D-standart

Session 4 - Embedding Sustainability in the Design Process: D-STANDART Framework and Roadmap to Adoption

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Order of play

1. Reminder of D-STANDART objectives
2. Framework for LCA / LCC
3. Socio-economic survey results
4. Discussion

01

Introduction

General

Objectives of D-STANDART

The overall ambition of the D-STANDART project is to enable reduced time-to-market, material waste and increased lifespan of composite products in the aerospace and wind energy industries.

The project addresses several challenges which are integral to this objective:

1. The complex, unreliable nature of fatigue assessments of composite designs; addressed by development of rapid simulation and test techniques using machine learning (ML) and high-frequency testing
2. The difficulty of quickly making good product design decisions based on appreciation of the whole product lifecycle; addressed by development of ideas in rapid, accurate life-cycle assessments
3. The challenge of effective re-use of composite parts at end-of-life; addressed by the development of Digital Product Passport data ontologies based on the EMMC MODA and CHADA principles and EMMO ontology.

02

Framework for LCA / LCC

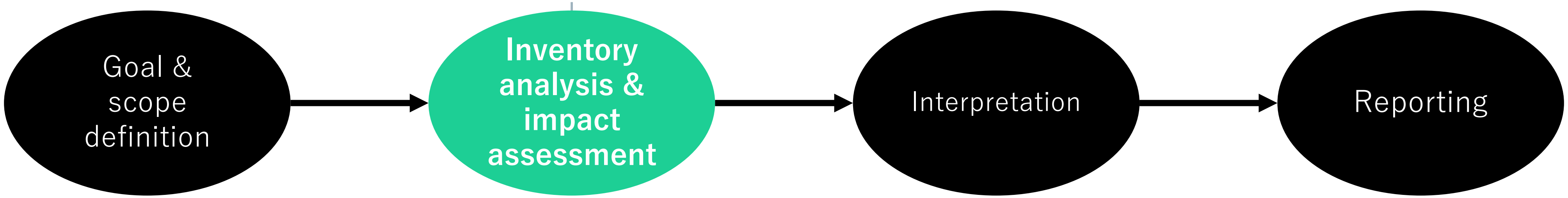
Using demonstrators from Aerospace & Wind

INTRODUCTION: State of the art

"Systems analysis that calculates the impact of a product or process on the environment over its full life cycle, from production and use through to disposal or reuse"

1. Inventory –
Gather data on the system being studied:
- Number of inputs / outputs over time
- Electricity monitoring
- Consumables
- Auxiliary materials
- Times / temperatures
- Any other recordable data

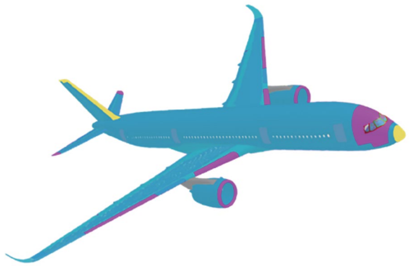
2. Convert that inventory into impact:
- Databases
- Tools
- Models
- Industry / Gov reports
- Academic articles
- Textbooks, patents
- Any other publicly available data

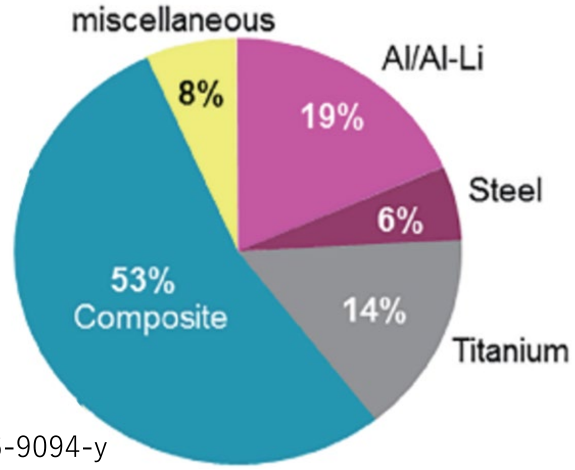


PROBLEM:
There is not enough high-quality inventory data being collected to calculate accurate impact scores for early concept design

CHALLENGE: Integrate LCA/LCC into fatigue testing

- To enable rapid, accurate estimation of environmental and economic impacts using integrated LCA & LCC tools.
- To reduce time-to-market while ensuring product robustness and safety
- To provide contextual, automated design support that reduces reliance on repeated manual assessments by specialist engineers.



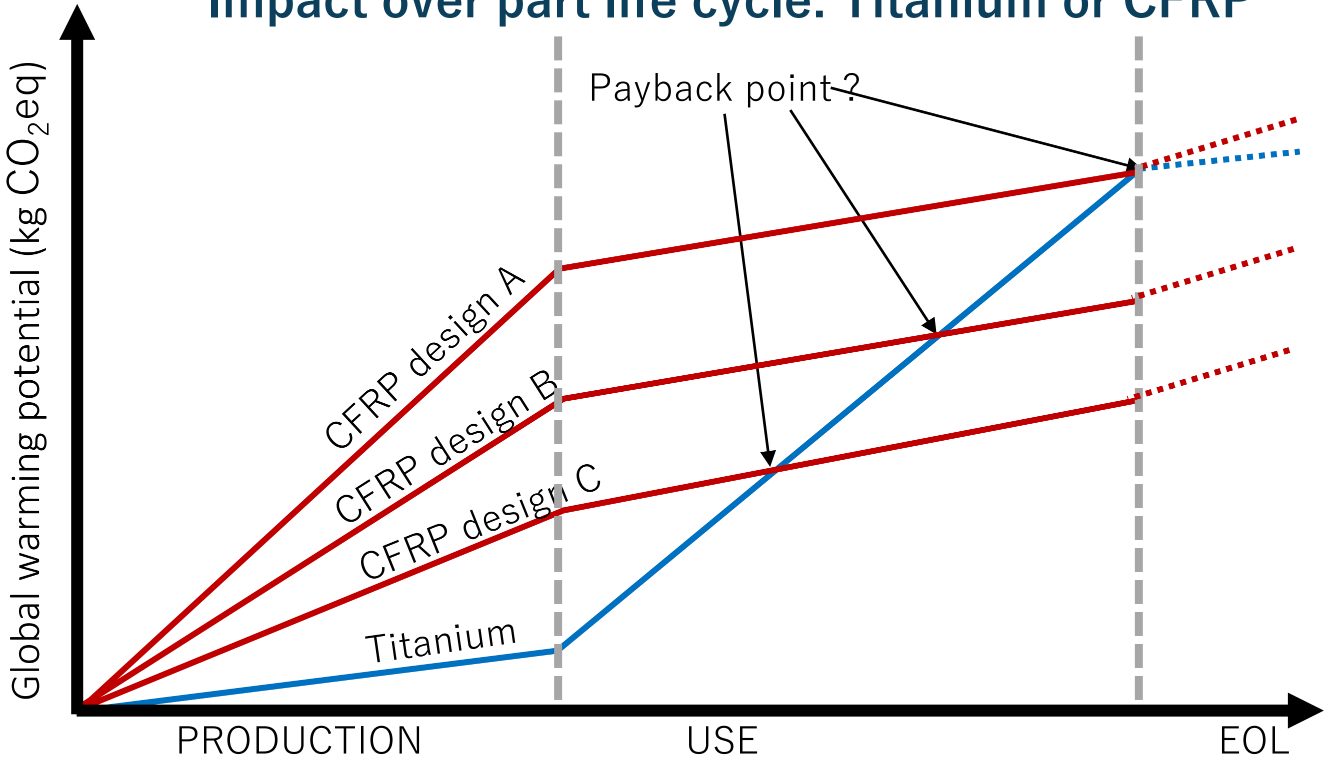


Approx. 66 tonnes CFRP per plane

doi.org/10.1007/s11431-016-9094-y

What could this mean for the aerospace industry?

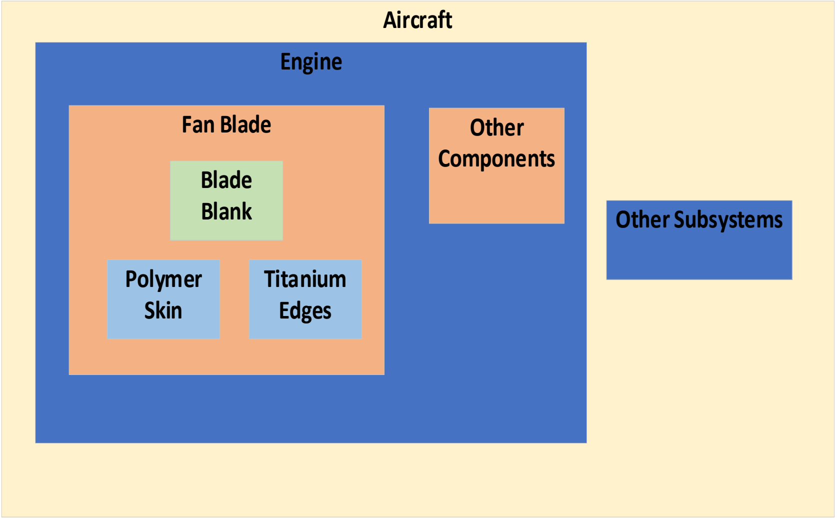
Impact over part life cycle: Titanium or CFRP

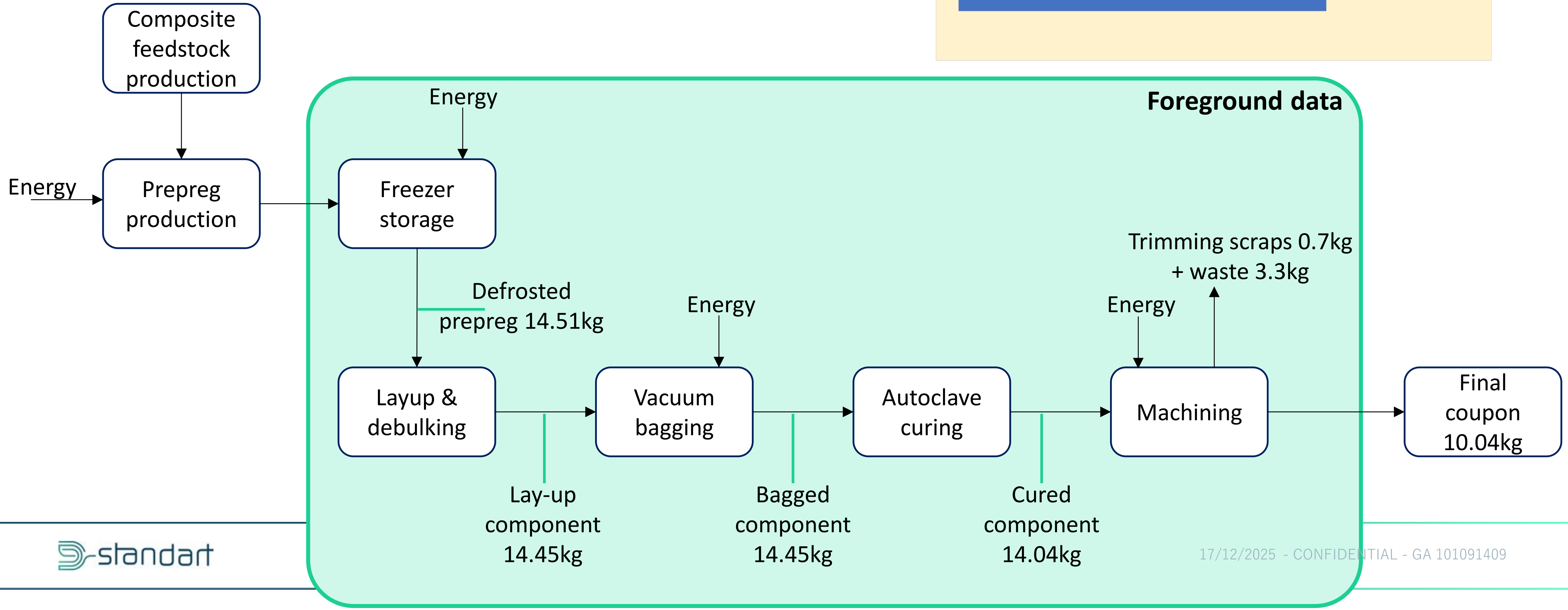


Aerospace demonstrator

Streamlined system boundary / process flow

Aerospace product system



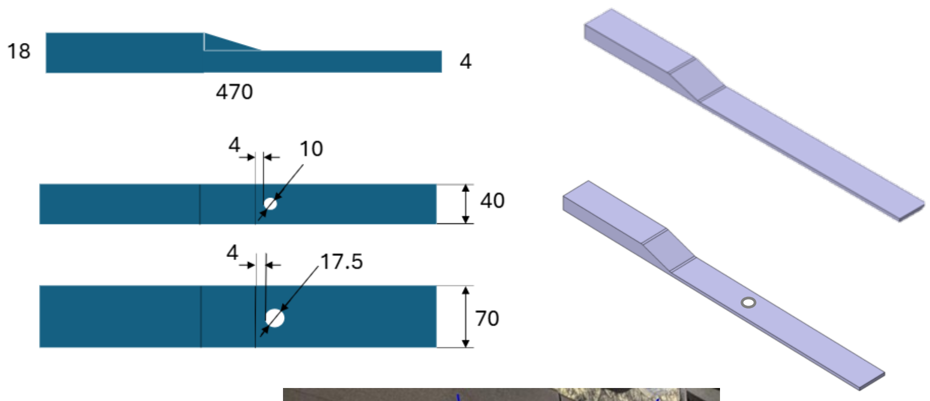


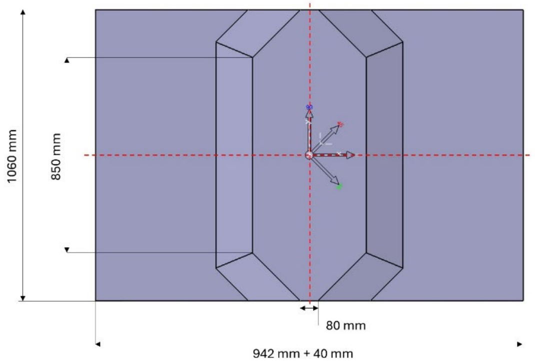
Chapter 2

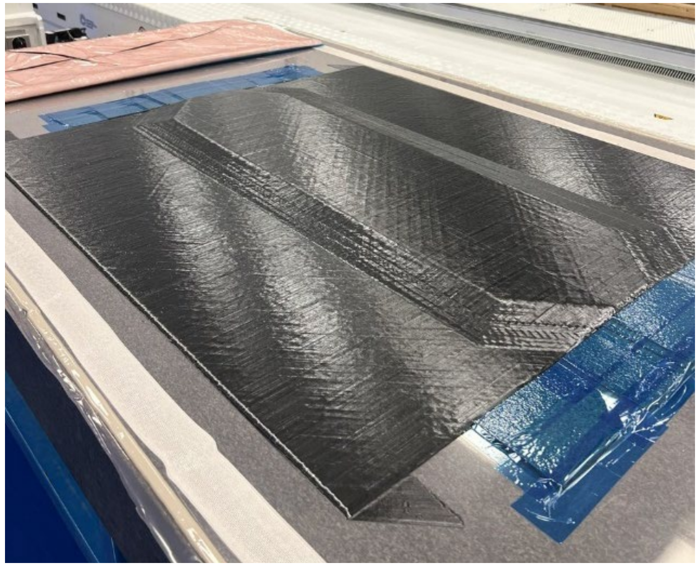
Aerospace demonstrator

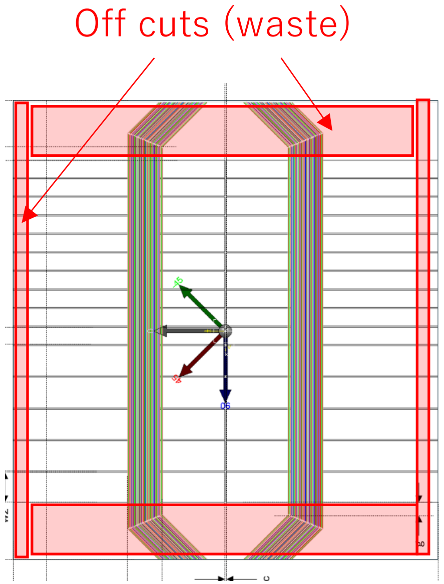
Manufacturing details

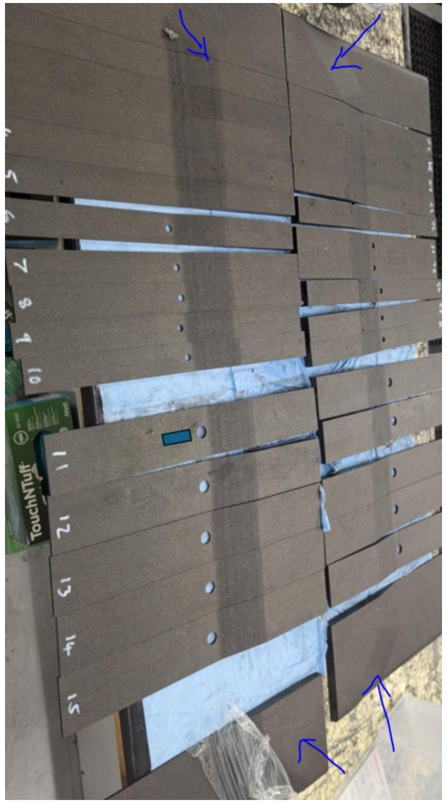
- Made of UD prepreg tape HEXCEL 8552 - IM7
- Manufactured using AFP Coriolis Automated Fibre Placement System
- 20 No 40mm and 10 No 70mm wide coupons cut from a single panel 1060mm x 982mm









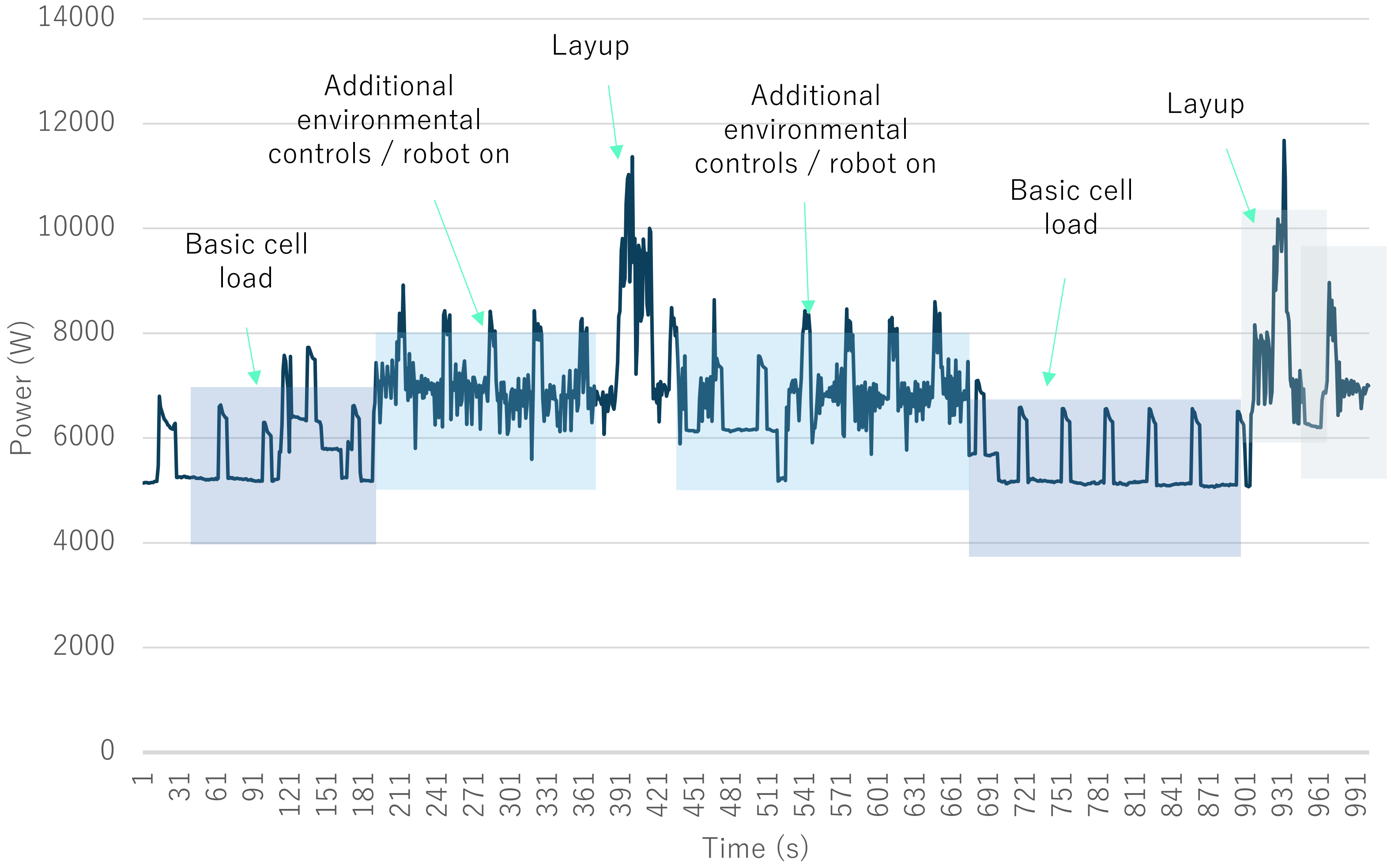


ANALYSIS: Part complexity – AFP power consumption for demonstrator

Energy is a major contributor to the manufacturing environmental impacts, and so accurate energy data is required to understand a manufacturing process.

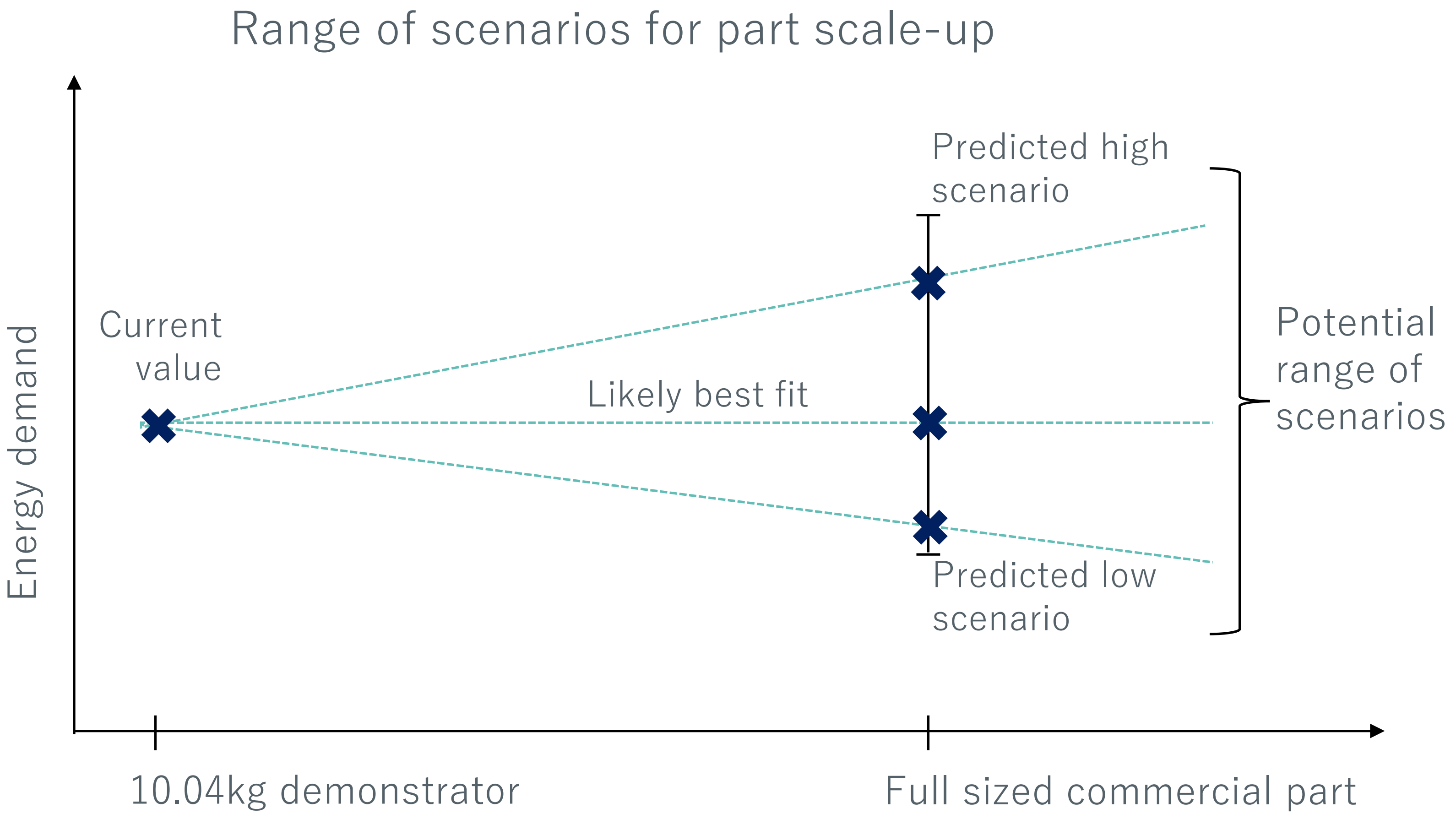
Energy monitoring of the Automated Fibre Placement (AFP) process has allowed for insights into hotspots, that will feed into LCA:

- Basic Cell Load (lights, environmental control…) is the major contributor, and so standby/ down time should be minimised
- Variation of layup parameters will dictate energy use, and should be accounted for in LCA data models



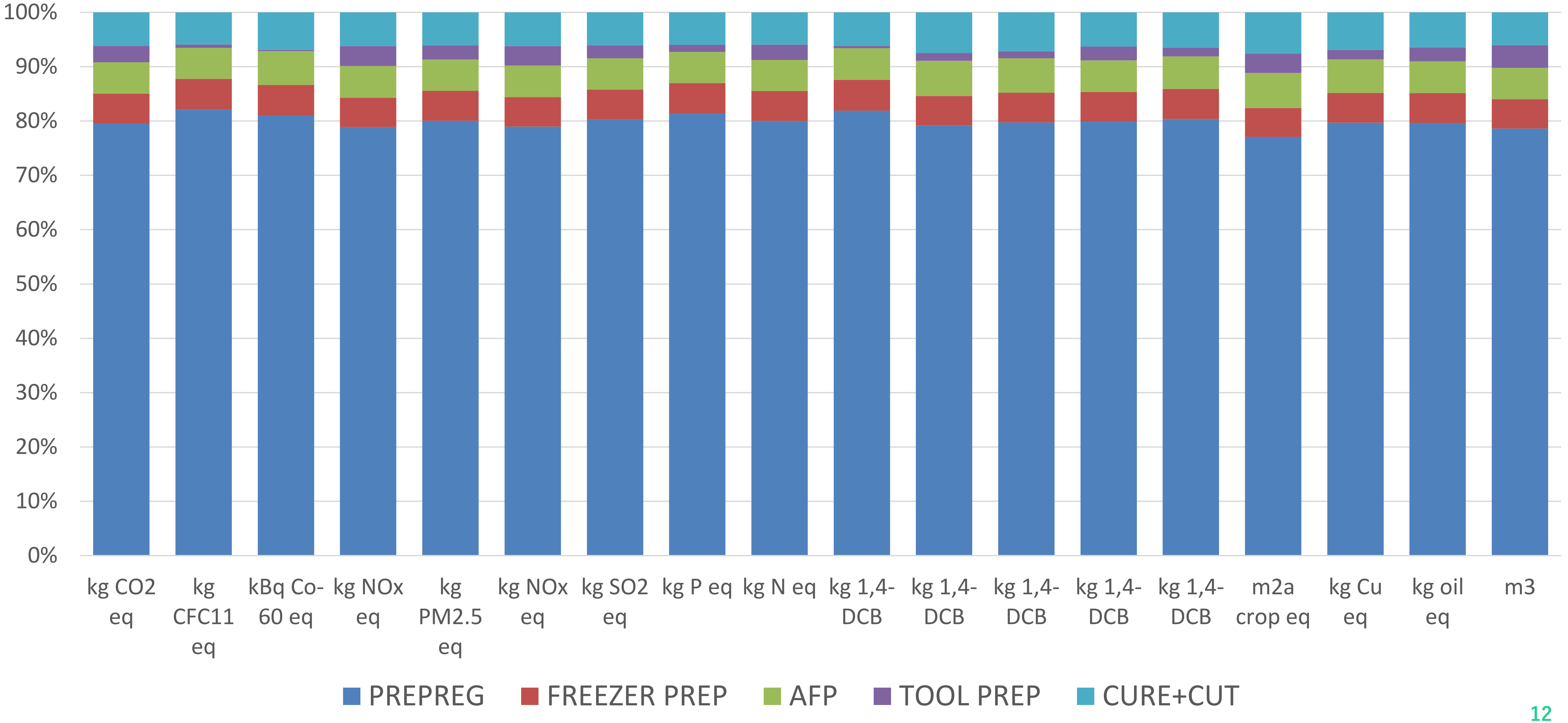
ANALYSIS: Scale-up modelling from demonstrator to commercial product

Whilst AFP is a layup process that is very accurate with minimal waste, there will be complexities when scaling this up to a full-size commercial product. The economies of scale are not fully known at this time, and remains the biggest gap in knowledge from this project.



RESULTS: LCIA of aerospace demonstrator (all environmental indicators)

Method: ReCiPe 2016 Midpoint (H)

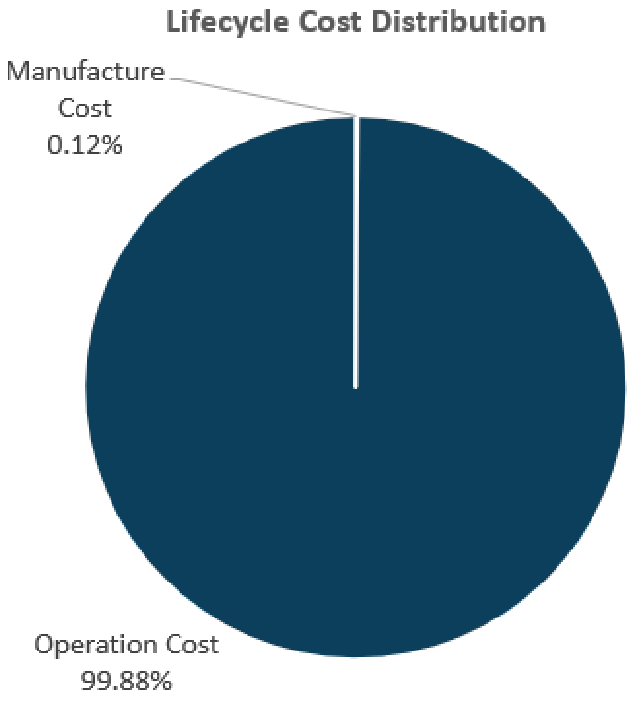


Chapter 2

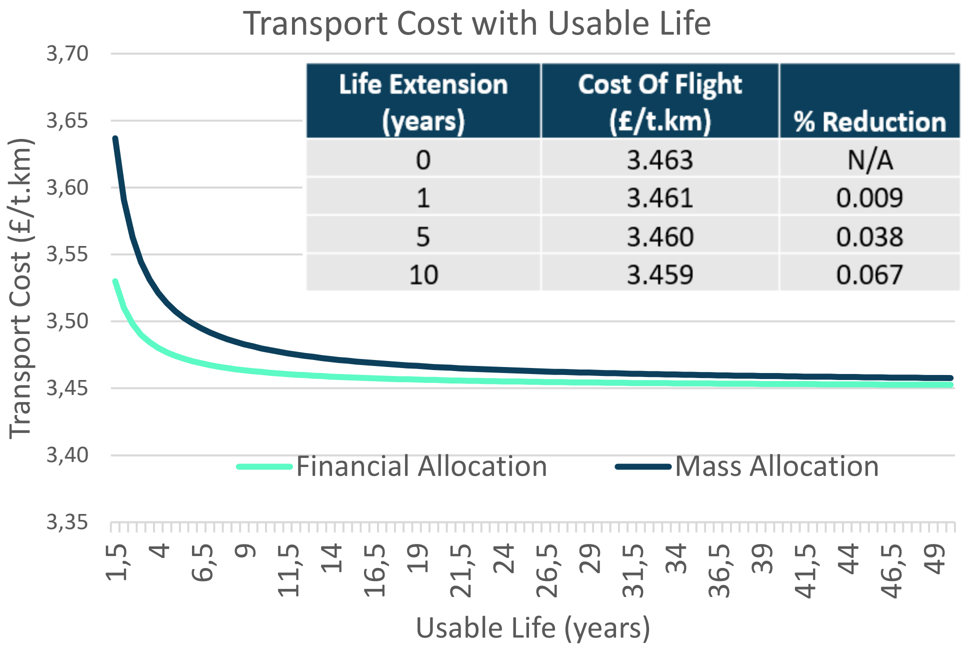
LCA / LCC RESULTS DISCUSSION

Aerospace demonstrator case study

Since operational expenses (OPEX) dominate the cost structure, extending the component's lifespan provides minimal tangible benefits. Therefore, the primary objective should be to reduce the component's mass, which will consequently lower operational costs.

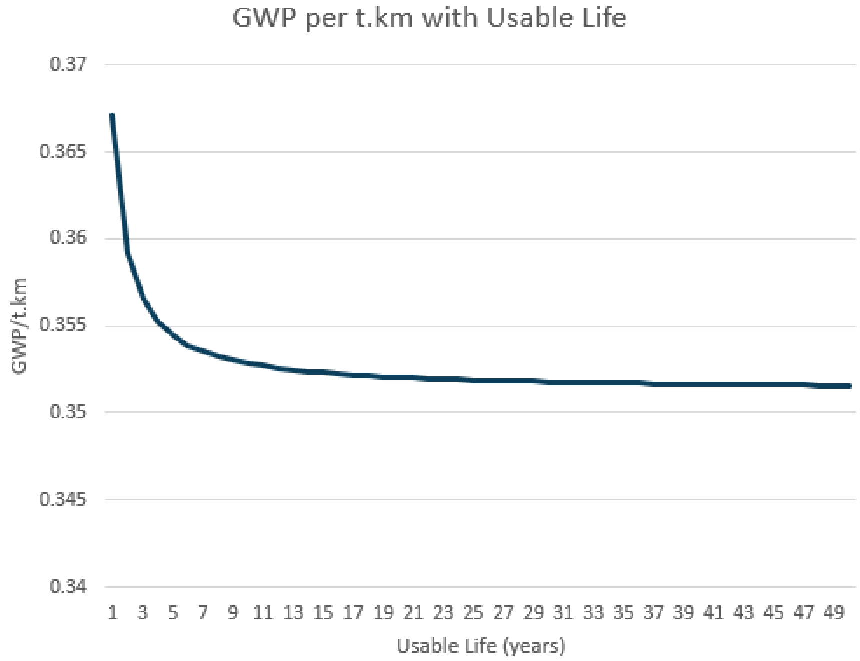


LCC results – life extension benefits



Life Extension (years)	Cost Of Flight (£/t.km)	% Reduction
0	3.463	N/A
1	3.461	0.009
5	3.460	0.038
10	3.459	0.067

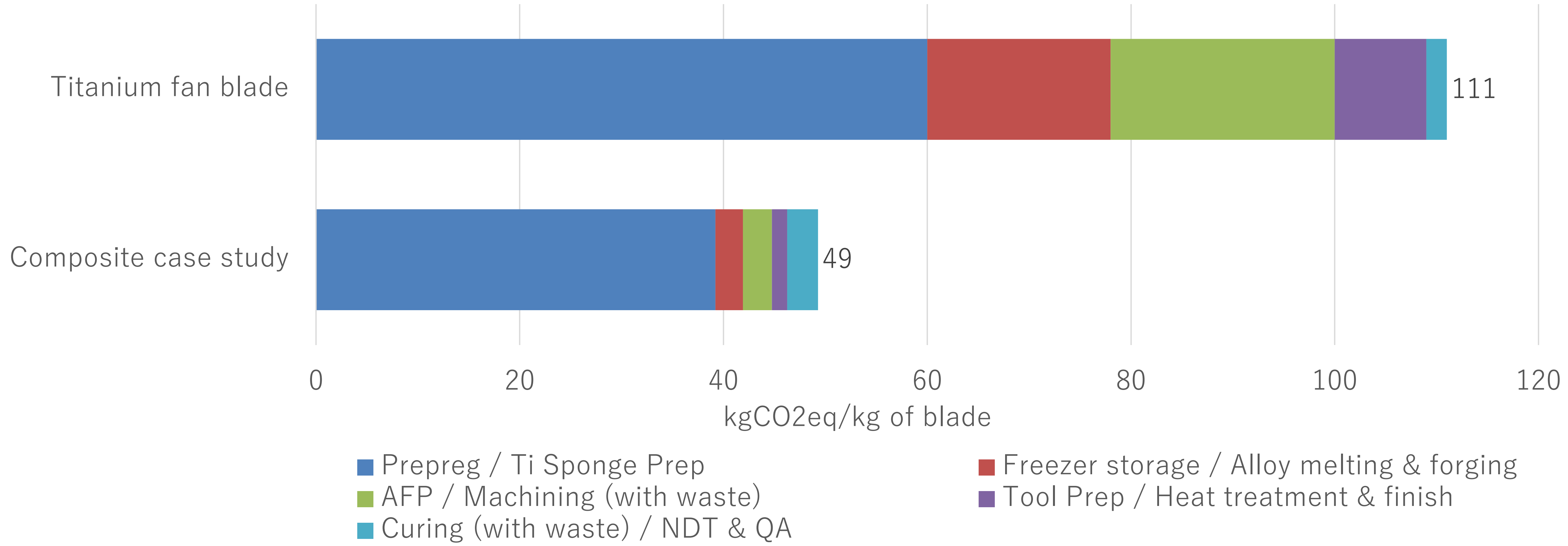
LCA results – GWP with usable life



RESULTS: GWP comparison per kg of manufactured blade, kgCO2eq./kg

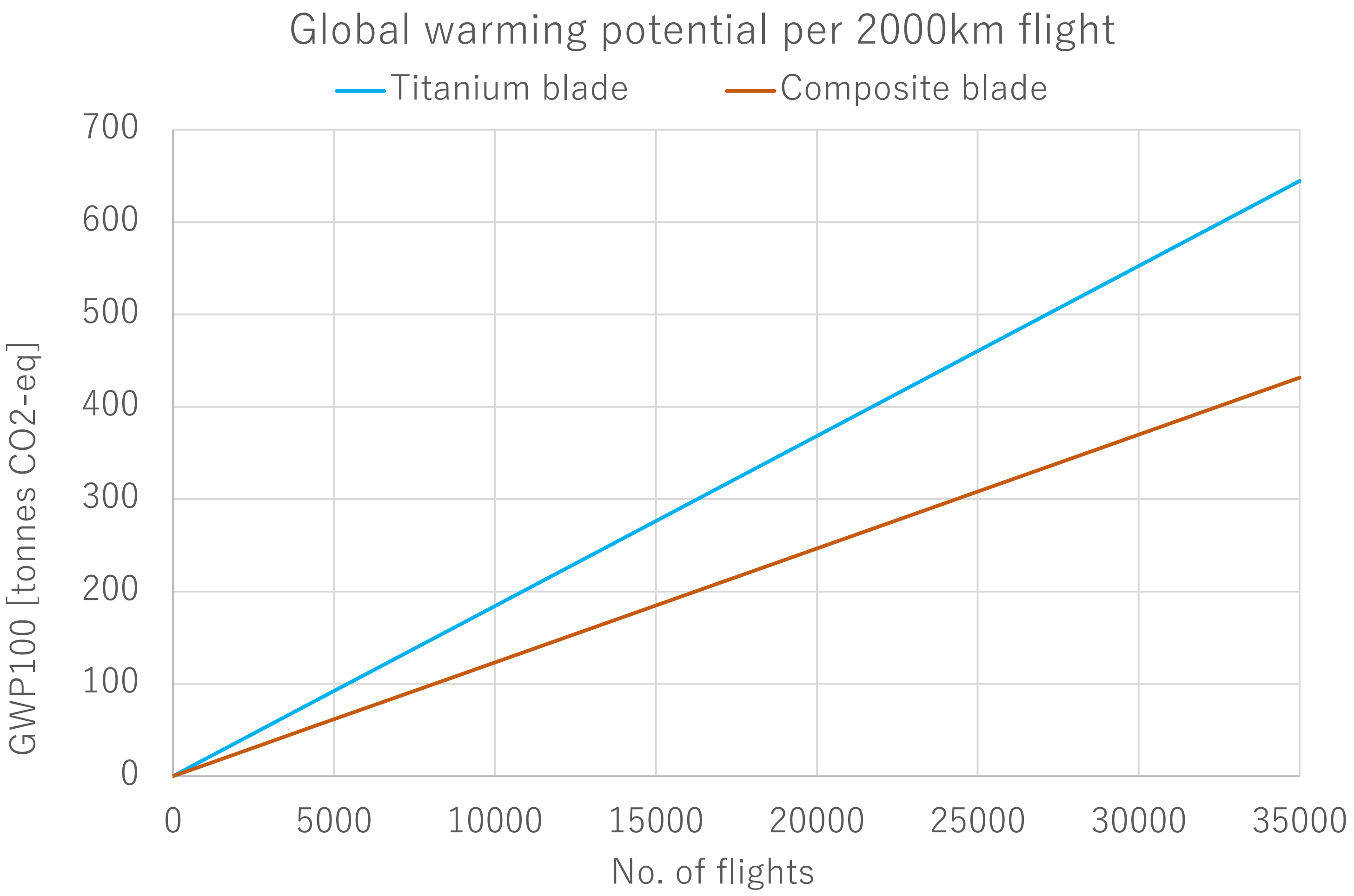
With titanium industry standard

using data from doi.org/10.1016/j.procir.2024.12.091



RESULTS: GWP comparison of inflight emissions over estimated use life

GWP100 per 2000km flight



Component	% GWP reduction
Titanium blade	0.00%
Composite blade	33.05%

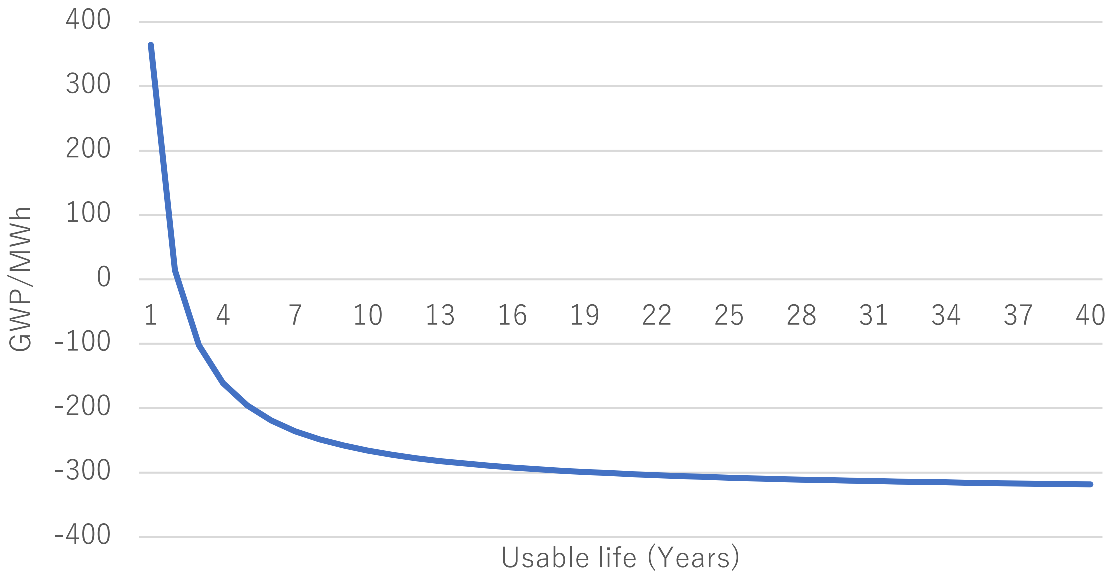
Type of aircraft - Maximum payload [kg]	**22000**
Capacity utilisation [%]	**82.40%**
Distance of flight [km]	**2000**
No. of flights (Pressurisation cycles)	**35000**
Calculate consumption of kerosene [kg]	**6395.57**

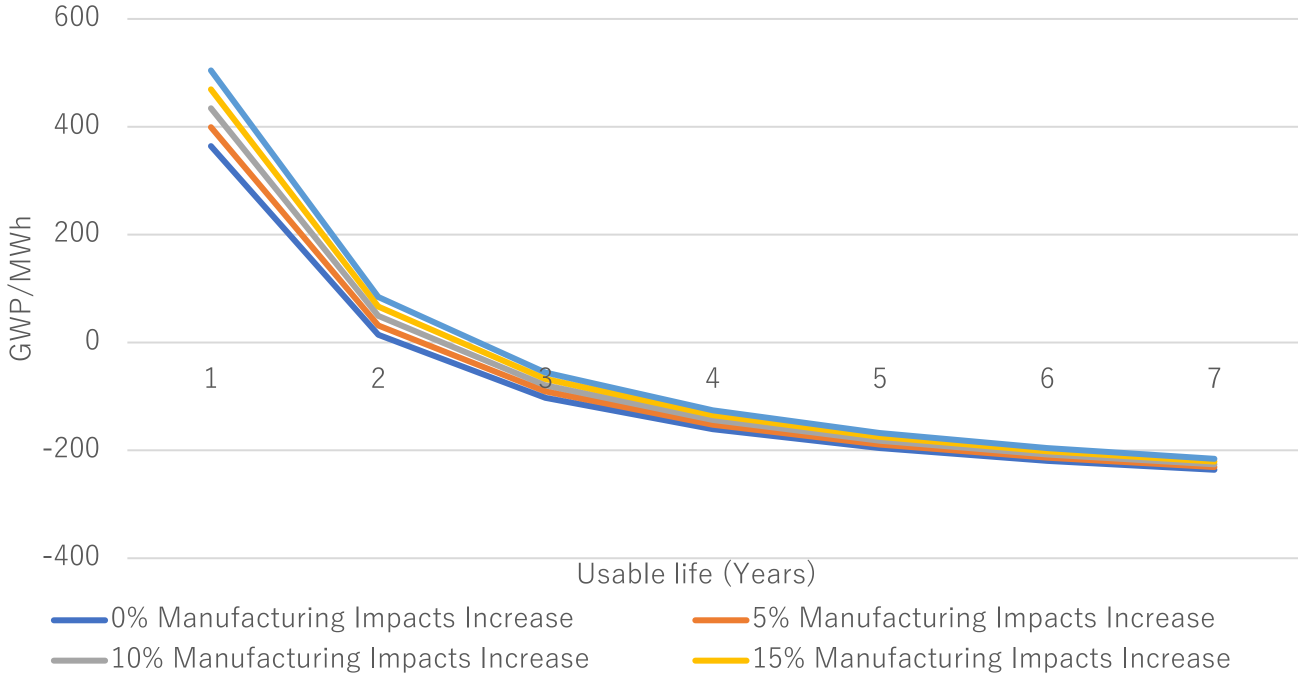
Chapter 2

LCA & LCC RESULTS DISCUSSION FOR WIND

Wind energy preliminary case study results

- Increasing the operational life of the WTB spar rapidly reduces GWP per MWh as upfront manufacturing emissions are spread over more clean energy generation.
- After an initial positive GWP/MWh, the spar reaches a payback point where impacts are offset, then delivers net climate benefits over time.
- Even with up to ~20% higher manufacturing emissions for life extension, all scenarios still achieve net environmental benefits within a reasonable timeframe.

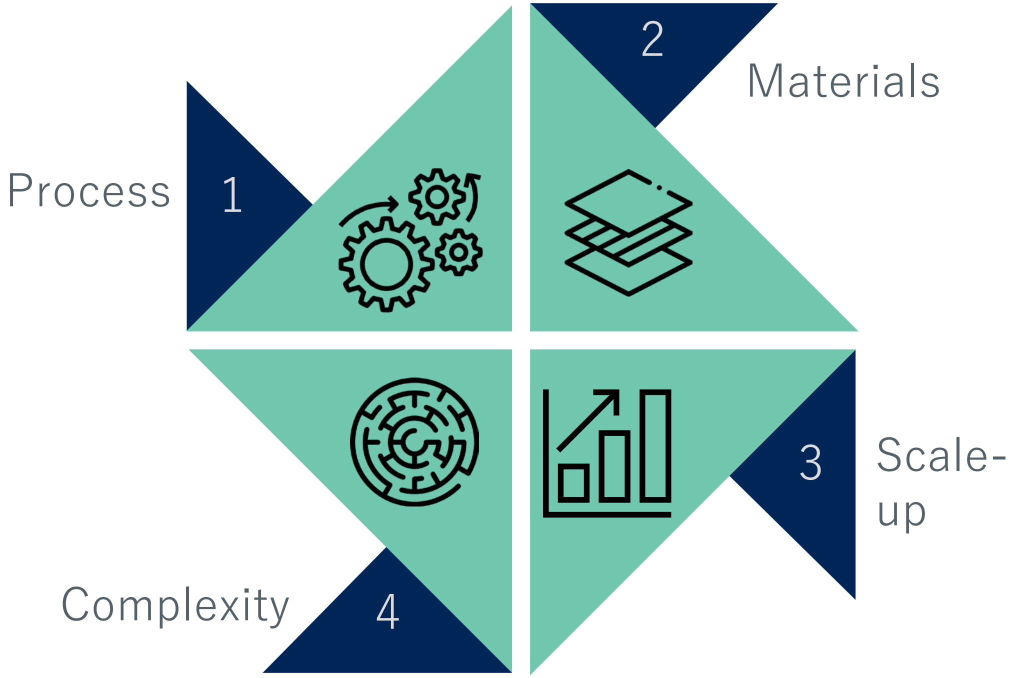




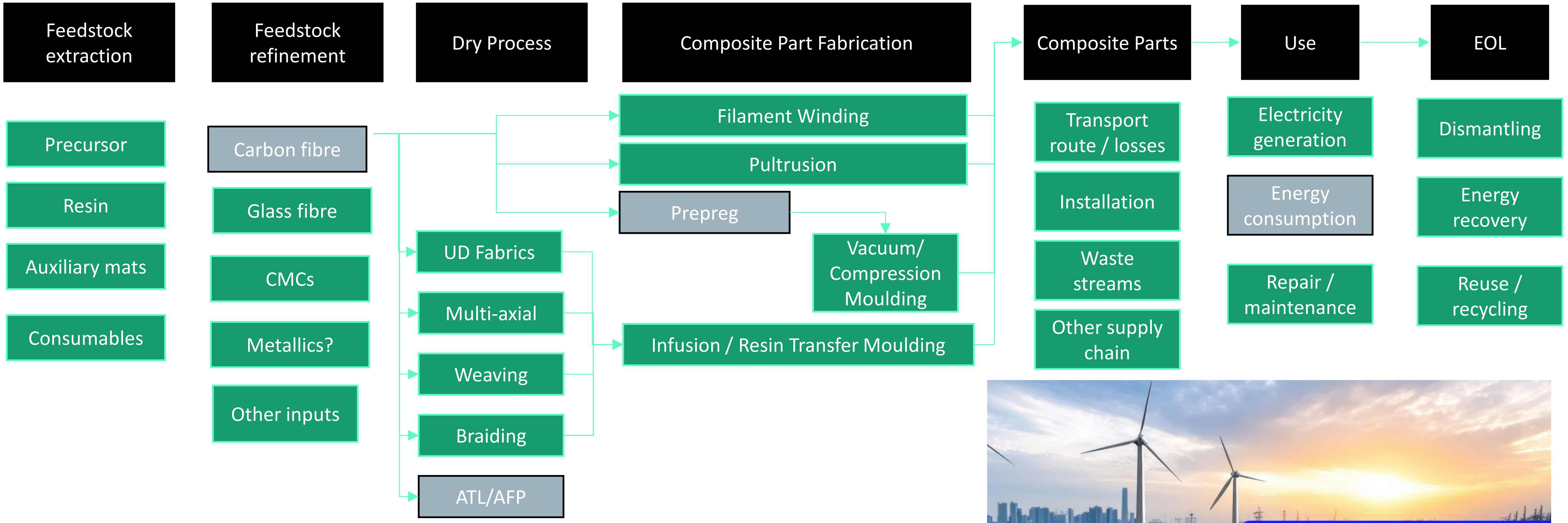
D-STANDART framework for LCA/LCC:

SUMMARY

CRITERIA	ACCURACY	ASPECTS AFFECTING
Process	High	Direct match for processes
Material	High	Direct match for materials
Complexity	Good	Tapered features identified and energy demand calculated
Scale-up	Low	Waste generation, economies of scale with energy use



Scope for further work



https://www.nccuk.com/insight-impact/UK-Large-Structures-Innovation-Centre/

03

Socio-economic study

Aerospace and Wind Energy Surveys

Socio-economic study

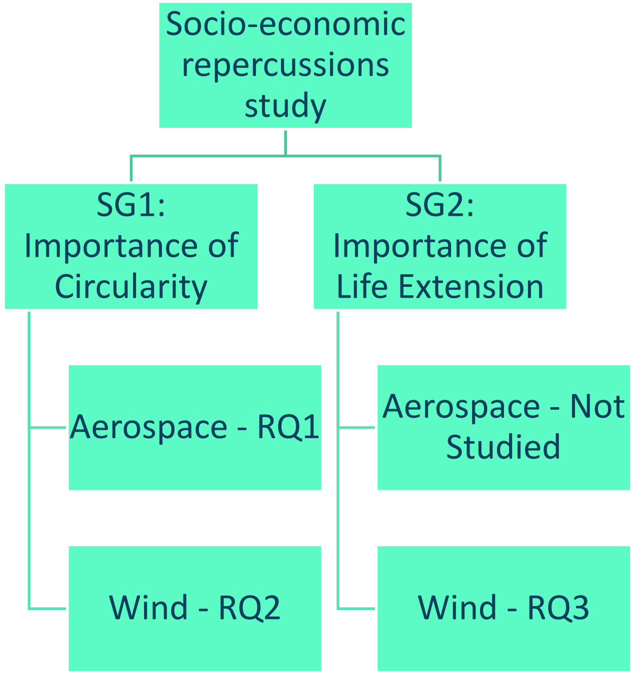
Aerospace and Wind Energy Surveys - OVERVIEW

AIM: Understand the degree of importance that the public attaches to sustainability considerations when forming their attitudes to technological solutions, and use that understanding to investigate how the outcomes of D-STANDART can positively affect European society

APPROACH: Three Research Questions (**RQs**) aligned to two Social Goods (**SGs**) seeking to define D-STANDART role in progressing the SGs, which are societal outcomes assumed to be desirable.

- **SG1**: A reduction in primary materials and energy usage caused by an increase in materials circularity
  - Are more circular products more saleable?
  - Does increased circularity reduce opposition to positive change?
- **SG2**: A reduction in primary materials and energy usage caused by an increased service lifetime
  - Are longer product lives useful market differentiators in markets where the public buys the benefit of a product and not the product itself?
  - Do longer product lives reduce opposition to positive change?

  - **RQ1**: Is the travelling public willing to pay in increased air fares for aircraft which make more use of circular materials, and if so, to what degree?
  - **RQ2**: Do perceptions of materials circularity affect public acceptance of wind farm developments, and if so, to what degree?
  - **RQ3**: Do perceptions of service lifetime affect public acceptance of wind farm developments, and if so, to what degree?



Socio-economic study

Aerospace and Wind Energy Surveys - IMPLEMENTATION

RQ1
Willingness-to-Pay (WTP) study

Air travel choices are financial decisions over which individuals have more or less complete agency.

RQ2 & RQ3
Willingness-to-Accept (WTA) study
Decisions around wind farm developments are made primarily by developers and consenting authorities, with individuals only able to apply secondary pressure via campaigning.

Both surveys conducted using online tool Conjointly

The effect of aircraft circularity on public willingness to pay for regional flights was investigated in a conjoint analysis with **160 respondents**.

Markov Chain Hierarchical Bayes (MCHB) methodology based on the concept of “utility”: a variable that defines how likely an individual is to choose one product over another, given their respective combinations of attributes.

The effect on wind turbine circularity and durability on public willingness to accept wind farm development was investigated in a controlled trial with **374 respondents**.

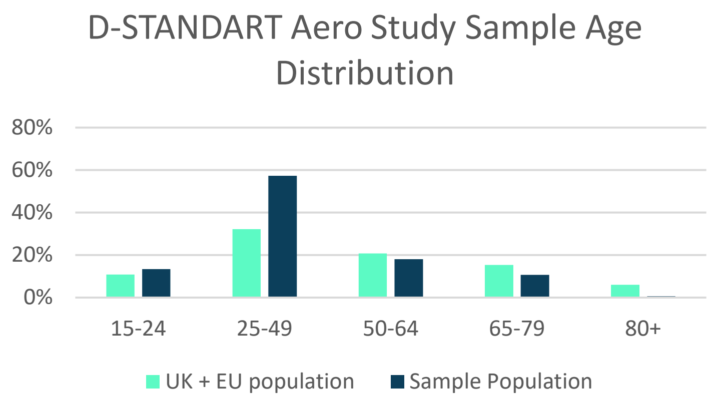
Participants shown one of three framings:
Acceptance of disposable turbines with a 20-year lifetime (control)
Acceptance of disposable turbines with a 30-year lifetime (life extension)
Acceptance of recyclable turbines with a 20-year lifetime (circularity)

Socio-economic study

Aerospace and Wind Energy Surveys – SAMPLE CHARACTERISATION

Willingness-to-Pay (WTP) study Aerospace

The sample used Conjointly's "Self-Serve Sample A" methodology, which puts the survey out to a variety of partner apps and online platforms. Each respondent was paid $3 for completing the survey. The partner platforms provide the study with demographic information for each respondent.



Gender Identity	Expected Number*	Sample Number
Male	70	60
Female	70	84
Other	1	6
Prefer not to Answer	9	0

*Based on the 2021 census of England and Wales

Willingness-to-Accept (WTA) study Wind

Key factor for the WTA study is whether the sample groups are consistent with each other based on demographic questions to control for the following factors:

1. Demographics (variable type)
   1. Age bracket (ordinal)
   2. Gender identity (categorical)
   3. Which continent you live in (categorical)
   4. Perceived wealth (ordinal)
   5. Highest educational level (ordinal)
   6. Household decision maker (categorical)

2. Attitudes (variable type)
   1. Sympathy with green agenda (ordinal)
   2. Optimistic or pessimistic view of the future (categorical)

3. Habits (variable type)
   1. Have you made green upgrades to your home (categorical)
   2. Do you have a renewable energy tariff (categorical)

Differences between the sample groups were investigated with a series of chi-square independence tests at the 0.05 significance level for each possible dimension of difference finding **no significant differences** between the sample groups. Therefore, if there are differences in the responses, these can reasonably be attributed to the different framings of the question of acceptance.

Socio-economic study

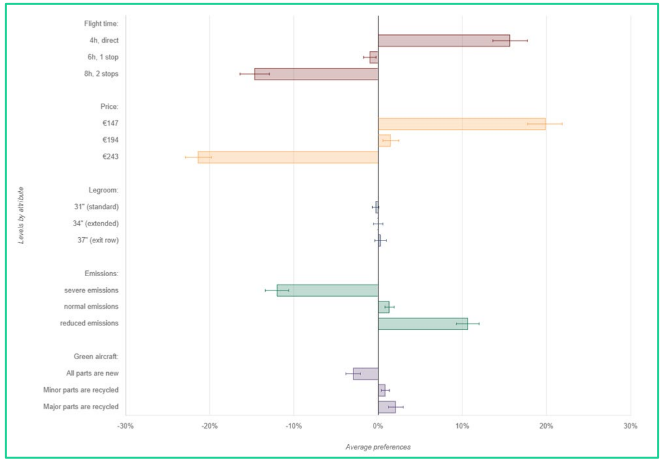
Aerospace and Wind Energy Surveys - RESULTS

Willingness-to-Pay (WTP) study
Aerospace

RQ1: Flight choices were created by Conjointly by combining different levels of various attributes according to an experiment design.

	Level 1	Level 2	Level 3
Flight Time	4h, direct	6h, 1 stop	8h, 2 stops
Price	€147	€194	€243
Legroom	31" (standard)	34" (extended)	37" (exit row)
Emissions	severe emissions	normal emissions	reduced emissions
Circularity	All parts are new	Minor parts are recycled	Major parts are recycled

- After price and flight time, aircraft emissions is most important.
- The effect of legroom on preference is within the margin of error.
- The effect of circularity is small, but positive and significant. More recycled parts increase the preference for the flight product



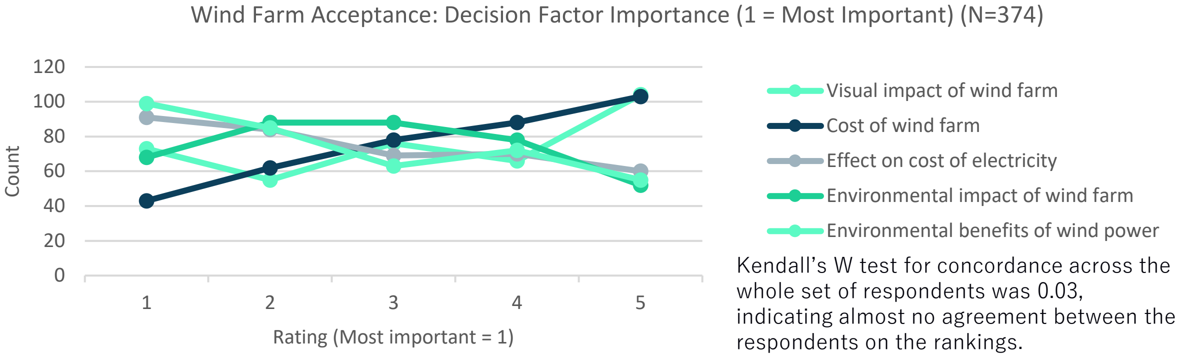
Willingness-to-Accept (WTA) study
Wind

RQ2: Small but significant positive effect on public acceptance.

The one-tailed Mann-Whitney U-test was used with a significance level of 0.1 to test for increases in acceptance to an exploratory level of confidence.
$N = 256$, $\alpha = 0.1$, $p = 0.095$
$p < \alpha$ therefore **the increase in acceptance is significant**.
$r = 0.082$ ($r = 0.1$ small effect, 0.3 medium effect, 0.5 large effect)

RQ3: A small positive effect is seen, but it is not significant at $\alpha = 0.1$.
$N = 241$, $\alpha = 0.1$, $p = 0.109$
$p > \alpha$ therefore the **increase in acceptance is NOT significant.**
$r = 0.079$ ($r = 0.1$ small effect, 0.3 medium effect, 0.5 large effect)

Factor importance: The most important factors are effect on cost of electricity and environmental benefits of wind power.



Kendall's W test for concordance across the whole set of respondents was 0.03, indicating almost no agreement between the respondents on the rankings.

Socio-economic study

Aerospace and Wind Energy Surveys - CONCLUSIONS

Conclusions were:

- Material and product circularity has some salience in the public mind when making buying and acceptance decisions.
- Product longevity does not have that same salience (noting that neither of the studies conducted involved the direct purchase of a product)
- Material and/or product circularity can be a positive marketing factor in both airline and wind energy industries, with small but significant impacts on both willingness to pay for flights and willingness to accept onshore wind farm development
- Life extension of aircraft or turbines is unlikely to affect either willingness-to-pay for flights or willingness to accept wind farms. It does, of course, directly affect asset earning potential.

Further work:

- This was a small study, working with samples exhibiting some bias. There would be value in a larger study specifically focussed on the effect of material and product circularity on buying and acceptance decisions.
- Efforts to improve product longevity in the airline and wind industries are primarily focussed on companies' bottom line, and should not be part of marketing
- Efforts to improve circularity, by contrast, have a direct impact on revenue and acceptance, and should be very much a part of marketing, with a particular focus on ensuring the positive framing is present when decisions are being made
- In order to ensure this does not acquire the negative framing of "greenwashing", real efforts to develop circular material and product solutions and markets are valuable, and should be supported by further research.

Thank you!

Contact points for any question:

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04

Discussion

Q&A

Impact of the D-STANDART value chain

Considerations & Questions of the D-STANDART value chain:

- Is the in-field performance of your products typically limited by fatigue?
- If not, what normally causes your products to be removed from service? (*Corrosion, fretting/wear, discrete source damage, other*)
- Which of the following are of most importance to your business: *manufacturing rate, part cost, development cost, long-term durability, strength, weight*
- As a business, do you validate your products mostly as a system or as individual parts?
- When validating the product system, do you lean more toward simulations or tests?
- If validated physics-based simulations for composite fatigue were available to you, would this avoid any tests?
- As a business, do you typically use lifecycle analysis to understand the environmental impact of your products?
- Do you typically use lifecycle costing to set pricing?

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for Durability Modelling of Composites

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