

# **OPTIONS FOR ASSESSING THE CO<sub>2</sub> INTENSITY OF COMMERCIAL AIRCRAFT UNDER AN AIRFRAME STANDARD**

Dan Rutherford, Ph.D.  
International Council on Clean Transportation

## **ABSTRACT**

There is considerable interest within ICAO and member states regarding options to set CO<sub>2</sub> or GHG emission standards for commercial aviation. This paper identifies several possible carbon intensity metrics suitable for use in a CO<sub>2</sub> standard for new commercial airframes, and evaluates those metrics relative to simple design criteria. It demonstrates that previous inconclusive ICAO work on efficiency metrics, which was specific to in-operation aircraft, does not preclude the establishment of a CO<sub>2</sub> standard for new aircraft. Setting an airframe CO<sub>2</sub> standard should be less technically challenging than ongoing efforts to set equivalent standards for other transport modes, notably heavy-duty vehicles and oceangoing vessels, that have greater diversity of duty cycle and vocation.

## **INTRODUCTION**

The scientific and political consensus that substantial, rapid reductions in greenhouse gases (GHG) will be needed to avoid dangerous climate change grows stronger day by day. Despite the growing number of climate scientists arguing that radical action will be needed in the next decade to constrain the growth of GHG emissions worldwide, a CAEP review of four emission models suggests that emissions of carbon dioxide (CO<sub>2</sub>) and cruise nitrogen oxides (NO<sub>x</sub>) from aviation will approximately double from 2010 to 2025.<sup>1</sup> Immediate and responsible actions are required from governments and the International Civil Aviation Organization (ICAO).

Reflecting this urgency, since the summer of 2008 considerable interest has developed on options to set CO<sub>2</sub> or GHG emission standards for commercial aviation. ICAO's Group on International Aviation and Climate Change (GIACC) has requested technical input from ICAO technical bodies on this matter. International action on emission standards for aircraft has also been urged by agencies of member states. The UK Department for Transport (DfT) announced in January 2009 that it will seek an international CO<sub>2</sub> standard for aircraft to help mitigate increased GHG emissions from the expansion of Heathrow International Airport.<sup>2</sup> In the absence of ICAO action, domestic standards may instead be adopted, as demonstrated by US EPA's 2008 request for public comments on, among other measures, options for a GHG standard to be applied to aircraft engines, airframes, or airlines under the Clean Air Act.<sup>3</sup>

One prerequisite for a potential CO<sub>2</sub> standard for new commercial aircraft is a metric to compare the CO<sub>2</sub> intensity (hereafter referred to simply as "carbon intensity") of aircraft models. Some have suggested that previous ICAO work on efficiency metrics, which failed to identify a fuel efficiency parameter that sufficiently correlates with the performance of in-use aircraft or their engines, precludes the development of such a standard. This paper reviews options for a carbon intensity metric for new aircraft, in doing so demonstrating that, given sufficient priority by ICAO, a suitable metric could be developed to support an airframe CO<sub>2</sub> standard in the near future.

---

<sup>1</sup> GIACC/2-IP/2.

<sup>2</sup> "Hoon Outlines Air, Road and Rail Improvements to Boost Economy and Jobs." DfT News Release, 15 January 2009.

<sup>3</sup> Federal Register, Vol. 73 No. 147. 30 July 2008.

## CRITERIA FOR CO<sub>2</sub> INTENSITY METRICS FOR NEW COMMERCIAL AIRCRAFT

Fuel economy, and, increasingly, GHG emission standards have been important policy tools for governments to meet petroleum dependence and climate protection goals for the passenger vehicle sector. Standards are typically established for new vehicles only, with performance measured on a representative duty cycle that provides a degree of certainty that required improvements in new vehicles will translate to reductions in fuel use and emissions during actual operation.

More recently, efficiency and emission standards have begun to be considered for other transport modes, including two and three-wheelers and heavy-duty vehicles. International Marine Organization (IMO) work to develop a design index that could lead to a standard for oceangoing vessels is also well underway. In addition to selecting a representative duty cycle, policymakers must choose the metric, or unit of measurement, through which compliance with the standard is verified. Previous ICAO work, which failed to identify a suitable efficiency metric for in-operation aircraft, was confronted with greater complexities than work to define a carbon intensity metric for new airframes: notably, the need to estimate the efficiency of thousands or tens of thousands of aircraft with substantial diversity of form and function in real time. This paper demonstrates that an accurate and equitable carbon intensity metric can be identified for new, as opposed to in-operation, aircraft due to the much smaller numbers of models considered and through the identification of a simple representative test cycle.

To be useful in establishing a CO<sub>2</sub> standard for new aircraft, at a minimum a carbon intensity metric *should*:

- 1) Accurately characterize emissions per unit productivity (e.g. available ton kilometres, available seat kilometres, etc.) Where proxies for productivity are used, they should not provide a perverse incentive to “reduce” the carbon intensity of aircraft by taking actions that systematically increase emissions in actual use.
- 2) Provide “face validity” (be consistent with established industry experience). For example, it is well-understood that aircraft are most efficient when flown at stage lengths for which they are optimized, and that there are systematic differences in the efficiency of aircraft designed to operate over different flight lengths: for example, in general regional jets and long-range aircraft are less efficient than short and medium-range aircraft when operating over similar stage lengths. These differences should be made evident by a metric.
- 3) Recognize and reward technological progress. By definition, a CO<sub>2</sub> standard for new aircraft can only provide real emission reductions by spurring efficiency improvements in excess of what pure market forces would naturally provide. A metric should therefore recognize and reward technological progress in new aircraft models as they are brought into service.

A CO<sub>2</sub> intensity metric for new aircraft *need not*:

- 1) Provide a perfect correlation between the measured CO<sub>2</sub> intensity of new aircraft and their intensity in operation. Commercial aircraft can be modified in important ways following delivery. For example, an alteration of seating configurations that increases or decreases available seat kilometres on a given route may lead to a change in the environmental performance of an aircraft in-operation. A standard for new aircraft need not operate in isolation: where there is concern about differences

between test and operational intensity other measures may be adopted to address those differences.

- 2) Control for systematic differences in the emissions per unit productivity of aircraft serving different functions. Metric development and standard setting are related but independent tasks. All commercial aircraft regardless of size or designated range serve the same function: to move passenger and/or freight. A useful carbon intensity metric for aviation provides an objective means by which to compare emissions from various aircraft as a function of their productivity, without attempting to “control” for systematic differences in emissions owing to diversity in function. If necessary, these differences can be dealt with by setting separate standards for aircraft serving different, valued functions (“binning”). Binning under an aircraft standard is discussed further in Section 5.2.
- 3) Apply universally to all aircraft types. For example, a g/ASK metric may be appropriate for passenger aircraft, while a supplemental g/ATK metric could be developed for new dedicated freight aircraft.

## CANDIDATE CO<sub>2</sub> INTENSITY METRICS

One possible metric, a variant of which was previously considered in CAEP/6 as the basis for a revenue neutral emissions charge, is grams CO<sub>2</sub>/take off weight ton-km (g/TOW ton-km). Maximum TOW is considered by some as a useful proxy for payload capacity, and has the advantage of being a widely certified value that could be used to approximate capacity for in-operation aircraft in real time. As discussed in CAEP/6 IP/8, however, MTOW is of limited value in estimating efficiency in that MTOW assumes highly inefficient fueling patterns (i.e. maximum fuel loaded onto even short flights). TOW, defined here as maximum zero fuel weight (MZFW) plus the amount of fuel needed to fly a given route with adequate reserves, is more appropriate in defining aircraft efficiency or emissions. Here, we consider g/TOW ton-km as a carbon intensity metric, although it is likely to be of limited utility for use in a new airframe CO<sub>2</sub> standard because more direct measures of productivity such as ATK and ASK will be available for the more limited models and configurations under consideration.

A second possible carbon intensity metric would compare the relative emissions of aircraft on the basis of grams CO<sub>2</sub>/available tonne kilometre (g/ATK). ATK denotes the potential mass of payload that can be carried on an aircraft independent of load factor in use. A g/ATK metric could be readily used for both passenger and dedicated freight aircraft through the application of a mass conversion factor for passengers. A g/ATK metric could also be applied to new dedicated freighters alone even if it is judged as inappropriate for new passenger aircraft, although care would need to be taken to see that standard stringency is maintained across similar aircraft models being sold in both new passenger and freight applications.

The final metric considered in this paper is grams CO<sub>2</sub>/available seat kilometre (g/ASK). Much like ATK, ASK denotes the maximum number of passengers that can be carried on an aircraft independent of load factor in use. Reliance upon ASK for an airframe standard would likely require designating a reference seating arrangement.<sup>4</sup> A reference seating arrangement close to the maximum would likely be the best option; that seating could be based upon the FAA exit limit for a given aircraft. Alternatively, member states could designate a relatively shallow “reference pitch” for seats and estimate reference

---

<sup>4</sup> Since airlines can and do change seating configurations after sale, setting a g/ASK standard based upon actual configuration at time of sale could create a perverse incentive for manufacturers to maximize seat number in aircraft for delivery, with airlines reducing seats prior to use.

seating in that manner. How best to designate a reference seat number under a g/ASK standard is a key design question should be addressed before adopting such a metric under an airframe CO<sub>2</sub> standard.

## ANALYSIS AND RESULTS

To evaluate these metrics based upon the design criteria outlined in Section 2, the carbon intensity of two sets of aircraft totalling seventeen distinct models were compared using the proprietary aircraft analysis software Piano-X ([www.lissys.demon.co.uk/PianoX.html](http://www.lissys.demon.co.uk/PianoX.html)). Previous versions of Piano have been used in CAEP/6 work on efficiency metrics, and the model itself was extensively validated during the development of the EC's AERO2k emissions inventory.<sup>5</sup>

The first set of aircraft was used to evaluate the metrics according to the first and second design criteria. Aircraft were included in this set if they met one of three conditions: first, make a large contribution to global emissions inventories, as estimated the FAA's SAGE model and AERO2k; second, are representative of important aircraft types that make a modest contribution to total fuel burn (regional jets and turboprops); third, are indicative of future performance but not included in SAGE or AERO2k, notably the A380 and Boeing 787.

The wide variety of sizes and functions among these aircraft, combined with their relatively similar date of entry into service (EIS), means that a separate sample of aircraft was needed to test the sensitivity of carbon intensity metrics to technological progress. For this purpose, we chose six models of the Boeing 737 family of similar design range and with dates of entry into service spanning nearly forty years.

Piano-X was used to estimate fuel burn for each aircraft type. Default values were adopted for design weights, thrust, drag, and fuel flow. Aircraft were "flown" over representative routes, including landing and take off, at flight level 350 (300 for the Q300) and at speeds allowing for maximum range. Fuel reserves and allowances were set at 370 km diversion distance, 30 minutes holding time, and 5% mission contingency fuel for all aircraft. CO<sub>2</sub>/ATK was estimated through fuel burn with maximum payload (up to design distance, maximum zero fuel weight minus operating empty weight), while emissions per ASK were approximated by assigning 100 kg to each passenger to cover passenger weight and baggage. No additional allowance was made for belly freight.

Figure 1 and Figure 2 show the performance of selected aircraft on a g/TOW ton-km basis for medium to long-range aircraft and short-haul/regional aircraft, respectively. These figures demonstrate that the g/TOW ton-km metric does not perform well on two of the design criteria outlined above. First, g/TOW ton-km lacks "face validity" in that it falls continuously as a function of stage length: the farther a given aircraft flies, the less carbon intensive it appears. This violates two well understood facts: first, aircraft become inefficient (and therefore carbon intensive) at flight lengths beyond their design range; second, that, all things being equal, long-haul aircraft are more energy intensive than short-haul aircraft over shorter stage lengths. These problems arise because a g/TOW ton-km metric fails to discriminate between emissions generated productively – to carry payload (passengers or freight) – from emissions generated by lifting a heavy airframe or carrying large volumes of fuel. Since the purpose of commercial aviation is to move payload, the g/TOW ton-km metric violates a commonly held industry measure of productivity.

At a given level of technology, larger and heavier aircraft perform better on a g/TOW ton-km basis than do lighter aircraft. This is shown most clearly in Figure 4, which graphs MTOW versus the minimum value of the three metrics considered in this analysis for each of the short, medium, and long-haul jets

<sup>5</sup> See Evers, C.J. "AERO2k Global Aviation Emissions Inventories for 2002 and 2025." QinetiQ Ltd December 2004. pp. 59 to 76. Available at [http://www.aero-net.info/fileadmin/aeronet\\_files/links/documents/AERO2K\\_Global\\_Aviation\\_Emissions\\_Inventories\\_for\\_2002\\_and\\_2025.pdf](http://www.aero-net.info/fileadmin/aeronet_files/links/documents/AERO2K_Global_Aviation_Emissions_Inventories_for_2002_and_2025.pdf). Piano fuel burn and emissions estimates have also been used to develop the CORINAIR methodology, itself the basis for ICAO's carbon calculator, and in the Manchester Metropolitan University's FAST model.

summarized above in Table 1. To enable graphing all metrics together, the minimum value for a given aircraft – g/TOW ton-km in black, g/ATK in blue, and g/ASK in green – are each normalized to a reference aircraft, in this case the B737-800 (set at value = 100). In contrast to g/TOW ton-km, which declines as MTOW increases, the carbon intensity of aircraft on a g/ASK basis increases with MTOW as heavier airframes and more fuel carried reduces the relative payload available on larger aircraft. There is no clear correlation between MTOW and the carbon intensity of aircraft on a g/ATK basis.

Figure 4 suggests several that a CO<sub>2</sub> standard set on a g/TOW ton-km basis may have unintended consequences, for several reasons. At a minimum, a g/TOW ton-km standard would punish ongoing industry efforts to reduce airframe weight through the use of advanced composites. Moreover, a g/TOW ton-km standard could encourage compliance strategies that “reduce” the carbon intensity of a given aircraft model while increasing emissions in use. Two such strategies can be envisioned. First, a manufacturer may selectively market longer-range aircraft, which tend to perform better on a g/TOW ton-km basis. Second, manufacturers may increase the capacity of passenger aircraft to carry freight, which in turn boosts TOW by increasing operating empty weight and fuel mass carried.<sup>6</sup> Since air freight is approximately 20 times as CO<sub>2</sub> intensive as marine-based shipping,<sup>7</sup> an increase in belly freight capacity under an g/TOW ton-km standard has the potential to increase transport sector emissions by promoting modal shift from marine to aviation.

A g/TOW ton-km metric does perform well on the third design criteria: it clearly recognizes and rewards technological improvements (as typified by year of entry into service) as measured by the carbon intensity of the B737 aircraft family. As indicated in Figure 3, the g/TOW ton-km metric estimates an approximately 0.9% annual decrease in the carbon intensity of the B737 aircraft series over time.

Figure 5 and Figure 6 illustrate the performance of the selected aircraft on the g/ATK metric for medium to long-range aircraft and short-haul/regional aircraft, respectively. The carbon intensity of selected 737 aircraft on the g/ATK metric is shown as the blue line on Figure 3. In contrast to g/TOW ton-km, the carbon intensity of aircraft as measured on g/ATK is consistent with the understanding that there is a relationship between stage length and emissions. For a given aircraft, initially emissions per unit payload capacity decreases with stage length, as proportionately more time is spent at efficient cruise altitudes. Past a given point, but well before the design range, emissions per ATK increase gradually with stage length, as the need to “burn fuel to carry fuel” begins to impose an efficiency penalty. Past the design distance, fuel tank capacity has already been maximized, and the only way to increase flight length is by reducing payload: thus the rapid increase in emissions per unit payload capacity. In this manner, a g/ATK measure provides face validity in a manner that g/MTOW-km does not.

A poorly designed g/ATK metric may provide an incentive for manufacturers to reduce the apparent carbon intensity of passenger aircraft by boosting belly freight capacity, although to a somewhat lesser degree than g/TOW ton-km. Although the wide variation in function of aircraft included in this analysis make it difficult to detect in Figure 4, comparison of Figure 5 and Figure 7 shows that aircraft designed to carry large amounts of belly freight, notably the B777 and 787, appear to be disproportionately efficient when measured on a g/ATK basis. Because passengers require additional, weighty service equipment and occupy greater volumes than an equivalent mass of freight, a standard employing a g/ATK metric could provide an incentive for manufacturers to comply by increasing the belly freight capacity of passenger aircraft, in doing so leading to an aggregate increase in emissions in operation.

---

<sup>6</sup> As discussed below, a g/ATK standard may also promote belly freight, although less so than a g/TOW ton-km metric because it credits only the extra payload capacity and not the airframe weight and fuel mass required to support it.

<sup>7</sup> Buhaug, Ø. et.al. Updated Study on Greenhouse Gas Emissions from Ships: Phase I Report; International Maritime Organization (IMO) London, UK, 1 September, 2008.

The g/ATK does provide a good correlation between date of entry into service and carbon intensity (blue line on Figure 3) for the six models of the 737 family, although with the worst fit of the three metrics considered in this paper.

Figure 7 and Figure 8 illustrate the performance of the selected aircraft on the g/ASK metric for medium to long-range aircraft and short-haul/regional aircraft, respectively. The carbon intensity of selected 737 aircraft on the g/ASK metric is shown as the red line on Figure 3. Like g/ATK, aircraft CO<sub>2</sub> emissions as measured on g/ASK is consistent with our understanding of the relationship between stage length and efficiency, both for individual aircraft and across aircraft models. As noted above, the shift from a g/ATK metric to a g/ASK metric has reordered the relative carbon intensity of aircraft, with those aircraft designed to carry relatively small amounts of belly freight (A320-200 and B767-300ER, for example) faring better than proportionately heavier aircraft designed to carry greater freight. To the extent that policymakers believe that CO<sub>2</sub> emissions should be reduced from aviation while maintaining high levels of service for passenger traffic, a g/ASK metric may be judged as most appropriate for a CO<sub>2</sub> standard for passenger aircraft.

Even more so than on g/ATK, the carbon intensity of most aircraft (although not regional jets) remains close to constant over a surprising range of stage lengths shorter than the aircraft's design range. As described below, a similar stable relationship holds for the carbon intensity of representative aircraft at 100% load (what we have defined as ASK) and at lower loads. These relationships suggest that an airframe CO<sub>2</sub> standard set near the g CO<sub>2</sub>/ASK minimum for a given aircraft should reduce emissions in use.

Finally, the g/ASK metric is effective at reflecting and rewarding improvements in the efficiency of new aircraft over time. As shown as the red line on Figure 3, the g/ASK metric provides the best correlation between EIS of the 737 series and reductions in carbon intensity.

The discussion above suggests that two of the metrics (g/ATK and g/ASK) developed in this analysis may be suitable for use in setting a CO<sub>2</sub> standard for new commercial aircraft. A g/TOW ton-km metric, by failing to distinguish between emissions generated by moving heavier airframes and carrying excess fuel from those produced to move passengers and freight, could provide a perverse incentives for manufacturers to comply with a stringent standard by increasing design range and/or increasing freight capacity, in doing so increasing emissions in use. A g/ATK metric avoids the first problem but could also increase emissions from goods movement by passenger aircraft.

The g/ASK metric, while in need of further refinement, meets all of the key criteria set out in this paper for passenger aircraft: it incorporates a measure of productivity and does not provide perverse incentives to increase emissions, rewards technological progress, and is consistent with common industry experience.

## **APPLICATION OF CO<sub>2</sub> INTENSITY METRICS TO AN AIRFRAME CO<sub>2</sub> STANDARD**

Figure 5 and Figure 7 point to several important conclusions regarding the technical barriers faced in setting a CO<sub>2</sub> standard for new airframes. With the exception of regional jets, which make up a relatively small portion of overall aviation emissions, the carbon intensity of a given aircraft as measured on a g/ATK basis or g/ASK basis remains roughly constant across a broad range of stage lengths. A g/ASK carbon intensity metric in particular has a large "sweet spot" in which to target a standard. Assuming that airlines are proficient at matching aircraft to routes on the basis of efficiency, in the absence of radical redesigns a CO<sub>2</sub> standard set either at a reference stage length (say 70% of design distance), or based upon the minimum carbon intensity stage length for an aircraft will translate to predictable emission reductions in operation. Figure 9 and Figure 10, which show the correlation between the carbon intensity

of representative aircraft at lower loads with that at 100% loads (g/ATK and g/ASK, respectively), suggest that the same relationship holds for variations in load factor as well.

Systematic differences in the carbon intensity of aircraft under an airframe CO<sub>2</sub> standard could be handled in at least two different ways. First, separate standards can be set for less efficient aircraft types believed to serve valued functions, a practice generally referred to as “binning” in the literature on efficiency standards for road transport. Compared to other modes of transport, notably heavy-duty vehicles and ocean-going vessels, commercial aircraft could likely be covered under a relatively small number of bins. For illustrative purposes only, Figure 11 demonstrates how four representative aircraft (CRJ-200ER, B737-800, B767-300ER, and A380-800) may trace out possible stage length bins for a g/ASK standard for new passenger aircraft. Separate standards might also be set for new dedicated freighters, likely on a g/ATK basis. In comparison, Japan’s 2005 fuel economy standards for heavy-duty vehicles established 25 bins to cover its truck and bus fleet.<sup>8</sup>

Another approach, previously discussed by US EPA in the context of a domestic airframe GHG standard<sup>9</sup>, would be to set minimum, sales and activity-weighted intensity targets for individual airframe manufacturers. Given the relatively small number of aircraft delivered in a given year and the predictable relationship between the carbon intensity of most aircraft under reference conditions (i.e. at a defined stage length and 100% load) and in operation discussed above, an intensity target for airframe manufacturers falling faster over time than predicted technological trends should generate real reductions in operation.

A single sales and emissions-weighted target for manufacturers would have several advantages over a standard relying upon individual bins for aircraft. First, it would avoid the need to identify individual standards bin for aircraft types, an activity that policymakers may wish to avoid. Second, a well-designed single sales and activity weighted target would offer manufacturers maximum flexibility to adopt least-cost compliance strategies: carbon intensity could be reduced by adopting efficient technologies for a given aircraft type, by preferentially marketing and delivering aircraft optimized to fly at lower speeds and/or over more efficient stage lengths, by reducing the capacity to carry belly freight (in the case of a g/ASK standard for passenger aircraft), or other approaches as appropriate.

Whatever the exact metric and approach adopted, this analysis suggests that several carbon intensity metrics capable of supporting a CO<sub>2</sub> standard for new airframes exist and could developed with a reasonable level of effort. WG3 should consider clarifying the outstanding questions and design issues outlined above as part of a broader effort to recommend an airframe CO<sub>2</sub> standard during the CAEP/9 workcycle.

## CONCLUSIONS

This paper has identified at least two carbon intensity metrics (g CO<sub>2</sub>/ATK for dedicated cargo planes and g CO<sub>2</sub>/ASK for dedicated passenger aircraft) suitable for use in establishing a CO<sub>2</sub> standard for new commercial aircraft. In particular, the g/ASK metric, while in need of further refinement, meets all of the key criteria set out in this paper when applied to passenger aircraft: it incorporates a measure of productivity and does not provide perverse incentives to increase emissions, rewards technological progress, and is consistent with common industry experience. Analysis of representative aircraft responsible for the majority of the commercial aviation’s fuel burn suggests that, from the perspective of metrics, there are no technical barriers to setting a CO<sub>2</sub> standard for new aircraft. Diversity of function for various aircraft could be handled either by setting separate standards for different aircraft types, or by establishing a sales and activity-weighted intensity target for individual manufacturers.

---

<sup>8</sup> “Final Report of the Joint Study Group on Heavy-duty Fuel Economy Standards.” METI/MLIT. November 2005.

<sup>9</sup> Federal Register, Vol. 73 No. 147. 30 July 2008.

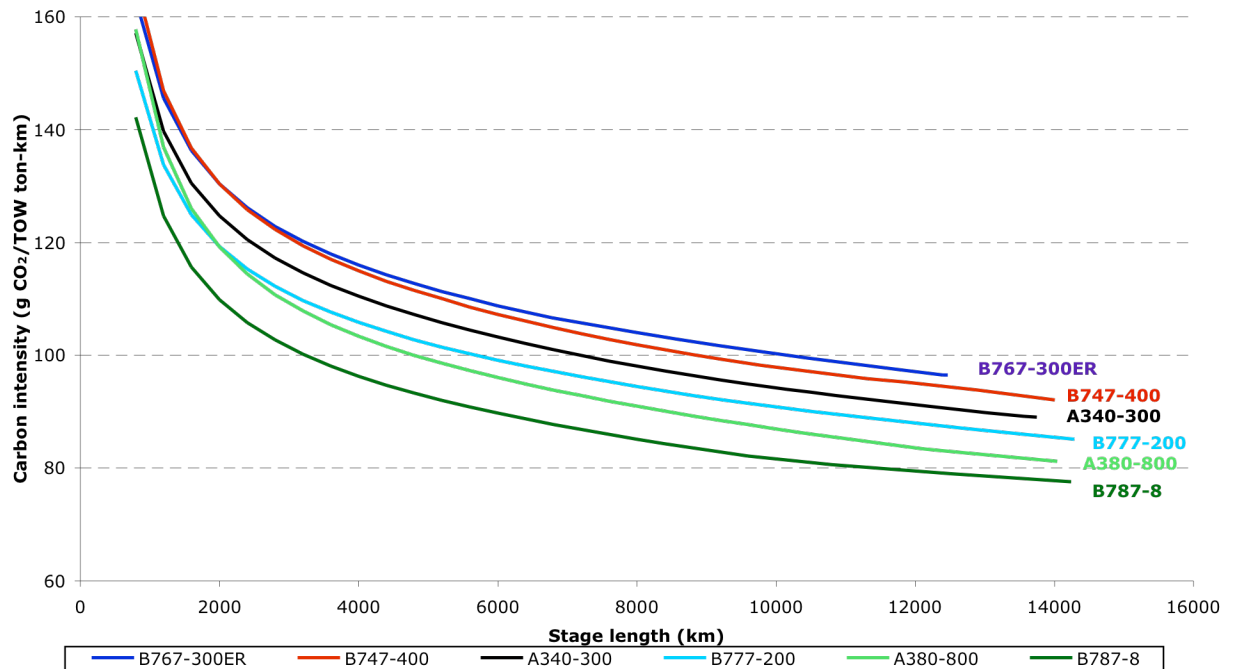


Figure 1: CO<sub>2</sub> emissions per TOW-km as a function of stage length (mid to long-range)

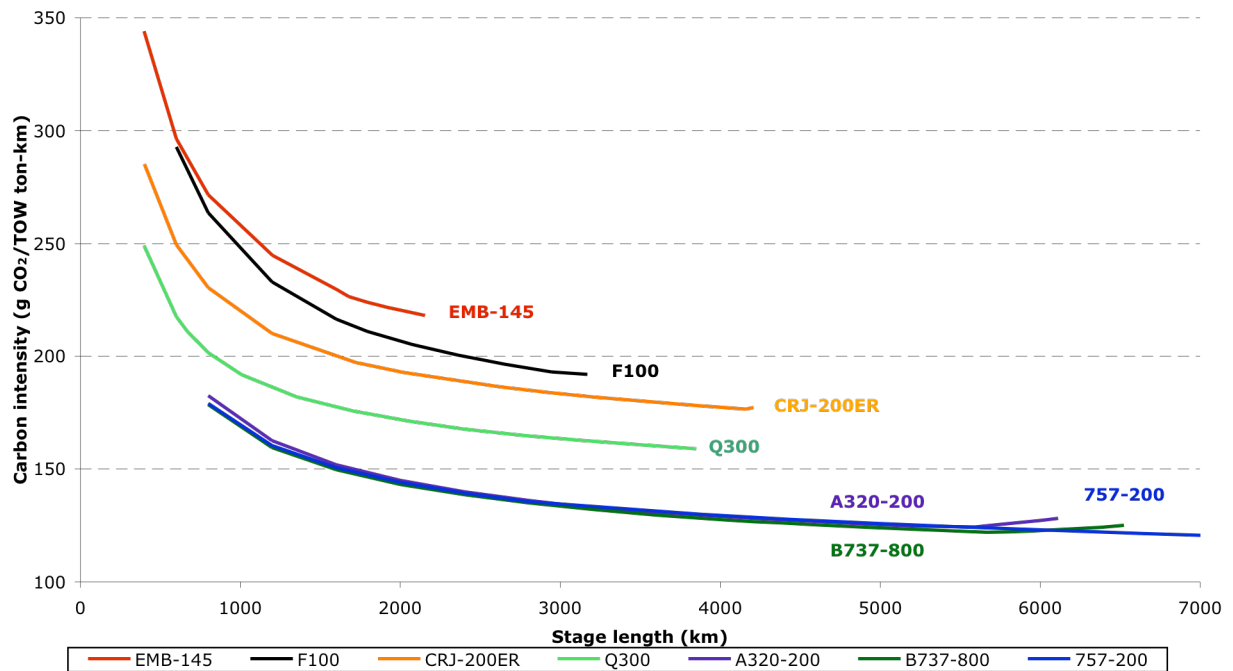


Figure 2: CO<sub>2</sub> emissions per TOW-km as a function of stage length (regional jets and short-haul)



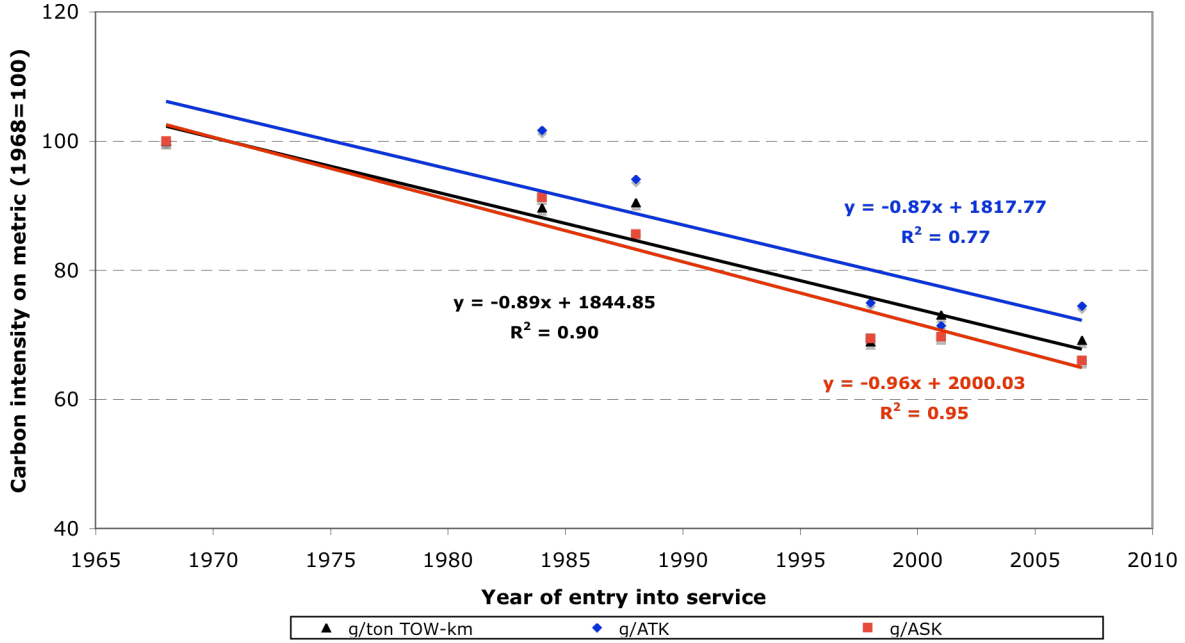


Figure 3: Year of entry into service vs. carbon intensity for various metrics

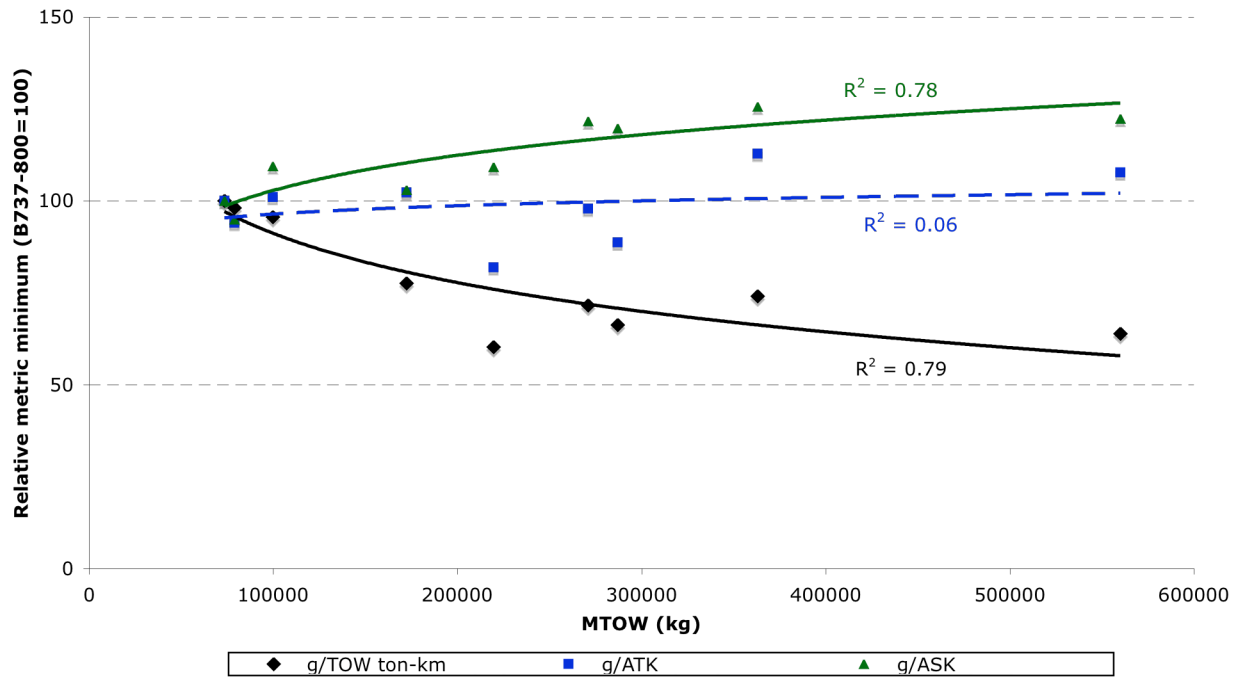


Figure 4: Maximum Take Off Weight vs. Analyzed Metric for Short, Medium, and Long-Haul Jets

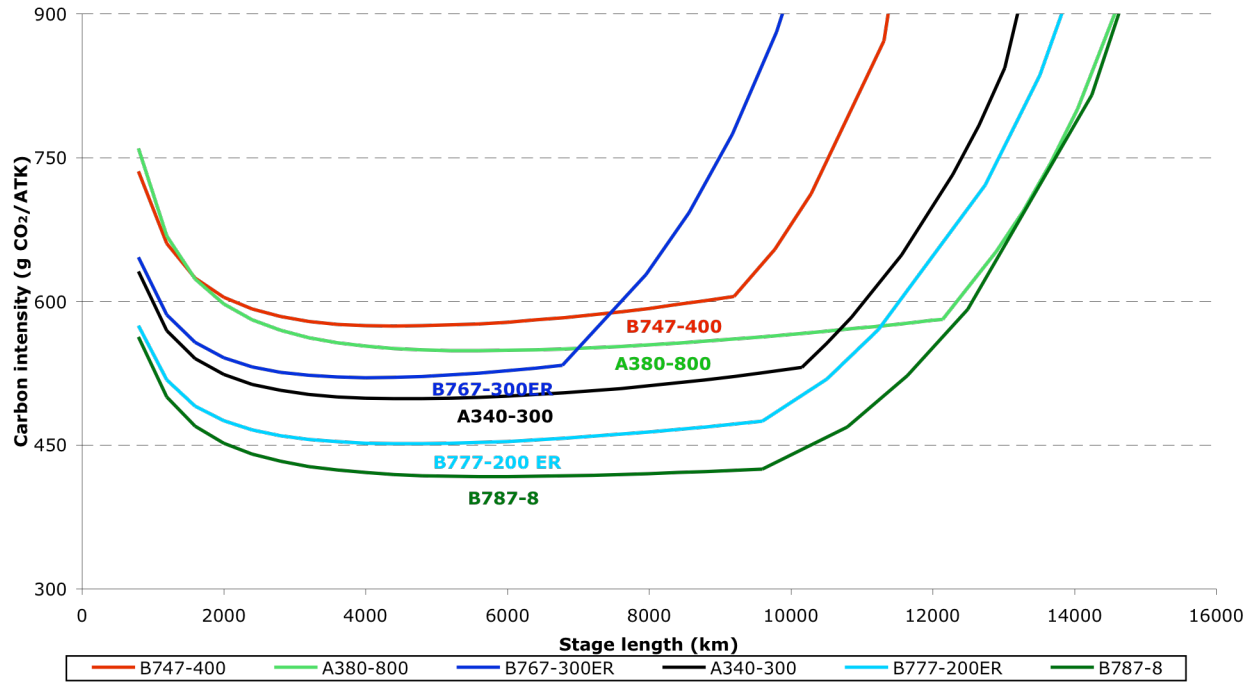


Figure 5: CO<sub>2</sub> emissions per ATK as a function of stage length (mid to long-range)

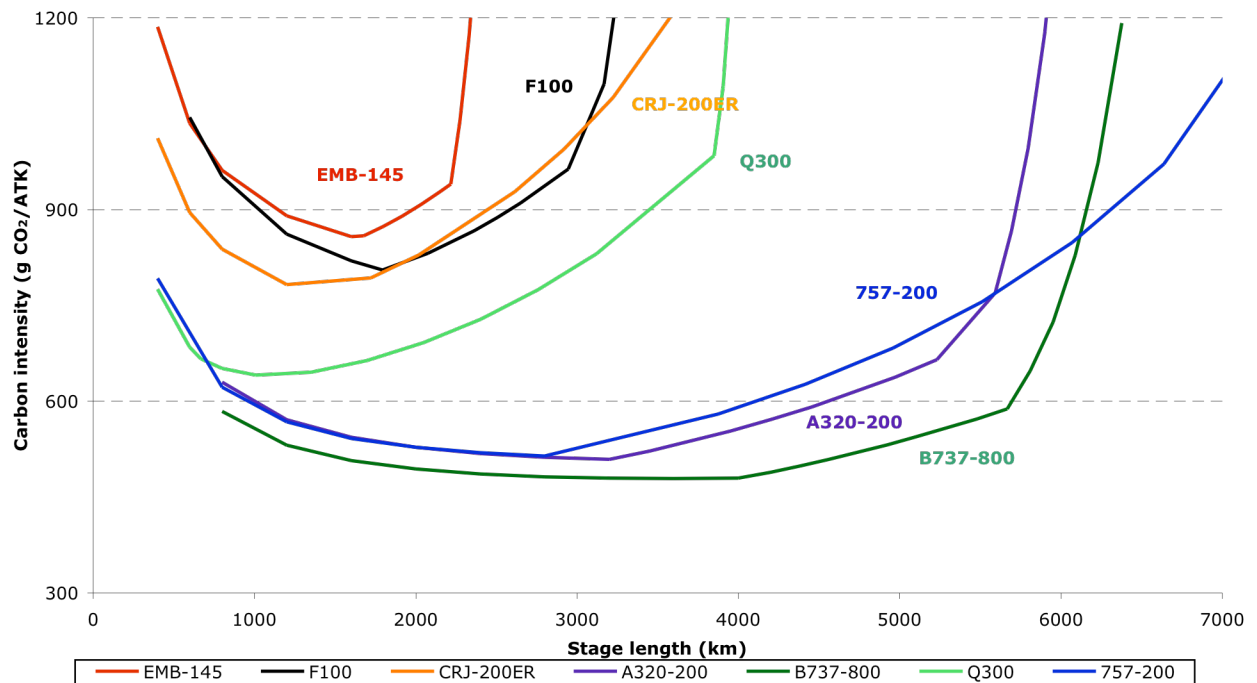
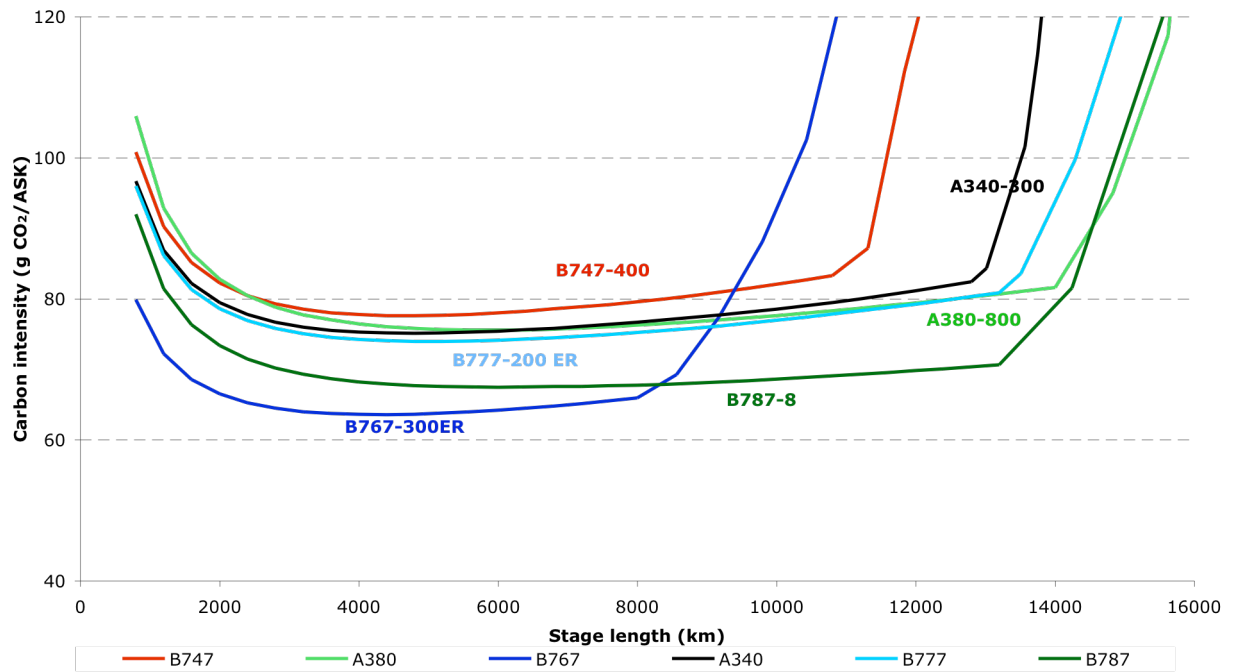
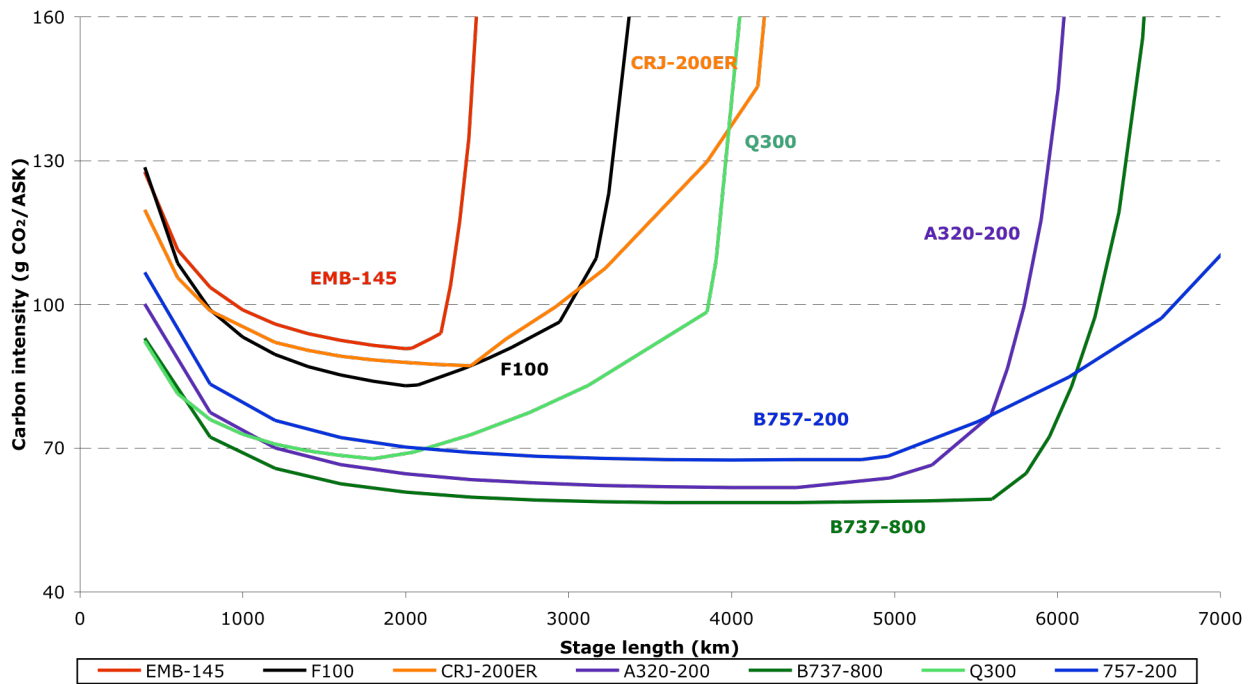


Figure 6: CO<sub>2</sub> emissions per ATK as a function of stage length (regional jets and short-haul)



**Figure 7: CO<sub>2</sub> emissions per ASK as a function of stage length (mid to long-range)**



**Figure 8: CO<sub>2</sub> emissions per ASK as a function of stage length (regional jets and short-haul)**

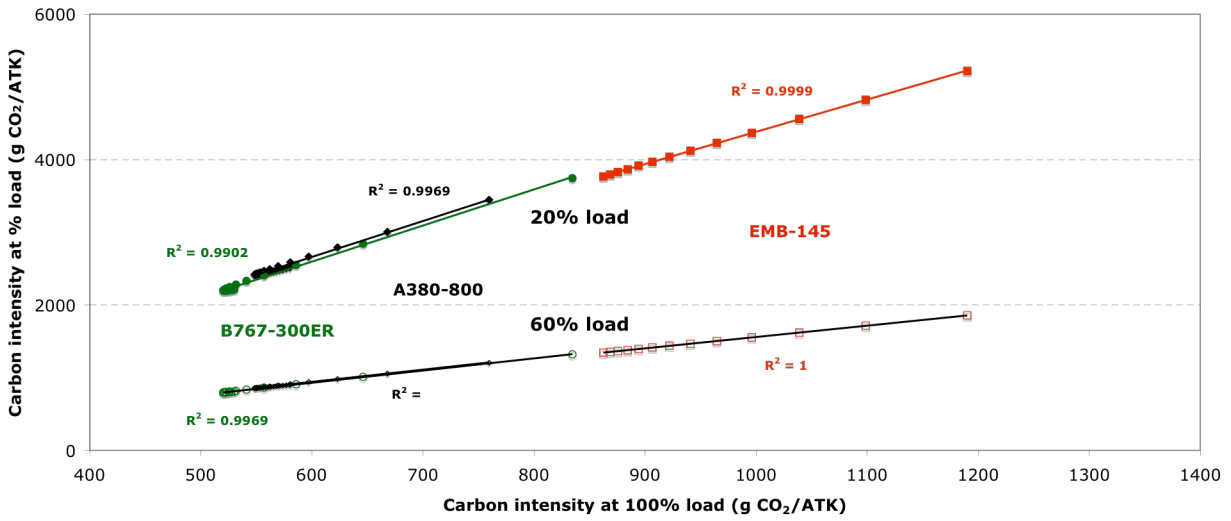


Figure 9: g/ATK intensity at 100% load vs selected loads for three aircraft at subdesign range stage lengths

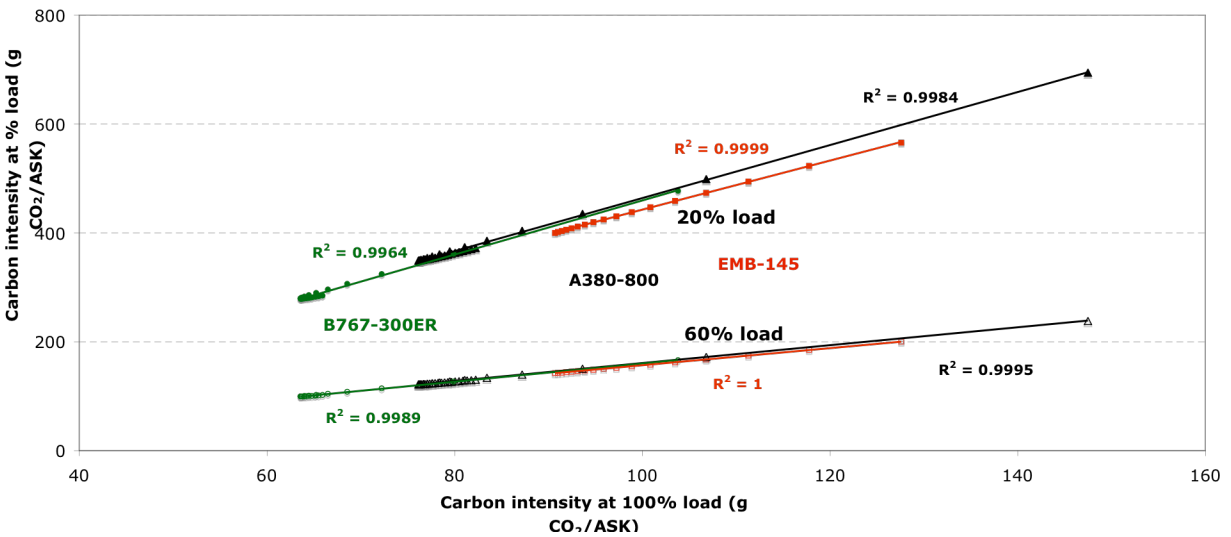


Figure 10: g/ASK intensity at 100% load vs selected loads for three aircraft at subdesign range stage lengths

