $3,387-4,267 higher than those of the RR-powered 787-8 across the four airport-pairs.

The Trent 1000-J-powered 787-8 has the lowest fuel costs per ASM on each sector. These costs increase with route length, and range from 2.05 cents per ASM on LHR-BWI to 2.14 cents per ASM on LHR-SAN. The RR-powered 787-8's fuel costs per ASM are 0.04-0.06 cents lower than those of GE-equipped variant. This is equivalent to 2% lower fuel costs per ASM on LHR-BWI, LHR-AUS and LHR-SAN and 3% less on LHR-ATL. The RR-powered 787-8's fuel costs per ASM are 0.07-0.23 cents lower than those of the A330-200 and 0.18-0.38 cents lower than those of the 767-300ER This is equivalent to 3-10% and 8-16% lower fuel costs respectively.

The GE-powered 787-8's fuel costs per ASM range from 2.10-2.18 cents. Its fuel costs per ASM are 6-14% less than those of the 767-300ER and 1-7% less than those of the A330-200.

The two 787-8s have the shortest block times on all four routes. The GE-powered aircraft has slightly shorter block times than the aircraft with RR engines.

The 787-8 with GE engines has block times ranging from seven hours and 55 minutes on LHR-BWI, to 11 hours and 19 minutes on LHR-SAN. It demonstrates block time savings of 5-7 minutes over the RR-powered 787-8, 22-29 minutes over the A330-200 and 39-50 minutes over the 767-300ER.

The 787-8's block fuel burn is 9-11% lower than the 767-300ER's on missions of up to about 4,200nm. The 787-8's advantage diminishes to 2-3% on longer routes. Similarly, the 787-9's block fuel burn is about 8% lower than the A330-200's on the shorter long-haul routes, but the 787-9 has a smaller advantage on longer sectors.

The disparity in block times can be partly explained by differences in LRC speeds. In this analysis the GE-Powered 787-8 had an assumed LRC speed of Mach 0.85 compared to LRC speeds of Mach 0.84, Mach 0.83 and Mach 0.80 for the RR-powered 787-8, A330-200 and 767-300ER respectively.

In addition to lower fuel burn and shorter block times, the two 787-8s also demonstrate superior payload-range performance to the A330-200 and 767-300ER. Both 787-8s are able to operate without payload restrictions on LHR-BWI, LHR-ATL and LHR-AUS. The GE-powered variant suffers a 1% payload restriction on the longest route from LHR-SAN but this only results in a small reduction in the payload available for cargo.

Although the A330-200 and 767-300ER are both able to operate with their maximum payloads on LHR-BWI, they each suffer from payload restrictions on the other sectors. The A330-200 suffers a very slight payload restriction of less than 1% on LHR-ATL, while the 767-300ER suffers an 8% payload restriction.

The A330-200 and 767-300ER operate with 15% and 23% payload restrictions on LHR-AUS. The A330-200 and 767-300ER are only able to operate at 74% and 66% of their maximum payload capability on the longest sector from LHR to SAN. Although both types would still be able to operate with a full passenger and baggage load, the remaining payload for cargo is restricted on the longer sectors.

The 787-8s offer the lowest potential payload for cargo on LHR-BWI when all four aircraft are able to operate without restrictions. The 787-8's superior payload-range performance means they offer more potential payload for freight than the A330-200 and 767-300ER on the two longer sectors.

787-9, A330-300, A350-900, 777-200ER

The two 787-9s burn the least block fuel in this category across all four sectors. Despite this, the A350-900 demonstrates the lowest fuel burn per ASM and therefore has the lowest fuel costs per ASM on each airport-pair. The A350-900 was assumed to have 25 more seats than the 787-9, and so the A350-900 generated more ASMs.

The 777-200ER is the heaviest aircraft in the analysis, and burns the most block fuel on all four sectors. It also has the highest fuel burn per ASM, and highest fuel costs per ASM in this size category. The 777-200ER's assumed capacity of 278 seats means that it had 15 fewer seats than the A350-900, 10 more than the 787-9 and only four more than the A330-300. The number of comparative ASMs it generates are therefore not enough to offset its higher block fuel burn.

On all four sectors the 787-9 equipped with GEnx-1B-74/75 engines burns slightly less fuel than the Trent 1000-J-powered variant. The GE-powered aircraft burns 3% less block fuel than the RR-powered variant on LHR-BWI, LHR-ATL and LHR-AUS, and 2% less on LHR-SAN.

The GE-powered 787-9 burns 6% less block fuel than the A350-900 on all four airport-pairs. It burns 21% less block fuel than the 777-200ER on each route, and 4-12% less than the A330-300. The RR-powered 787-9 burns 4% less block fuel than the A350-900 on each of the four sectors, and 19% less than the 777-200ER. It uses 1-10% less block fuel than the A330-300. Both 787-9s saw their block fuel burn advantage over the A330-300 decrease as sector length increased.

The A350-900 burns 16% less block fuel than the 777-200ER on all four sectors. It uses 7% less block fuel than the A330-300 on LHR-BWI, and 4% less on LHR-ATL. The A350-900's advantage over its smaller predecessor decreases with increasing sector length. On LHR-AUS, the two aircraft have equal block fuel burns; and the A350-900 actually uses 2% more block fuel on LHR-SAN.

The GE-powered 787-9 has the lowest trip fuel costs in this size category, ranging from $18,479 on LHR-BWI to $28,212 on LHR-SAN. This compares to trip fuel costs of $18,967-28,854 for the RR-powered 787-9, $19,660-29,934 for the A350-900, $21,048-29,256 for the A330-300 and $23,471-35,820 for the 777-200ER *(see table, page 20)*.

The A350-900 demonstrates the lowest fuel costs per ASM. These increase with sector length and range from 1.87 cents per ASM on LHR-BWI, to 1.93 cents per ASM on LHR-SAN. The A350-900's fuel costs per ASM are 0.03-0.04 cents lower than those of the GE-powered 787-9 on all four sectors, and 0.08-0.09 cents lower than those of the RR-powered 787-9. This is equivalent to 2% lower fuel costs per ASM than the GE-powered 787-9, and 4-5% less than the RR-powered 787-9. The A350-900's fuel costs per ASM are 6-12% lower than the A330-300's, and 19-20% lower than the 777-200ER's.

The GE-powered 787-9's fuel costs per ASM range from 1.90-1.97 cents. Its fuel costs per ASM are 0.05-0.06 cents lower than those of the RR-powered variant across the four sectors. This equates to a difference of 2-3%. The GE-powered 787-9's fuel costs per ASM are 5-11% lower than the A330-300's. It also demonstrates 18% lower fuel costs per ASM than the 777-200ER on all four routes.

The RR-powered 787-9's fuel costs per ASM vary from 1.95-2.02 cents. Its fuel costs per ASM are 16% lower than the 777-200ER's on all four sectors. In comparison to the A330-300, the RR-powered 787-9 demonstrates 2-8% lower fuel costs per ASM.

The A350-900 has the shortest block

The A350-900's efficiency is demonstrated by it having a 10% lower gross weight and 37% smaller fuel capacity than the 777-200ER, while the A350-900 has a 16-18% block fuel advantage and can match the 777-200ER is operating performance.

times in this size category, ranging from seven hours and 55 minutes on LHR-BWI, to 11 hours and 20 minutes on LHR-SAN. The 787-9s have the next shortest block times with the GE–powered aircraft, offering slightly shorter trip times than the RR-powered variant. The A330-300 has the longest block times.

The A350-900's block times are 2-5 minutes and 6-8 minutes shorter than those of the GE- and RR-powered 787-9s. The A350-900 also demonstrates 12-15-minute and 25-28-minute block time savings over the 777-200ER and A330-300. The GE-powered 787-9's block times are 1-4 minutes shorter than the RR-powered variant. It also has 9-10-minute and 21-24-minute shorter block times than the 777-200ER and A330-300. The RR-powered 787-9's block times are 5-9 minutes and 17-22 minutes shorter than those of the 777-200ER and A330-300.

The A350-900's LRC speed is Mach 0.85, compared to Mach 0.86 for the 787-9s. The A350-900 offers shorter block times than the 787-9s despite having a slower LRC speed. This is because it operates at different flight levels with reduced head winds. The A350-900's higher climb and descent rates may be a contributing factor in it ability to operate at different flight levels to the 787-9s. The 777-200ER and A330-300 have lower LRC speed of Mach 0.84 and Mach 0.83 which partly explains their longer block times.

The A350-900, both 787-9s and the 777-200ER are all able to operate on LHR-BWI, LHR-ATL and LHR-AUS without payload restrictions. The GE-powered 787-9 and 777-200ER are also able to operate without restrictions on the longest sector, LHR-SAN, but the A350-900 and RR-powered 787-9 suffer from small 2% and 3% payload penalties on this airport-pair. All four variants are able to operate with full passenger and baggage loads across each sector, while maintaining additional payload capacity for belly freight. The two 787-9s offer the most remaining payload for cargo on LHR-BWI, LHR-ATL and LHR-AUS, followed by the 777-200ER. The GE-powered 787-9 and 777-200ER offer the highest potential cargo payloads on LHR-SAN.

The A330-300 suffers from the highest performance penalties in this size category, and offers the least additional payload for cargo. Although the A330-300 operates with a maximum payload on LHR-BWI, it suffers from increasing restrictions on the other three airport-pairs as the sector length increases.

On LHR-ATL, it only has 88% of its maximum payload available and this decreases to 74% on LHR-AUS and 63% on LHR-SAN. It is able to operate with a full passenger and baggage load on the shorter three sectors while maintaining an increasingly limited capacity for additional cargo payload. The A330-300's available payload on LHR-SAN does not allow it to operate with a full passenger and baggage payload. According to the assumptions used in this analysis the A330-300 needs to be limited to 250 passengers on this sector, 24 fewer than the maximum assumed capacity. Even then it would have no additional payload available for belly freight. The restricted passenger payload increases the A330-300's fuel costs per ASM, since it reduces the number of ASMs it could generate. The weight specifications used for the A330-300 are not the highest currently available from Airbus. With higher certified weights the A330-300 may be able to operate on all four sectors without the same level of payload restrictions.

Summary

The new generation long-haul variants offer lower fuel burn and lower fuel costs per ASM compared to older generation types as expected. The improvement in fuel burn performance does not always approach the marketed 20% reductions, however.

The 787-8s use the least block fuel and have the lowest fuel costs per ASM in their size category. The RR-powered variant uses slightly less fuel than the GE-powered aircraft. The RR-powered 787-8's fuel costs per ASM are 2-3%, 3-10% and 8-16% lower than those of the GE-powered 787-8, A330-200 and 767-300ER.

The 787-9s use the least block fuel in their size category, but the A350-900 offers the lowest costs per ASM. The A350-900's fuel costs per ASM are 2%, 4-5%, 6-12% and 19-20% lower than those of the GE-powered 787-9, RR-powered 787-9, A330-300 and 777-200ER.

The GE-powered 787-9 burns 2-3% less block fuel than the RR-powered example.

The differences in performance between the RR- and GE-equipped 787-8s and 787-9s should be treated with some caution since there are a number of different engine specifications and thrust settings available and the analysis does not differentiate between OEWs to account for potential variations in engine weight.

The 787-8s, 787-9s and A350-900 all offer block time savings over the older generation aircraft. They also offer improved payload-range performance on longer sectors when compared to some older generation aircraft. The 787-8s have the highest remaining payload for cargo on the two longest sectors in their size class. The GE-powered 787-9 had the highest payload remaining for cargo on all four sectors in its size category. AC