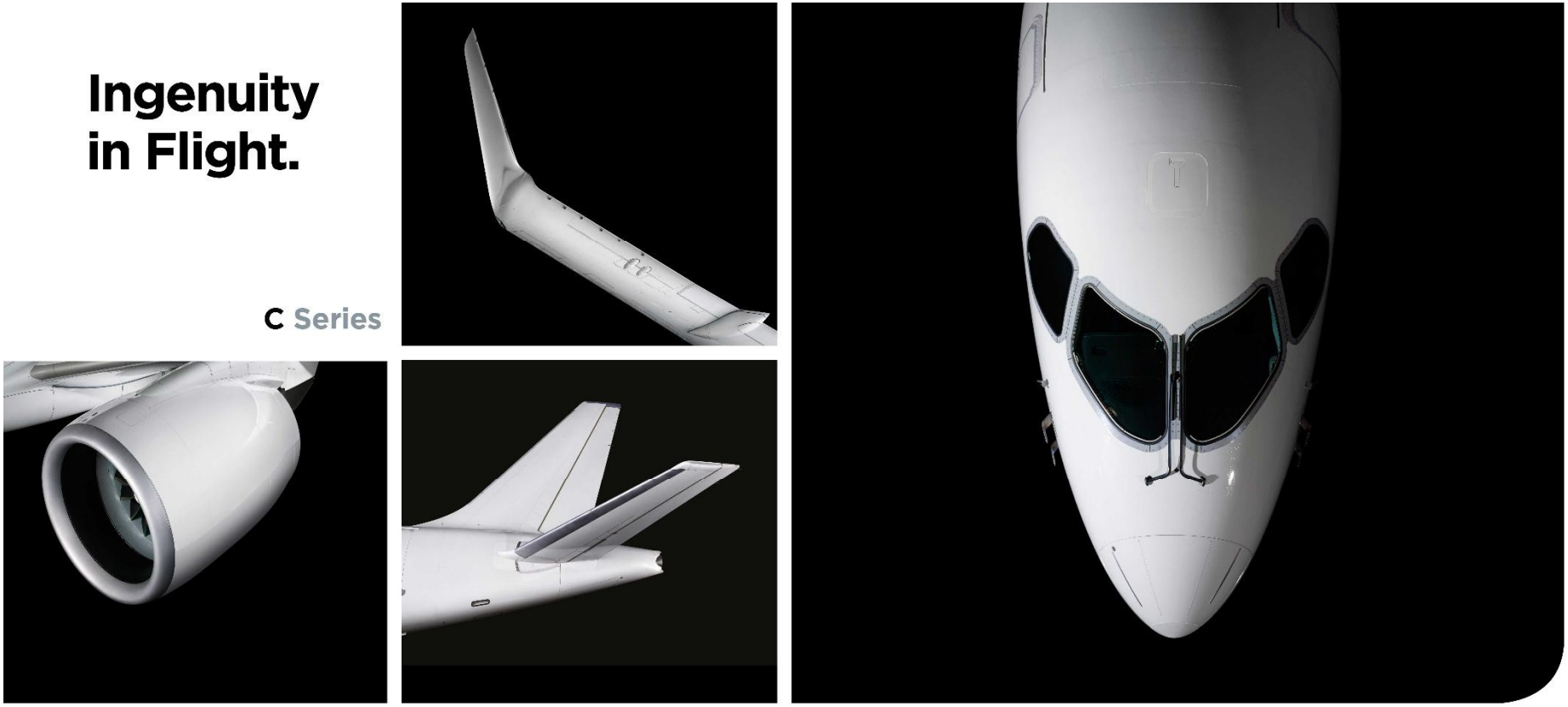

The CS100 EPD® the first-ever Environmental Product Declaration in the aerospace industry

Miguel Garcia Claro, MS., ADIQ, EP,
Eco-Design and Environmental Affairs
Bombardier - Product Development Engineering, Aerospace

National Colloquium on Sustainable Aviation
University of Toronto Institute for Aerospace Studies (UTIAS)
Toronto, May 21, 2017

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About Bombardier

The world's leading manufacturer of trains and planes

INNOVATION IS PART OF OUR DNA

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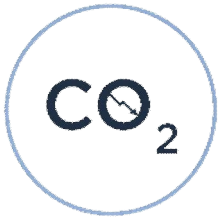
Aviation committed to reduce CO_2 by 2050



OBJECTIVE 1

Reduce CO_2 emissions by 50% by 2050, relative to 2005

OBJECTIVE 2

Improve fuel efficiency by 1.5% per year from 2010 until 2020

OBJECTIVE 3

Achieve carbon-neutral growth by 2020

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Objectives to be met by following an improvements roadmap

IMPROVED TECHNOLOGY
(including alternative fuels)

MORE EFFICIENT AIRCRAFT OPERATIONS

INFRASTRUCTURE IMPROVEMENTS

GLOBAL MARKET-BASED MEASURES

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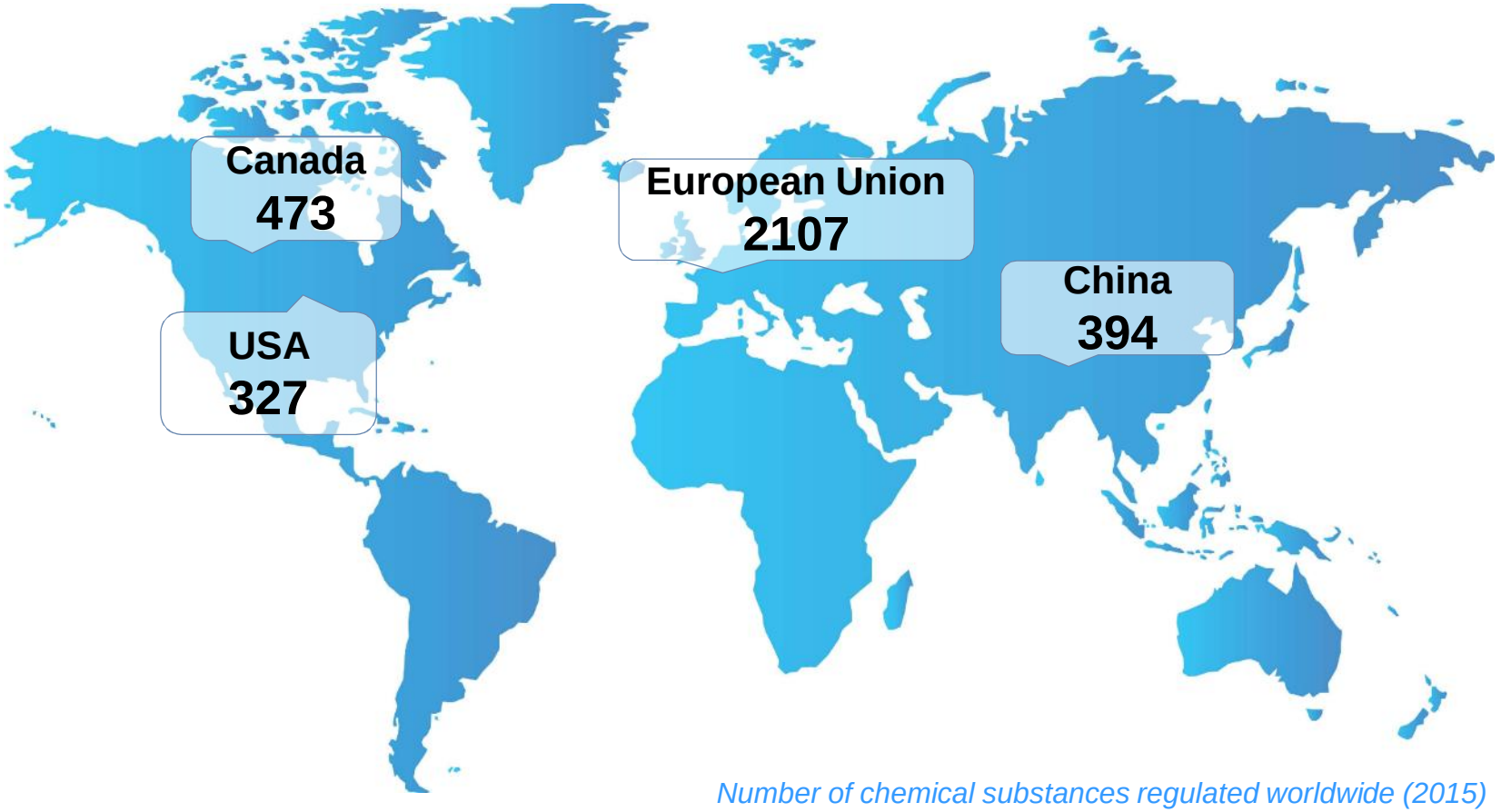
Environmental regulations are becoming more stringent



Number of chemical substances regulated worldwide (2015)

An increasing number of chemicals are being regulated worldwide

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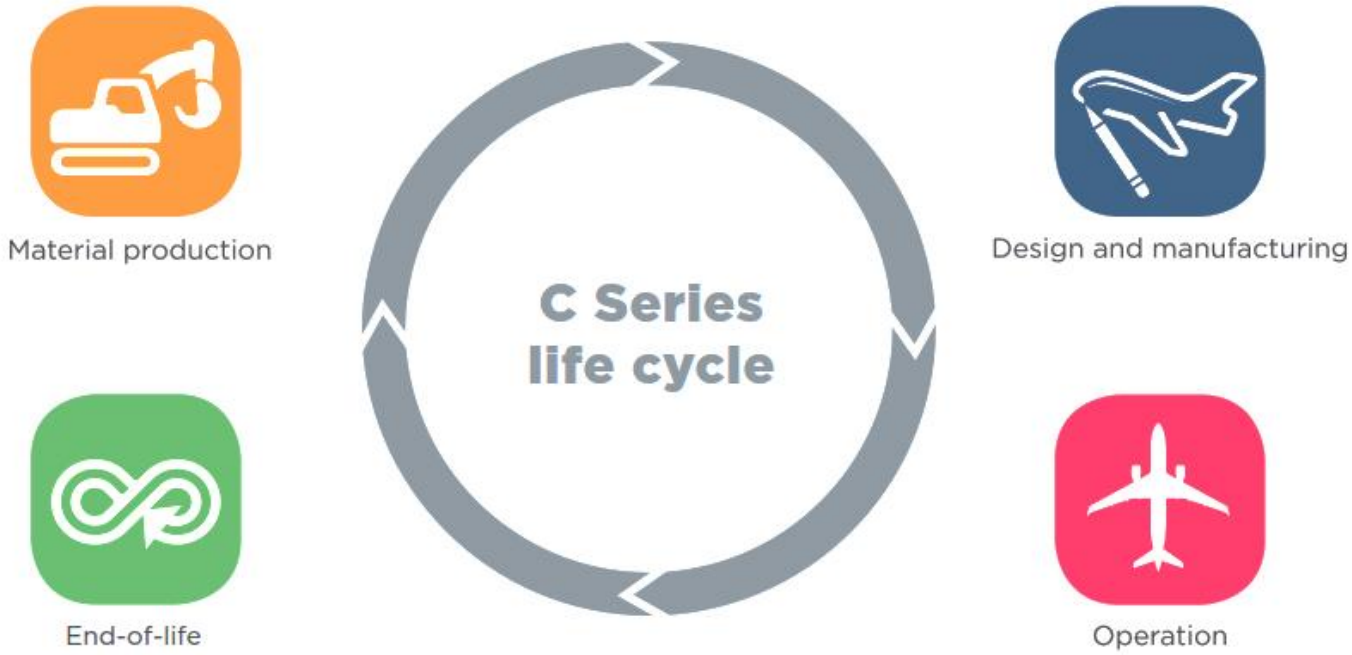
How is bombardier facing the challenges?
Integrating a life cycle approach



80%* of the product life cycle's environmental impact is determined at the design stage

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C Series • final assembly line and wing manufacturing sites are both LEED® certified

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C Series • clean-sheet design removes constraints imposed by the past

ADVANCED MATERIALS
12,000 lb. lighter
Right-sized structure

BEST-IN-CLASS CABIN COMFORT
19in. wide seats
One roller-bag per passenger

ADVANCED FLIGHT DECK
Pilot training: 5-day reduction
Increased situational awareness

ELECTRIC BRAKES
Improved dispatch reliability vs. hydraulic brakes
Towing without mechanics inside the cockpit

PUREPOWER® PW1500G ENGINE
Only 2L per PAX/100 km

FLY-BY-WIRE
Three-axis
Only 2 modes

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C Series • raising the bar with an unmatched environmental scorecard

UP TO 4x SMALLER NOISE FOOTPRINT

20% CO_2 ADVANTAGE

LESS * 50% NO_x

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*50% margin versus ICAO CAEP6 emissions standard. Quietest in-production commercial jet in its class

Bombardier released the aerospace industry's first environmental product declaration in 2016

An EPD® is a **public** document that communicates the **potential environmental impacts** of a product from cradle to grave

The C Series EPD®

released the 26th of September, 2016
http://environdec.com/en/Detail/epd921

1st in the aviation industry

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Environmental labeling landscape

QUALITY CHECK

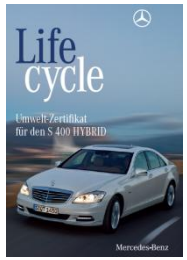
Third-party verification
No pass-or-fail criteria

Verification of eco-labeling body
Pass-or-fail criteria

No third-party verification
No pass-or-fail criteria

Type I
(ISO 14024)

Type II
(ISO 14021)



Type III
(ISO/TR 14025)

INFORMATION

Qualitative | **Qualitative / Quantitative** | **Quantitative**

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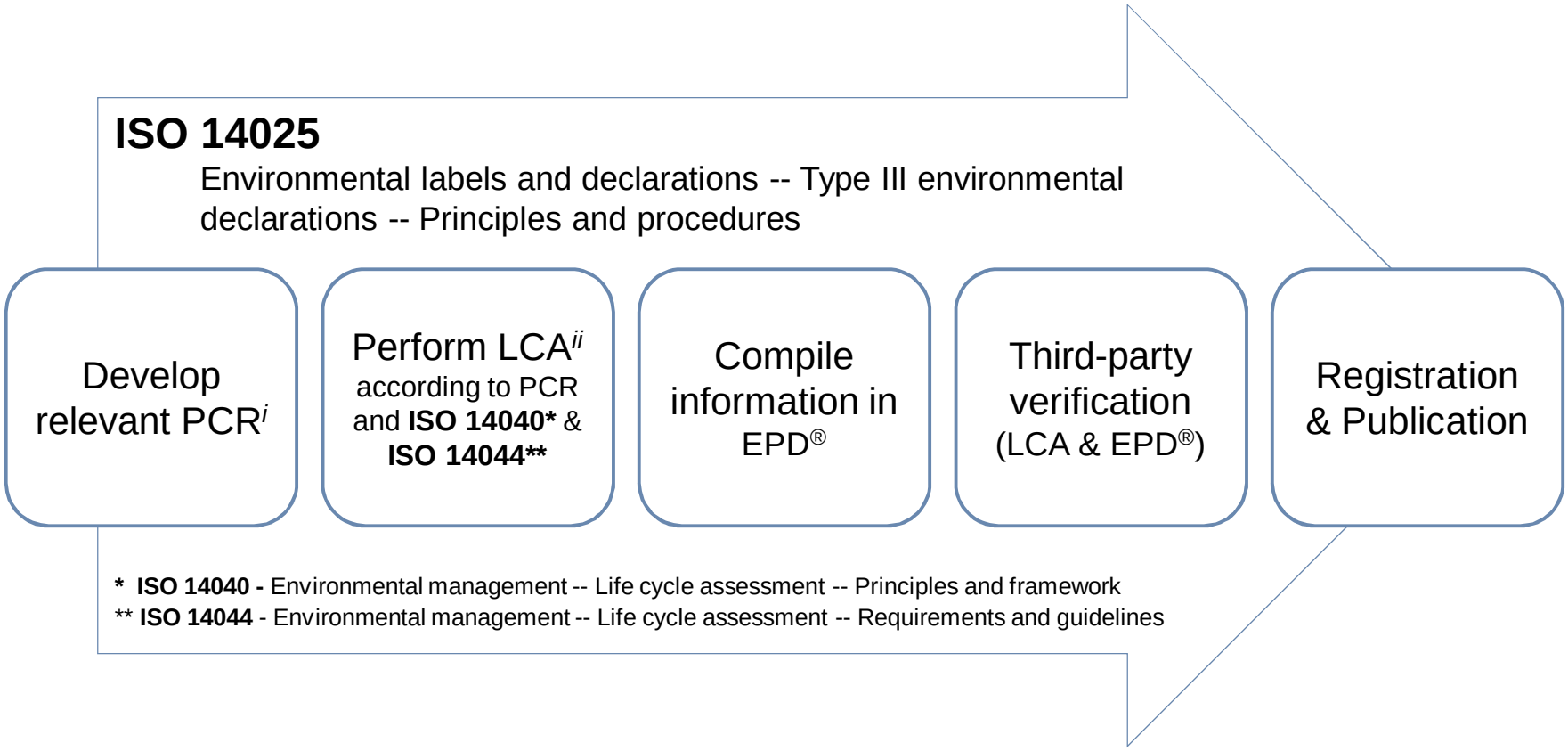
Steps followed to perform the CS100 EPD®



The process follows ISO standards and is audited by a third-party

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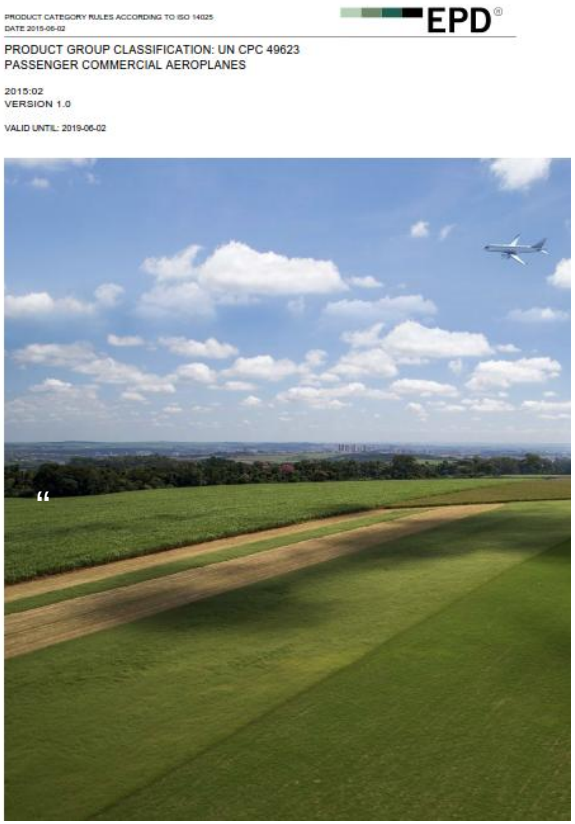
i Product Category Rules (PCR) / *ii* Life Cycle Assessment (LCA)

Product category rules is a pre-requisite to publish an EPD®



PCR details **all rules that must be followed by an airframer** to issue an EPD®

- ✓ Applicable category of products: single aisle or turboprop
- ✓ Scope of the LCA study and information for inclusion in an EPD®

“Passenger Commercial Airplanes” PCR was publicly released in June 2015 and is valid for four years

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Examples of PCR rules

LCA calculations include all upstream, core, operation and end-of-life processes

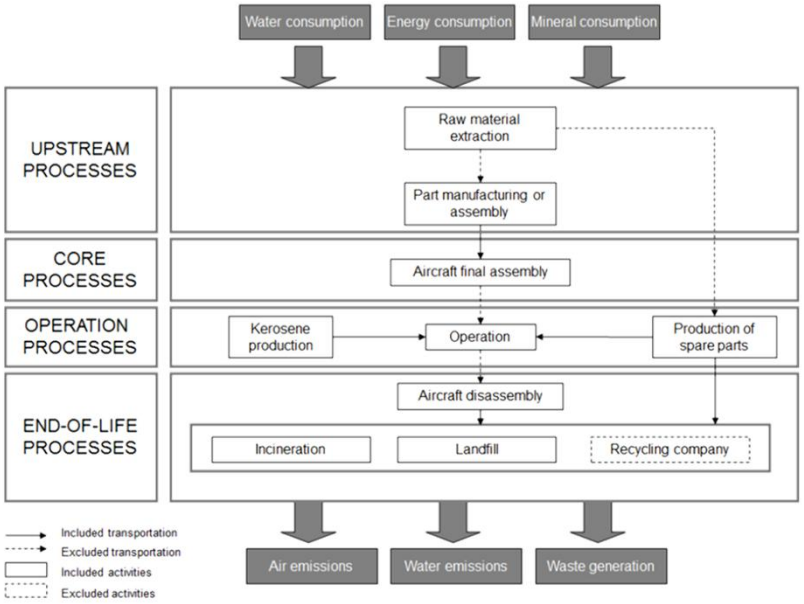

Figure 1: General system boundaries of upstream, core, operation and end-of-life modules

Profile to calculate the block fuel as well as in-flight emissions in the LCA

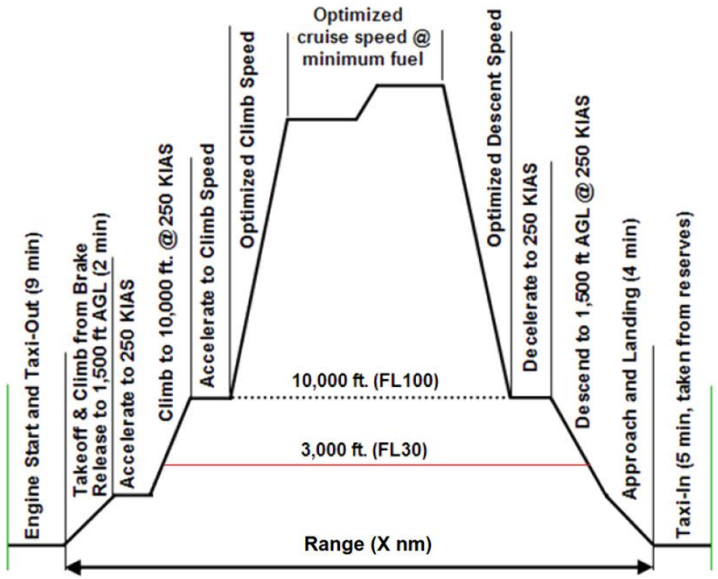

Figure 2: Flight profile to use in the LCA and EPD. LTO cycle is shown under the red line with the times that shall be considered

An airframer must follow all the PCR rules to issue an EPD®

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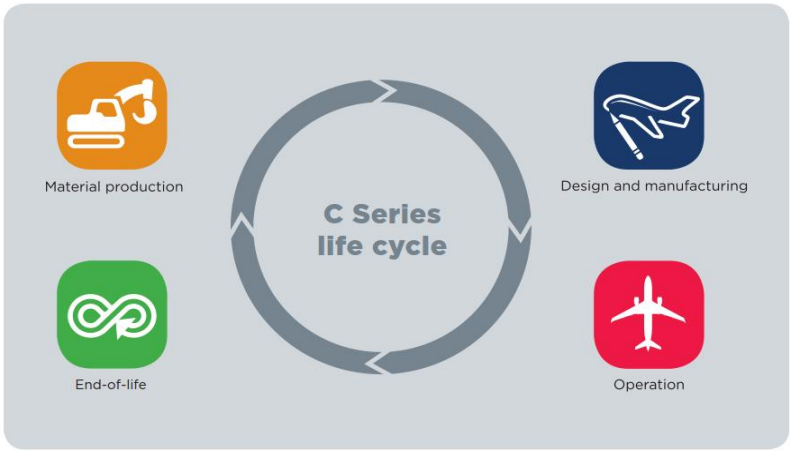
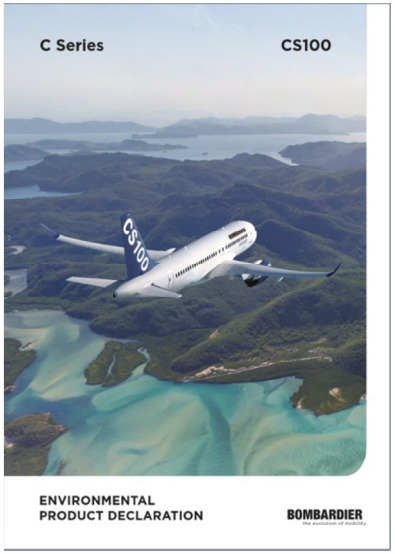
Environmental life cycle assessment feeds the EPD®

Proprietary info

Public info





Life Cycle Assessment (LCA)

Environmental Product Declaration (EPD®) Type III

Complex data translated into an user-friendly public document

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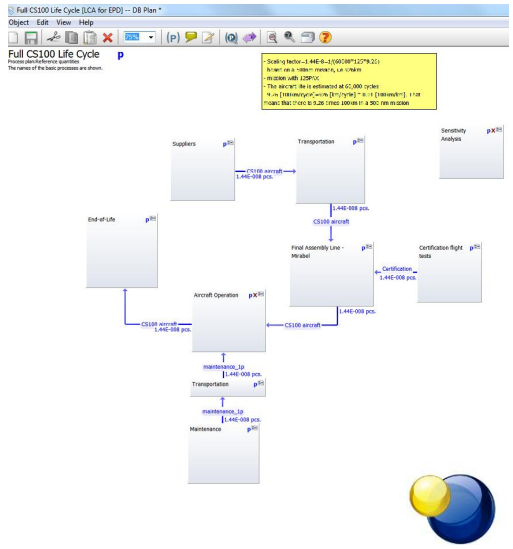
Environmental life cycle assessment

Environmental Data → GaBi – LCA software → Potential environmental impacts

- Raw materials
- Energy
- Water
- Wastes



	Upstream[1]	Core[2]	Operation[3]	End-of-Life	Total
Acidification (kg SO_2-eq)	5.70E-5	1.24E-6	7.46E-3	3.64E-8	7.52E-3
Eutrophication (kg Phosphate-eq)	3.66E-5	5.03E-7	1.69E-3	1.12E-7	1.72E-3
Global warming (kg CO_2-eq)	7.52E-2	1.89E-3	7.70	8.41E-5	7.78
Photochemical ozone creation potential (kg Ethene-eq)	1.60E-5	3.48E-7	1.37E-3	2.59E-8	1.39E-3
Water consumption (kg)[4]	7.50E1	1.31E1	2.10E2	2.38E-2	2.98E2

Note: These results are only valid for this range and this configuration. No linear assumption can be made to extrapolate environmental impact for another distance, another configuration or another aircraft type.

[1] Raw material extraction and component production
[2] Final assembly
[3] Use and maintenance
[4] 2.59 kg of water are also emitted during the operation phase as part of the combustion

Model for the entire aircraft is built in GaBi software

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Environmental life cycle assessment results

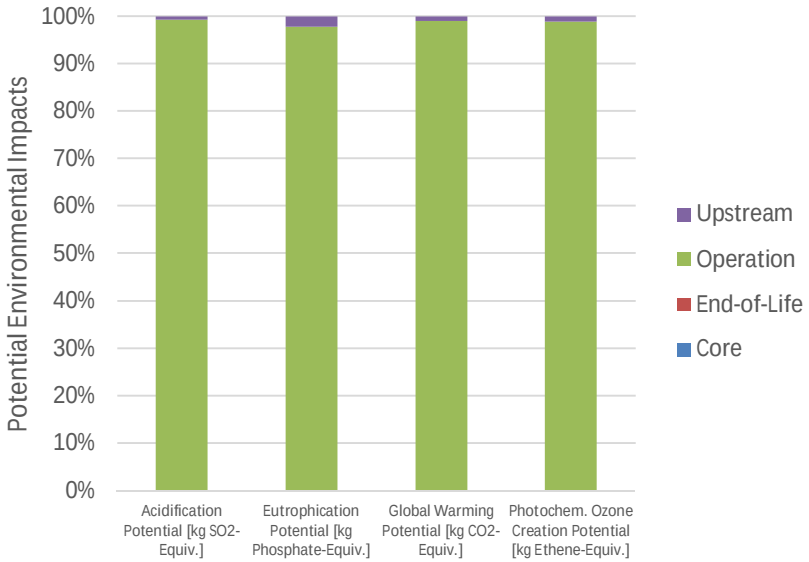
Functional unit (FU) ***"Transport one revenue passenger over 100 km"***

This FU will calculate the economic and elementary flows throughout the life cycle of the CS100 aircraft.

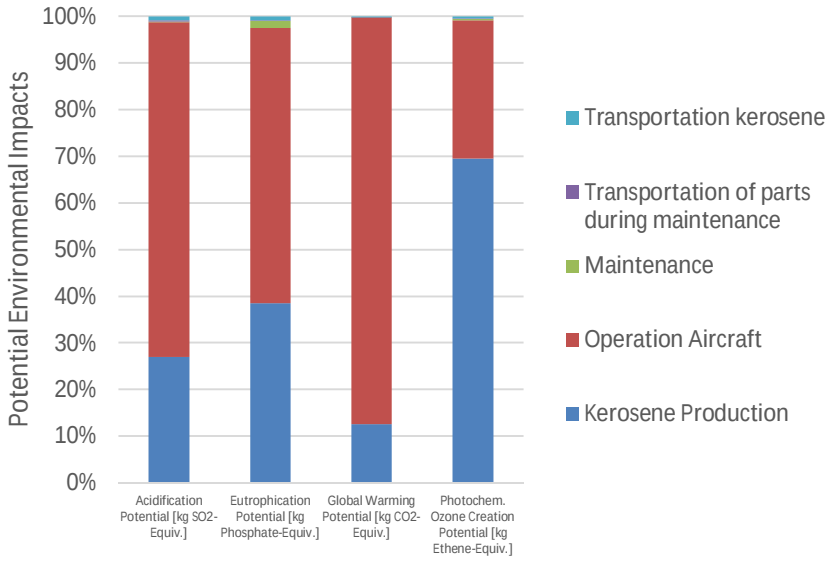
Reference flow (RF) The reference flow represents the product quantity required to fulfill the FU.

$$\frac{1[aircraft]}{A_1\left[\frac{cycles}{aircraft}\right] \times B_1\,[Nb.of\ PAX] \times C_1\left[\frac{km}{cycle}\right] \times 0.01\left[\frac{100\,km}{km}\right]} = Commercial\ aircraft\ RF\ \left[\frac{aircraft}{PAX.100km}\right]$$

CS100 LIFE CYCLE POTENTIAL ENVIRONMENTAL IMPACTS AND THEIR CONTRIBUTION



CONTRIBUTION ANALYSIS OF THE OPERATION PHASE



LCA and Eco-Design approach avoids environmental issues displacement

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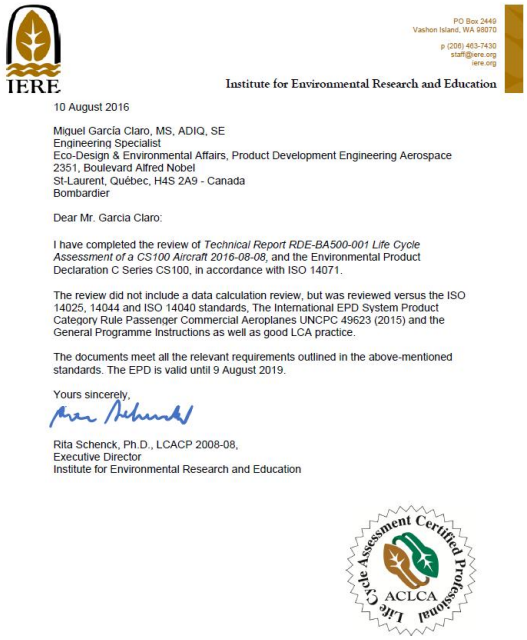
Verification and registration process of the EPD®

Third-party verification



IERE

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iere.org

Institute for Environmental Research and Education

10 August 2016

Miguel García Claro, MS, ADIQ, SE
Engineering Specialist
Eco-Design & Environmental Affairs, Product Development Engineering Aerospace
2351, Boulevard Alfred Nobel
St-Laurent, Québec, H4S 2A9 - Canada
Bombardier

Dear Mr. Garcia Claro:

I have completed the review of *Technical Report RDE-BA500-001 Life Cycle Assessment of a CS100 Aircraft 2016-08-08*, and the Environmental Product Declaration C Series CS100, in accordance with ISO 14071.

The review did not include a data calculation review, but was reviewed versus the ISO 14025, 14044 and ISO 14040 standards, The International EPD System Product Category Rule Passenger Commercial Aeroplanes UNCPC 49623 (2015) and the General Programme Instructions as well as good LCA practice.

The documents meet all the relevant requirements outlined in the above-mentioned standards. The EPD is valid until 9 August 2019.

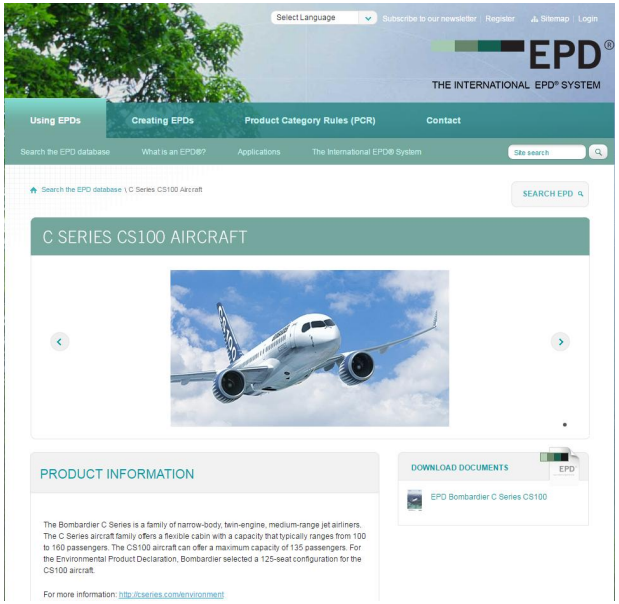
Yours sincerely,

Rita Schenck, Ph.D., LCACP 2008-08,
Executive Director
Institute for Environmental Research and Education

Life Cycle Assessment Certified Professional
ACLCA

The LCA and the EPD® itself are subject to an independent verification

Registration & Publication



EPD® is registered and published by the program operator

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http://environdec.com/en/Detail/epd921

C Series • an industry first!

Assessing an aircraft's impact on the environment

 https://youtu.be/t-o_u-oXtXs

What are the benefits of the life cycle approach for Bombardier?

- **Improves environmental performance** of our aircraft
- **Reduces costs** for the clients and the company
- **Provides transparency** to stakeholders and customers
- Allows us to **stay ahead of future regulations** and **have better access to all markets**
- **Increases competiveness**

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Q&A

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