POLICY UPDATE

AUGUST 2013

INTERNATIONAL CIVIL AVIATION ORGANIZATION'S CO_2 CERTIFICATION REQUIREMENT FOR NEW AIRCRAFT

ICCT **POLICY UPDATES** SUMMARIZE REGULATORY AND OTHER DEVELOPMENTS RELATED TO CLEAN TRANSPORTATION WORLDWIDE.

In February 2013, ICAO's environmental committee finalized a CO_2 certification requirement to serve as the basis for a global CO_2 (efficiency) standard for new aircraft. Under the requirement, the CO_2 intensity of new aircraft will be evaluated at three steady-state cruise test points, with aircraft required to meet efficiency targets set as a function of their maximum takeoff mass (MTOM) after correcting for the floor area of the aircraft. This approach is expected to rank the CO_2 intensity of new commercial aircraft in proportion to emissions per seat kilometer flown, can be used to set a standard via a single continuous line, and should be inexpensive for manufacturers to certify as it is patterned on existing data gathering practices. Disadvantages of the procedure include its failure to measure non-cruise fuel burn, the use of flight conditions unrepresentative of day-to-day operations, providing no direct crediting for lightweight materials, and uncertainty about whether some future technologies to reduce fuel burn will be accurately characterized under the procedure.

CO_2 CERTIFICATION REQUIREMENT

Following three years of work, the International Civil Aviation Organization's (ICAO) Committee for Environmental Protection (CAEP) finalized a carbon dioxide (CO_2) certification requirement, including metrics, fuel efficiency test points, and detailed certification procedures, to be added as a new volume to Annex 16 of ICAO's Convention on International Civil Aviation. The certification procedure describes how manufacturers should measure and report the CO_2 intensity of new aircraft to certificating authorities, and will serve as the basis for a global CO_2 (efficiency) standard for new aircraft when finalized.

The bulk of work on the certification requirement was devoted to developing a suitable metric system for the standard. Salient features of that system include:

1. A metric of 1/[SAR], divided by a proxy of aircraft floor area raised to an exponent of 0.24, by which CO_2 emissions intensity will be reported.
2. A scaling factor of maximum takeoff mass (MTOM) to assign regulatory targets to individual aircraft types.

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3. Three equally weighted steady-state test points, representing high, medium, and low gross weights, at which the efficiency of each aircraft type will be evaluated.

Further information regarding each of these components is provided below.

METRIC

Specific air range, or SAR[1], is a commonly used metric in the aviation industry to measure cruise fuel burn. SAR is typically measured in units of km traveled per kg of fuel, and was inverted for the purposes of the certification requirement such that a reduction in the CO_2 intensity of an aircraft would be reflected as a reduction in the metric score.

Because SAR does not directly measure fuel burn in flight segments other than cruise, and because it is sensitive to operating conditions such as altitude and cross sectional area, a metric of 1/SAR alone would provide disproportionately good scores to certain aircraft types, notably business jets and long-range aircraft, relative to those that operate at lower altitudes and/or are built to handle larger payloads. To correct for this, the fuel efficiency of aircraft certified to ICAO's CO_2 standard will be reported as 1/SAR divided by a reference geometric factor (RGF), which approximates the length of the pressurized fuselage times its maximum width, raised to the power of 0.24.[2] The RGF correlates with seating area for passenger aircraft as well as cargo volume, and somewhat improves the crediting of technologies to reduce aircraft empty weight (e.g. lightweight composites). Reflecting the importance of stretched and shrunk versions of base aircraft (the A321, A319, and A320, respectively), this metric is intended to position aircraft variants within a given family such that they will have approximately the same margin or deficit relative to an eventual stringency line.

SCALING FACTOR

Aircraft serve various applications and are manufactured in a variety of size classes, with both factors influencing fuel efficiency. Furthermore, because ICAO's standard will cover a large range of commercial and general aviation aircraft – turbofan aircraft above 5700 kg MTOM and turboprops above 8618 kg MTOM up to superjumbo aircraft such as the A380 at 560,000 kg – it was necessary to devise a means by which to assign regulatory targets to a wide range of aircraft sizes.

One of two approaches are generally adopted by policymakers to assign targets to vehicles or manufacturers under fuel efficiency standards: binning, under which separate standards are set for different vehicle types or sizes, or a scaling factors, which uses a vehicle parameter such as size or weight to represent vehicle productivity. Following extensive discussions, ICAO selected MTOM[3] as a scaling factor for the CO_2 certification requirement. MTOM serves as a general proxy for aircraft productivity across the wide range of aircraft to be covered under the standard, including general aviation aircraft, turboprops, and commercial passenger and freighter aircraft.

1 SAR, a measure of an aircraft's cruise performance, is a function of an aircraft's true air speed, its gross weight and aerodynamic characteristics, and the fuel consumption of its engines.

2 For double decker aircraft such as the 747 and A380, RGF is derived by adding the floor area of the upper deck to the shadow area of the pressurized fuselage.

3 MTOM, which is the aircraft approximate of gross vehicle weight for road vehicles, is the sum of the maximum aircraft empty weight, payload, and fuel allowed at takeoff.

TEST POINTS

After controlling for environmental factors such as winds, ambient temperature, transient pressure variations, etc., the specific air range of a given aircraft is determined by three operating conditions – gross weight, cruise speed, and pressure altitude. These three conditions thus define the test points for ICAO's CO_2 standard. Under the new certification requirement, the CO_2 intensity of new aircraft will be evaluated at three gross weight test points at optimal speeds and and altitudes[4]:

1. High weight test point: 0.92 x MTOM
2. Mid-weight test point: Average of high and low
3. Low weight test point: $(0.45 \times MTOM) + (0.63 \times (MTOM^{0.924}))$

Manufacturers will report a composite metric score for each airframe/engine combination based upon a simple average of the individual metric score $(1/[SAR*RGF^{0.24}])$ at each gross weight test point. The use of multiple test points, rather than a single steady-state point, will require that efficient cruise be demonstrated at multiple cruise conditions (altitude and/or speed), and is meant to help guard against aircraft designs that are optimized for a single cruise point at the sacrifice of fuel efficiency at other, potentially more common, points in its operational envelope.

Figure 1 shows the range of pressure altitudes at which the CO_2 emissions intensity of representative aircraft types would be tested under the standard. In the figure, lines denote the range of low and high pressure altitudes for certification, corresponding to high and low gross weights, respectively, while solid points indicate aircraft types for which data will be collected at the same altitude for all three test points. Commercial turbofan aircraft – regional jets in purple, single aisle aircraft in red, and twin aisle aircraft in black – will have their CO_2 intensity measured at between 30,000 and 42,000 feet, while business jets, which are designed to cruise at higher altitudes, will be tested above 40,000 feet. Service ceiling limited aircraft, notably turboprops but also some smaller business jets, would have their CO_2 intensity certified at a single pressure altitude but multiple cruise speeds, which are not shown in the diagram.

4 Under the certification procedure, manufacturers will be allowed to choose the speed and altitude that their aircraft are tested at for each gross weight. Presumably, manufacturers will select optimal conditions and certify aircraft at its best SAR value, or 100% maximum SAR.

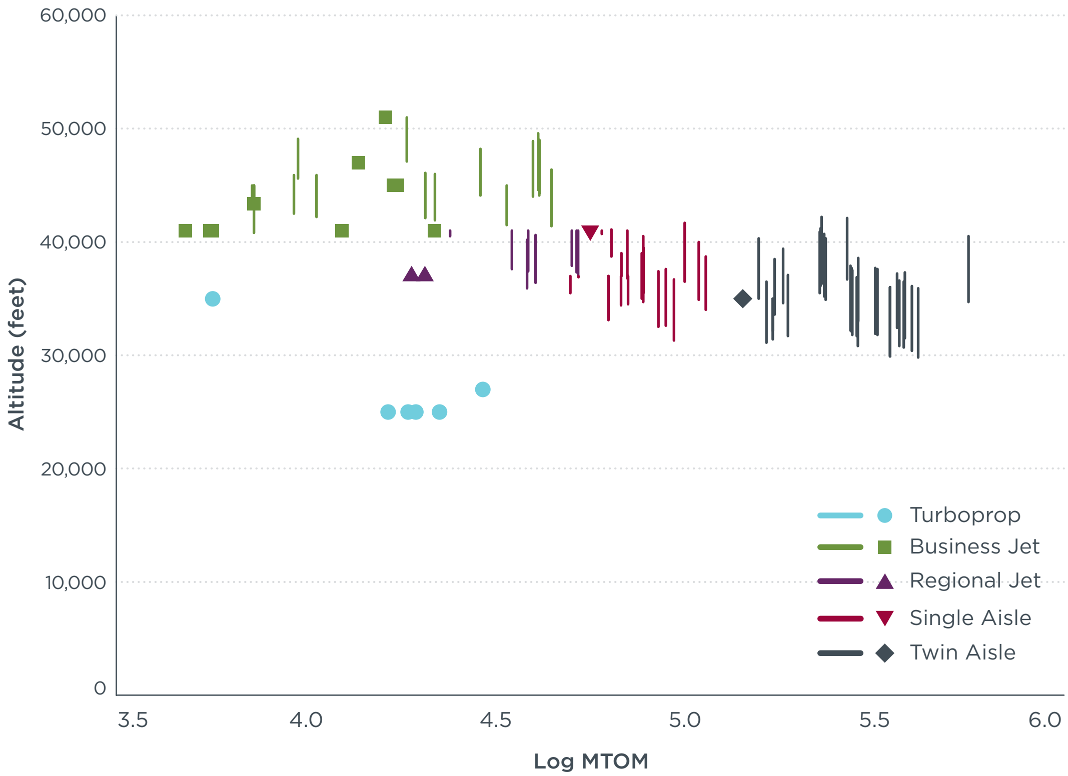

Figure 1: Pressure altitudes for CO_2 intensity testing
Source: ICCT, using PIANO-X database.

Figure 2 plots metric scores for representative in-production (blue) and older out of production (red) aircraft types as a function of their MTOM. As the blue and red regression lines on the figure demonstrate, the metric system is able to distinguish between different aircraft generations, a key test for a metric system designed to promote efficiency technologies. Over time, as technology advances and the standard becomes more stringent, the standard line will fall and flatten out, as demonstrated by the different between the in- and out-of-production lines in Figure 2.

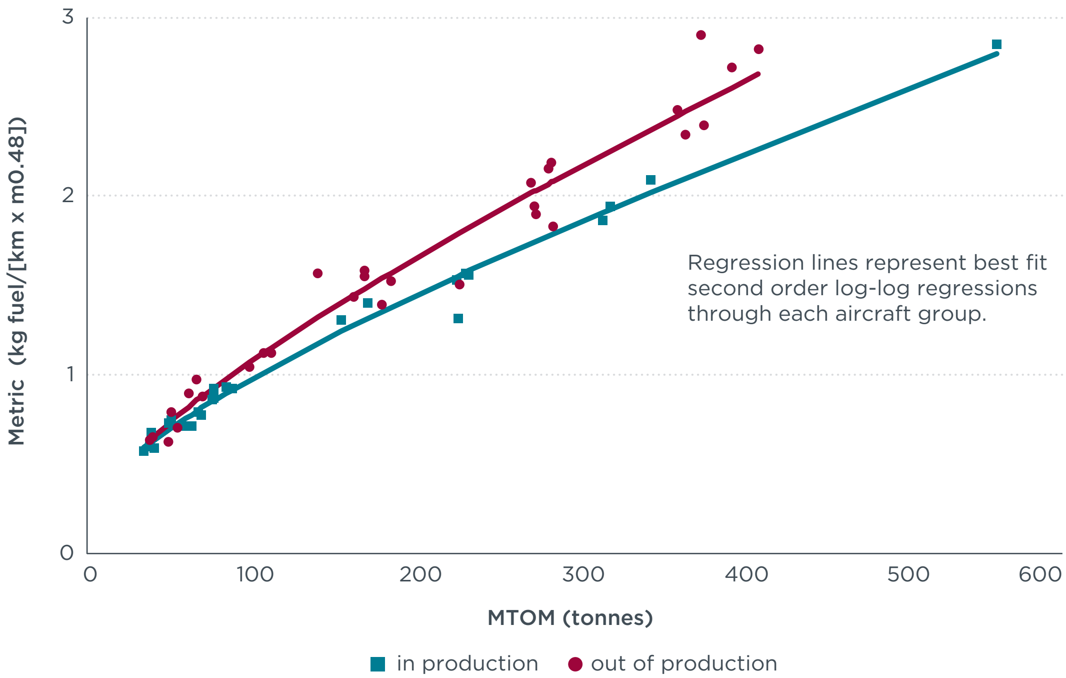

Figure 2: Metric scores for relevant in and out-of-production aircraft
Source: ICCT, using PIANO-X database.

In addition to technology, this metric system provides the potential for manufacturers to comply with CO_2 requirements through non-technical means, notably changes in certified MTOM. Because many operational expenses, including airport landing fees and en route charges, are levied as a function of MTOM, manufacturers today typically sell a given aircraft model under various MTOMs ("paper" variants), corresponding to differing nominal payload-range capabilities. This allows airlines not requiring an aircraft's maximum payload-range capability to reduce operational expenses by purchasing a lower MTOM variant.

Under ICAO's CO_2 certification requirement, low MTOM variants of most aircraft will score better on the standard than higher MTOM variants. This is demonstrated in Figure 3, which shows the in-production aircraft data presented in Figure 2 between 200 to 400 tonnes MTOM along with dotted lines representing a 10% MTOM "paper" reduction for two aircraft types. As the figure shows, the slope of the lines denoting the MTOM paper change is steeper than that of the overall fleet regression line, meaning that a manufacturer can increase the margin of a given aircraft type to the standard through a MTOM paper reduction.

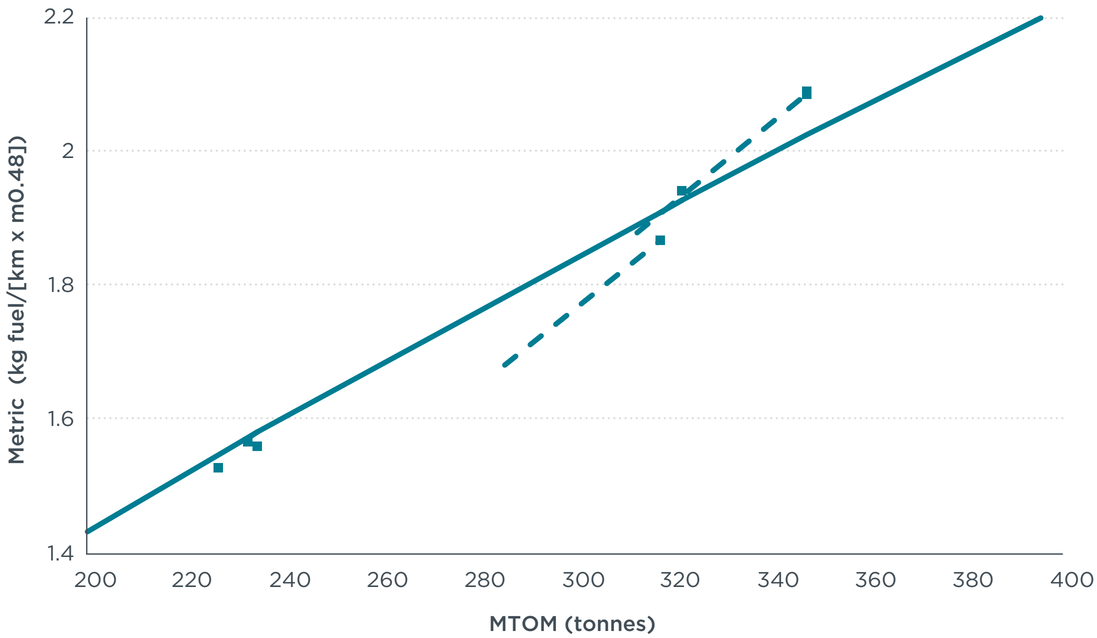

Figure 3: MTOM "paper" changes under a CO_2 standard

For this reason, it will be possible for manufacturers to make aircraft comply with the CO_2 standard without incremental investments in fuel efficiency technology by lowering the range of MTOMs at which they are marketed. These lower paper MTOM variants, while nominally complying with the standard, will have identical emissions to higher, non-compliant MTOM variants when used in service. As a rule of thumb, a 5% paper MTOM reduction, which would have marginal impacts on revenue and aircraft values, should provide an additional 1.5% margin to a standard.

ANALYSIS

ICAO's CO_2 certification requirement has certain merits. As noted above, the metric system is capable of distinguishing different aircraft technology levels, and is expected to rank the efficiency of commercial aircraft, which are responsible for the vast majority of civil aviation fuel use and CO_2 emissions, in rough proportion to emissions per seat kilometer flown. This is important because the latter quantity is not certifiable since the number of seats on a given aircraft is determined by an airline, not the manufacturers. The metric system can be used to set a CO_2 standard via a single continuous line, reducing the opportunity for gaming through means such as corner effects or reclassifying a given aircraft as a different type in order to gain access to a weaker standard. Finally, it should be inexpensive for manufacturers to certify their aircraft to the standard because the certification requirement is built upon industry practices already used by manufacturers to collect fuel burn data for airlines.

The metric system displays certain shortcomings, notably:

1. *Failure to measure non-cruise fuel burn:* Since SAR does not directly measure fuel consumed in non-cruise flight segments – landing and takeoff, taxi, climb and descent – technologies such as electric taxi or more efficient auxiliary

power units that reduce fuel burn on those flight segments will not be promoted by the standard.

2. *Unrepresentative of day-to-day operations:* Aircraft are typically operated at off-optimal flight conditions, meaning that the fuel efficiency test points identified above are not representative of typical operations, particularly for service ceiling limited aircraft such as turboprops and some regional jets. This divergence of test conditions from real operations means that improvements measured on the metric may not necessarily translate to real emission reductions in-service.
3. *No direct crediting of lightweight materials:* Since the empty weight of the aircraft is never defined in the certification requirement, ICAO's CO_2 standard will provide only limited, indirect incentives for technologies to reduce aircraft weight, notably lightweight composites.
4. *Concerns about "futureproofing"*: The RGF factor, which helps normalize efficiency scores across various aircraft types, was developed based upon empirical comparisons between today's business jets, turboprops, and turbofan aircraft, not an assessment of future technologies. It unclear whether this metric system will be appropriate for future aircraft with radically different engine or airframe architectures, including open rotor engines and, more speculatively, blended-wing body configurations.

OTHER CAEP/9 DECISIONS

In addition to the CO_2 certification requirement, the following decisions were also reached at the CAEP/9 meeting relevant to the CO_2 standard:

1. ICAO's traditional definition of technological feasibility (technology readiness level of 8 or greater, reflecting technologies that are already flight demonstrated) will be used to set the level of the standard.
2. Since fuel price already creates a baseline incentive for technology improvement, CAEP reaffirmed that the CO_2 standard should generate emission reductions beyond that which would occur in the absence of a standard.
3. The CO_2 standard will apply to new applications for aircraft type certifications beginning in 2020 or 2023, subject to further evaluation of cost effectiveness. Since it typically requires four to five years after the application for a new type certificate for an aircraft to entry into service, this implies that the CO_2 standard will apply to new aircraft designs entering into service in the 2024 to 2028 timeframe.
4. CAEP confirmed that the CO_2 standard will be implemented as a pass/fail requirement for individual aircraft types, without the option of emissions averaging at the manufacturer level.
5. Further analysis will be required to determine what requirements, if any, will be established for new deliveries of previously certified aircraft ("new in-production aircraft").
6. Due to delays in finalizing the certification procedures, ICAO is expected to finalize the CO_2 standard in late 2015, rather than 2013 as originally anticipated.