Enhancing our understanding of the circularity of aircraft

ecube.aero

An Aircraft Weight Study Initiative

This project demonstrates a repeatable process that reuses, repurposes and recycles a British Airways A320 aircraft.

ecube has completed the first stage of an ambitious journey to enhance our understanding of the circularity of aircraft. We were joined in this project by partners involved in the complete cycle of an aircraft's end-of-life. The involvement of companies from different parts of the industry ensured that this stage was a realistic, yet rigourous comprehensive investigation by key stakeholders with expertise in data, compliance and reuse concerned with maintaining the value of aircraft materials in the economy.

Companies working on Reuse, Repurpose & Recycling

ecube

Aircraft Storage, Disassembly & Transition provider. Managed the project and provided disassembly services.

BRITISH AIRWAYS

Airline and Maintenance team. Focussed on safety, delivery, reliability and value. Provided the aircraft and harvested parts.

PLANE RECLAIMERS

ecube's upcycling division and home to aviation memorabilia, specialising in repurposing material.

celsa STEEL UK

A leading producer of circular and low-emission steel. Recycled the ferrous, non-ferrous materials.

Organisations Backing and Supporting the project

AFRA

Focussed on industry performance and commercial value of end-of-service aircraft. ecube worked to AFRA's BMP Guidelines for disassembly.

AETHOS

Stimulates sustainable solutions for recycling of aircraft materials by supporting research and building the bridge between the industries.

BEYONDLY

A B Corp environmental compliance scheme and consultancy. It shares knowledge with businesses to help them become more confident about their environmental choices. Reviewed the validity of the methodology and data.

Typically, aircraft circularity projects have been modelled. This means they have not looked at actual data and outcomes.

The challenge with theoretical models is that they can give an overly positive message on recycling rates. Our aim is to set a datum built on actual, real-life results, so that we, as an industry, can measure our progress.

This project **comprehensively studies the Airbus A320 aircraft** from the moment it lands to its eventual disassembly and recycling.

Our holistic approach involved weighing the aircraft upon landing, documenting each stage of disassembly, and finally recording the recycling of the hull. The resulting data can serve as a baseline for our future initiatives and will facilitate informed discussions on our journey towards understanding if a 100% recycled aircraft is possible. This project shows what is possible and outlines the areas for improvement.

We would like to thank the team at British Airways and ecube, along with all our partners who have been involved in this project.

Terminology guide

In order to measure progress, the aviation industry needs to agree its terms.

Part of this project is to define what we mean by the various ways aircraft materials are processed at the end of life. At ecube we focus on reuse, repurpose, recycle. These ideas are born out of the 5 Rs of waste management; refuse, reduce, reuse, recycle, rot. This concept was developed from the European Union's Waste Framework Directive, originally introduced in 1975[1]. More recently it has been adapted for the recycling industry and materials management.

The focus on creating a sustainable economy that protects human health and the environment has led to the idea of the circular economy. Where as much material as possible is reused in some way, rather than being one-use only. However, as Kircher et al[2] showed in their research, this term is also in flux as the industry seeks to define what it means and what's involved. Kircher's research is entitled: Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. It examines the use of the term, and the various interpretations used.

Kircher's research cites a definition of the circular economy. It is described as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling".[3]

The European Union is also keen to define terms and processes. The EU Environment Agency mentions the practical solutions that create a circular economy, which 'include eco-design, waste prevention programs, and extending the lifetime of products (European Environment Agency, 2016). "Reduce, reuse and recycle" are three important waste management options'.[4]

The EU has its own glossary of terms. It says; 'reuse [is] meant as a material reuse without any structural changes in materials; recycling meant as a material recycling, only, and with a reference to structural changes in products; and recovery meant as an energy recovery only'.[5]

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[1] European Union Waste Framework Directive - Directive - 75/442 - EN - EUR-Lex

[2] Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions - ScienceDirect

[3] Quoted in Conceptualizing the Circular Economy (Revisited), referencing Zucchella, A., Previtali, P. (2018, p. 275)

[4] Quoted in Conceptualizing the Circular Economy (Revisited), referencing Geueke, B., Groh, K., Muncke, J. (2018, p. 492)

[5] EU Environment Agency Glossary - EEA Glossary — European Environment Agency

In disassembly we focus on three key elements for end-of-life aircraft materials: reuse, repurpose, recycle. We have used the following definitions in our project, which draw on research by Kircher et al. EU definitions and our own experience.

Reuse

An operation where components are used again for the purpose for which they were originally conceived. Reuse is ecube supporting components returning to aviation's supply chain with the intent of reuse on other aircraft. This may involve some repair work. *In this project, we cannot provide a guarantee that every part targeted for reuse is reused, however the intent for the removal of these components is primarily and solely to be reused.*

Repurpose

Where an aircraft part remains identifiable but is used in a new way. Also known as upcycling. For example: using doors and flight decks for training, or creating memorabilia from aircraft parts, as Plane Reclaimers does. ecube and Plane Reclaimers have repurposed a typical quantity [weight] as part of this project. We recognise demand for BA memorabilia may exceed other airlines.

Recycle

A recovery method which treats a product, so it can be used as raw material in the manufacture of the same or a similar product. For example: extracting aluminium from aircraft for use in other industries.

Once an aircraft and its parts have been reused, repurposed or recycled and 'recovered', what's left is waste. This is classified in different ways in different countries and regions. For this project we are following our supplier's guidance.

Waste / Disposal

Any materials that are not processed for recycling, reuse or repurposing. This includes plastics, composites, and fabric such as carpet. *ecube aim to minimise recovery and disposal by prioritising the waste hierarchy.*

One aim of this project is to help the industry agree its definitions. We would like to look at terms for end-of-life treatment of aircraft and build consistency across the industry. We recognise that there are some grey areas and overlaps between the three different types of work we are all doing.

We want to improve the processing of end-of-life materials. By agreeing and defining our terms we can monitor our progress towards reusing, repurposing and recycling as much of an aircraft as possible.

Programme Summary

The aim of this project has been to give the industry a recycling benchmark with a repeatable, industrialised process.

Previously, attempts to measure the recyclability of an aircraft have largely relied on modelling rather than real world examples.

Our findings show that it is possible to reuse, repurpose or recycle over 80% of an aircraft. The process has, of course, identified areas which are difficult to measure, where local conditions have an impact on weight and differences in the accuracy of load bridges.

At the end of this project, we have recorded a 0.48% variance in weight, amounting to around 200kg. We attribute this to rounding differences on the variety of scales used in the process. As an example, between the first weighing, on the aircraft's arrival, and it leaving for recycling, the variation was 17kg.

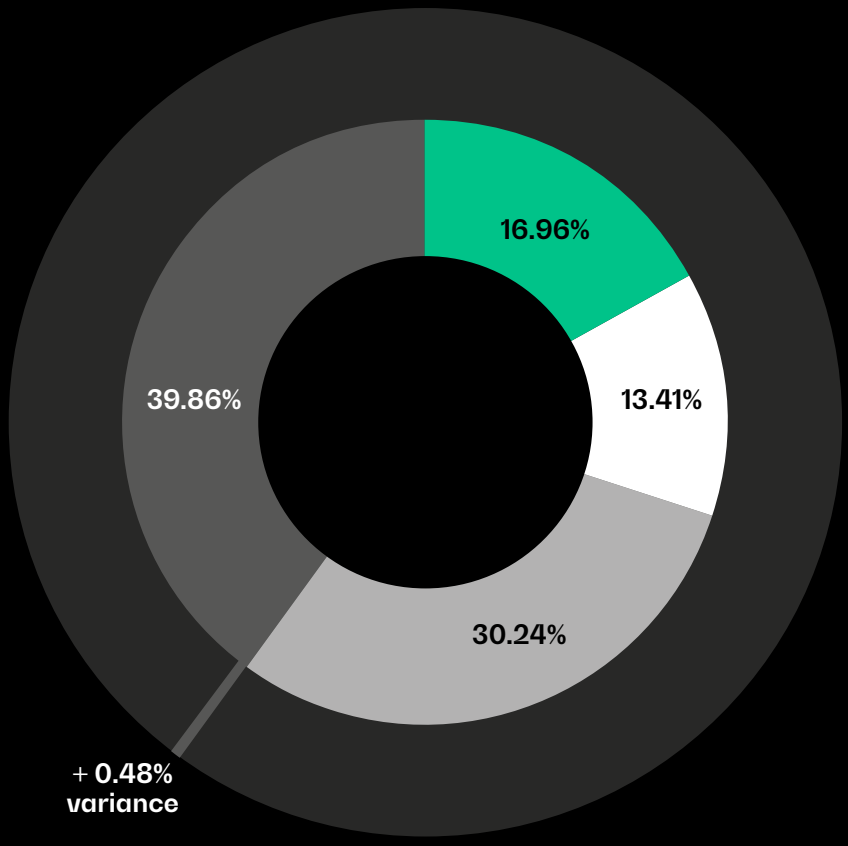
As a result, we have identified areas for closer scrutiny in a future project. We would like to focus on elements that can cause variation in weight and recyclability.

They include, but are not limited to:

- Gases like nitrogen and oxygen that are difficult to weigh individually and were not considered in this process.
- Moisture absorption caused by wet weather. This can occur during transportation to the recycling location, as well as during disassembly.
- Legacy material present at the recycling stage.
- The stack up effect or cumulative impact of small errors or uncertainties from multiple sources in a weighing system.
- Heavy rain (which we experienced during this project) can add weight to the trucks delivering the materials for recycling. The accuracy of some weighbridges can be to within about 20kg, plus or minus. This may also have affected this project.

A step beyond the benchmark is to look at how we can improve these areas. We would like to develop the process of measuring minor factors like gasses and moisture, as well as aligning the weighing and measurement capabilities throughout the recycling chain.

MSN 1424 Summary



	KG	%
Reuse – Return to Service Components	13368.91	30.24%
Repurpose – Non-Airworthy Material	5931	13.41%
Recycle – All Recycled Material	17622.25	39.86%
Waste / Disposal	7500	16.96%
Total		100.48%

Programme Details

①

G-MIDS Arrives at St Athan DGX

British Airways took the decision to retire the 23.7-year-old A320 aircraft. It arrived at ecube's HQ in St. Athan DGX, Wales on 24th September 2024. The papers, trolleys and other BA equipment had been removed ahead of arrival.

②

Part 145 Maintenance begins

The aircraft was accepted by the ecube Part 145 Maintenance team. This team typically provides services that include aircraft and engine preservation, Max Power Assessment Runs [MPA runs] and serviceable removal of engines and APUs. For this project, the work was carried out by the British Airways Maintenance Team. They started work with engine preservation.

Fuel was then removed for repurposing; this is utilised for power generation in non-aviation related sectors. Jet fuel is often very clean, and the entire fuel stock was collected. The majority of the fuel will be sold as kerosene for heating homes and businesses.

ecube worked with Crown Oil Environment to process the fuel. Crown Oil Group has been carbon neutral since April 2023 (ISO 14064 accredited), one of the first oil companies in the UK to do so. It is working on achieving net zero direct emissions by 2030.

③

Engines and Flight Controls to be Reused

The initial disassembly process was to harvest serviceable parts for reuse. The Engines, Nacelles, Flaps and the APU were identified as reuse components. They were removed by the British Airways Maintenance Team to be included in the inventory that supports BA's active fleet.

④

The Journey to Disassembly Begins

The first component to be removed was the rudder. It went on to be weighed as part of the final reuse weight. The next step was to remove components from the 500+ initial harvest list and subsequent identified parts. This took place over a 17 day period. The parts are set to be reused in aviation's circular economy.

All items were prepared for shipping or storage. This involved them being tagged, digitally logged, photographed and weighed by ecube on behalf of our airline and parts company partners.

5

Landing Gear is Removed

The disassembly phase concluded with landing gears being removed reuse. The landing gears and all other larger components were weighed and securely crated.

6

Plane Reclaimers Repurpose

Remaining material is then repurposed into a variety of items by the Plane Reclaimers team. This material is prepared, upcycled where appropriate, and shipped to customers. Flight Simulator conversion companies take cockpits; door cuts go for safety training; and fuselage cuts for glamping pods or garden offices, window clocks and even coasters to aviation enthusiasts.

7

The Final Step of the Process is Disposal and Recycling

The remaining aircraft material and weight was segregated into ferrous, non-ferrous, waste and moisture loss material data via Cardiff based recycling supplier, Celsa.

In conclusion

This project, completed on 18th November 2024, is the first to offer an industrial, repeatable baseline.

It has shown that it is possible to reuse, repurpose or recycle 83% of an aircraft. The partners involved in this project have set a benchmark for the industry, against which we can measure improvements to the process of ending an aircraft's life.

The final weight of the aircraft is within 0.5% of its arrival weight. As highlighted in the Programme Summary, the slight discrepancy is due to the variety of scales and weighing apparatus and some rounding decisions. There are also elements that are difficult to weigh, variations in components left on board and local conditions to consider. If this process were to be repeated regularly, these elements would be considered in detail and differences reduced.

This is a positive beginning. We now understand what's possible and where there's room for improvement. We need to do more, to repeat this process and to engage across the industry to work on materials and processes that will enable more of an aircraft to be reused, repurposed, or recycled.

Industry recommendations:

- Agree definitions. In order to measure our progress, we must agree what we're measuring. Let's set industry standards for reuse, repurposing and recycling. Aligning with leading waste frameworks such as the waste hierarchy to set standards and continuously improve performance, reducing recovery and disposal to landfill.
- Engage front and end-of-life development. The balance between light, strong and recyclable needs to be considered at both ends of an aircraft's life. 80% of a products carbon footprint is determined at the design stage.
- Encourage new technology. Work with companies that are developing new materials, perhaps outside of the aviation industry.
- Investigate how the reused parts and recyclable materials are used.
- Examine the complicated areas in more detail (highlighted in the Programme Summary).
- Work on consistent terms and measurements throughout the end-of-life process.
- Improve recycling processes using AI

Quotes from All Parties

We're delighted you've taken the time to read this paper, which we think shows a current repeatable baseline for end-of-life aircraft. This has been an enlightening project for all of us at ecube. Historically aircraft recycling projects have been theoretical. They've been modelled on what we think is possible, but not actually tested in practice. This project with BA is the first that is industrialised and therefore offers a repeatable baseline. We pride ourselves on our ability to expertly disassemble aircraft so as much as possible can be reused, repurposed or recycled. This project has set a fair baseline for the industry. We now understand what's possible and where there's room for improvement. But it's just a start. We need to do more, beginning with agreeing industry terms for processing materials at the end of an aircraft's life.In order to measure our progress, we must agree what we're measuring. We're always looking to improve and would like to invite innovators to let us know about progress they're making in the space. We'd also welcome discussion with the front end of the industry about how to combine not just weight and strength, but also think about end-of-life reuse when designing new components. We'd like to thank the team at BA and ecube, along with all our partners who have been involved in this project.

ecube

Demand for aircraft memorabilia is rising. A BA plane will always have a high opportunity for repurposing or upcycling to enthusiasts, but we have been able to upcycle a wide range of parts.Providing aircraft flight decks, doors and other parts for training purposes is also a large part of our work. It means that important parts can have a significant afterlife, long after they come off the plane.

PLANE RECLAIMERS

This project with ecube supports our BA Better World circular economy strategy and has given us a baseline for our aircraft disposals. It has also provided clarity around how much of an aircraft it is possible to reuse, repurpose, or recycle. Based on these insights we look forward to working with our suppliers on opportunities to maximise the value and resource recovered from our aircraft at their end of life.

BRITISH AIRWAYS

Beyondly reviewed and supported ecube's data management and methods applied in this sustainability project. We are delighted to have supported ecube in being able to share their work and the results indicate that by weight, 83% of this end-of-life aircraft has been kept in the economy through reuse, repurpose and recycling. Beyondly applied best available technique, established waste frameworks and the real-world challenges and opportunities for continuous improvement as observed through this project to capture ecube's controlled, scalable process. Beyondly has verified the component level data and controlled process of weighing the aircraft at key stages of component harvest and agree that there is an acceptable variance of +0.48% at the end of this project. ecube's project aims to inspire and guide future work as a practical classification and baseline of performance within the waste hierarchy. As such, this project is a positive step forward in how industry accounts for and measures at a component level, the end-of-life impact of a complex aircraft. It shows the value of curiosity, collaboration and adds credibility in how our industry engages with the circular economy, which supports a Net Zero future for this global industry.

BEYONDLY

Quotes from All Parties

This project has answered questions, and raised more. It has shown, in a repeatable process, that 83% of an aircraft can be reused, repurposed or recycled, but it has also identified room for improvement.

At AFRA we champion the needs of the industry and work to advance environmentally responsible end-of-service practices for the aviation industry. We want to take the findings of this project and use them to promote the circular economy in our industry. To do this we will develop and promote definitions of the stages of disassembly and the processing of materials, so the industry has coherent standard to work to.

AFRA

This project has performed a much needed first measurement. We are proud of ecube's lead and our involvement to get to this point. The key insight for us is that already 70% of the material can be recycled, in line with AFRA's recyclability rate formula. With this baseline from ecube, it is possible to identify opportunities and challenges to raise the bar for aircraft material recycling, including industry standards for measurement.

Aethos is looking forward to contributing further. Our goal is to bring the recycling of aircraft material to a next level. This project has shown what is possible, but there is still plenty of room for improvement. We're looking forward to exploring the next steps, including considering whether the stream of materials can be divided further. This project is a perfect starting point for our mission!

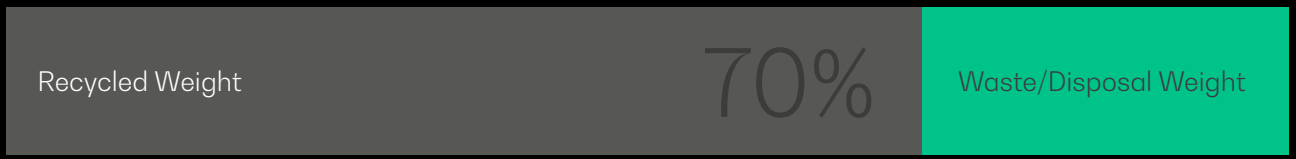
AETHOS

AFRA's Recyclability Rate Formula

In line with AFRA's recyclability rate formula*, the remaining material weight after Reuse and Repurpose was 70% recycled.

*Total Material weight after Reuse & Repurpose : 17622.25kg [Recycled] + 7500kg [Waste/Disposal] = 25122.25kg

Recycled Material = 17622.25kg / 25122.25kg *100% = 70%



UNICAL

"This project is a milestone not just for ecube, but for the entire aviation supply chain. At Unical, we rely on high-quality, responsibly sourced USM to keep fleets flying around the world. A repeatable and data-driven process like this helps us—and the industry—ensure that every aircraft reaches its full value potential at end-of-life."

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