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How Can Sustainable Manufacturing Save you Money and Help the Planet

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Introduction

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Learning Objectives

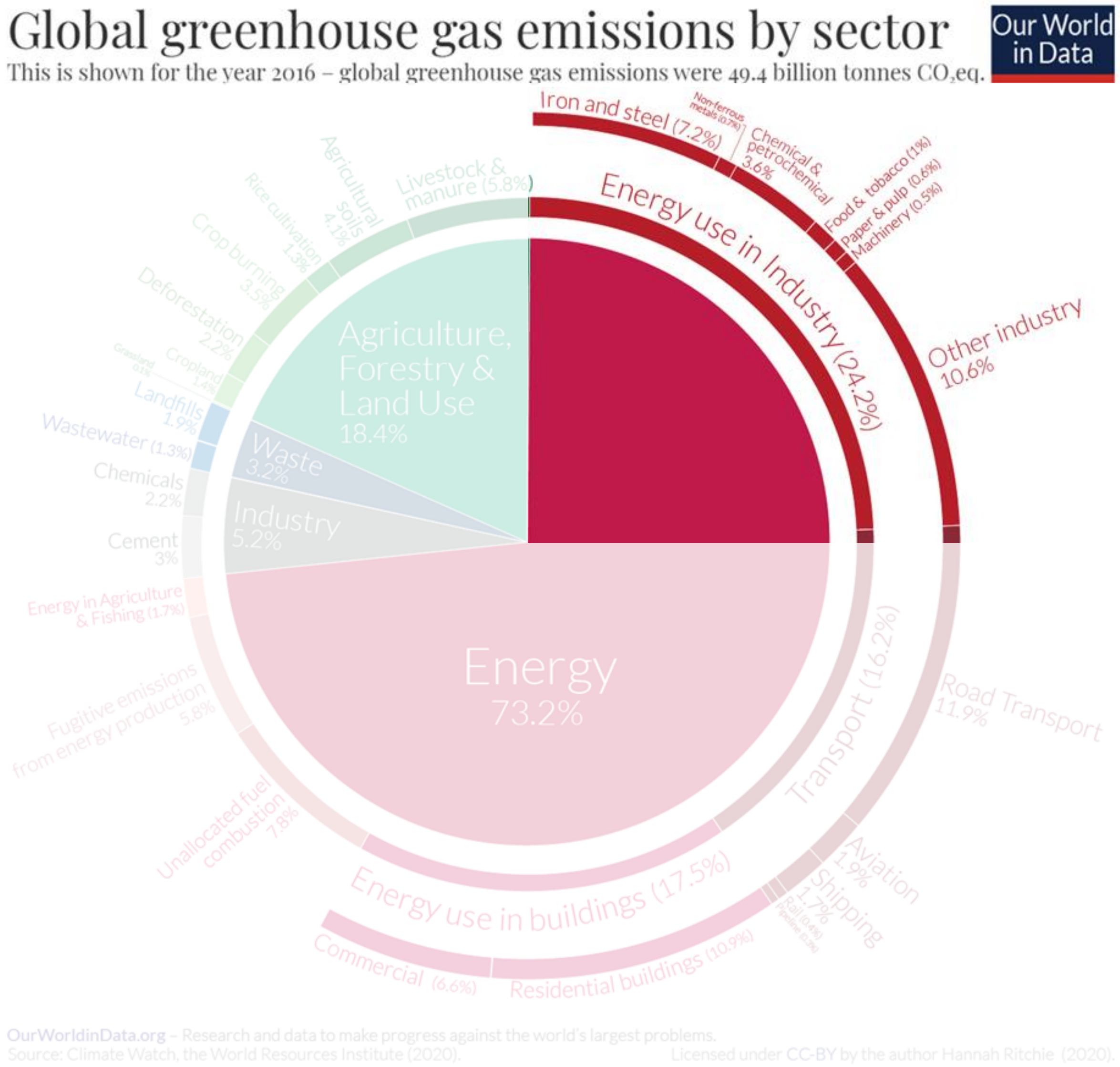
1. Compare different metal additive, subtractive and hybrid workflows.
2. Learn about sustainability metrics within manufacturing and how they impact the embodied carbon of manufactured components.
3. Learn about applying sustainability metrics to assess three manufacturing workflows to select the most sustainable methodology.
4. Evaluate how sustainability metrics can be predicted to enable the decision-making process within the design phase.

Presentation Agenda

1. Manufacturing’s Impact
2. What is Sustainable Manufacturing
3. The Case Study – Set Up
4. The Case Study – Manufacturing
5. The Case Study – Evaluation
6. Looking to the Future

Manufacturing’s Impact

Small Scalable Changes…



CO2 emissions from the : **Metallurgy**, **Machinery** and other **Manufacturing** based industries correspond to **9 Billion Tonnes of CO2eq**

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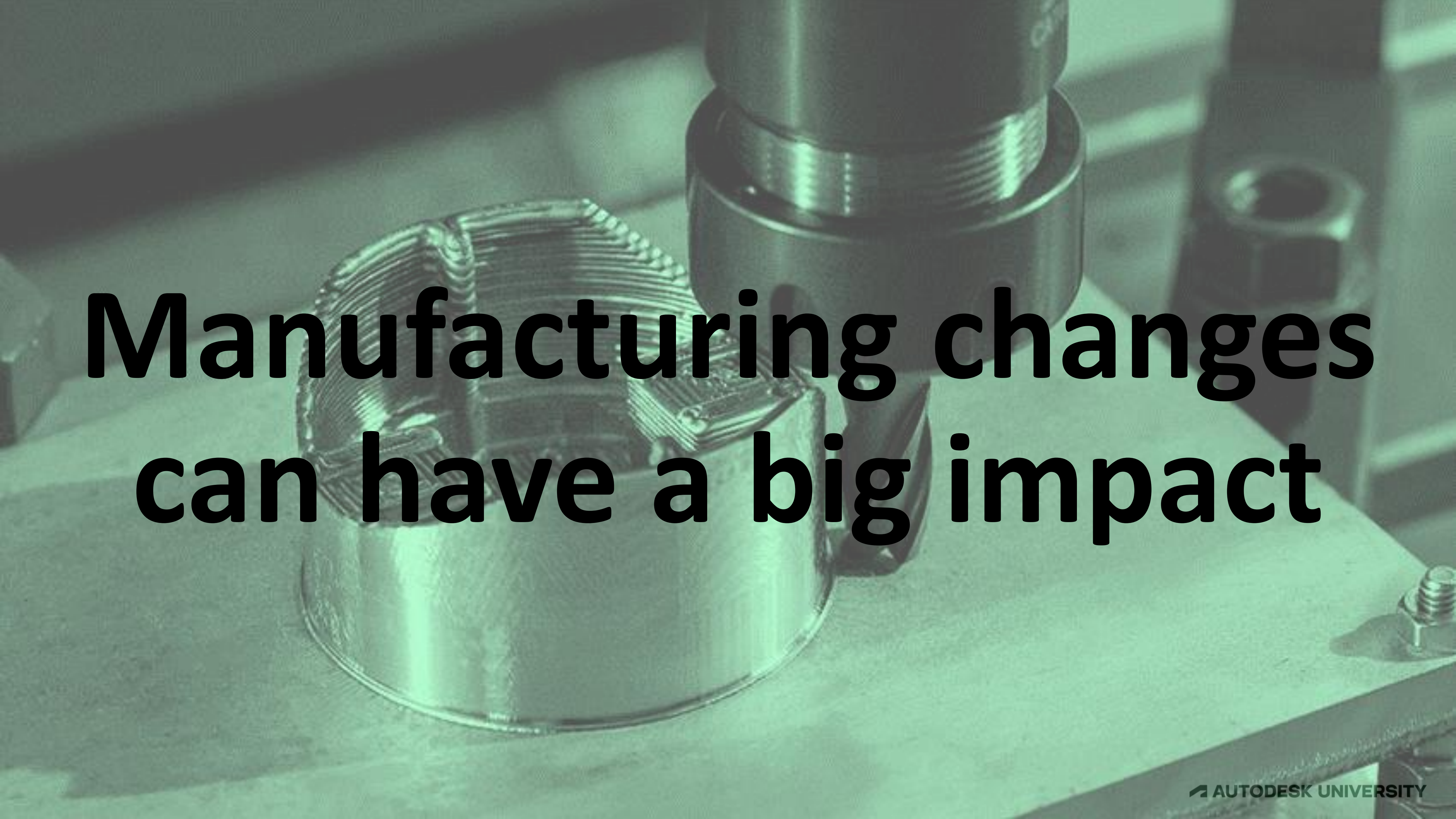


Manufacturing changes can have a big impact

What is Sustainable Manufacturing?

“The creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources”

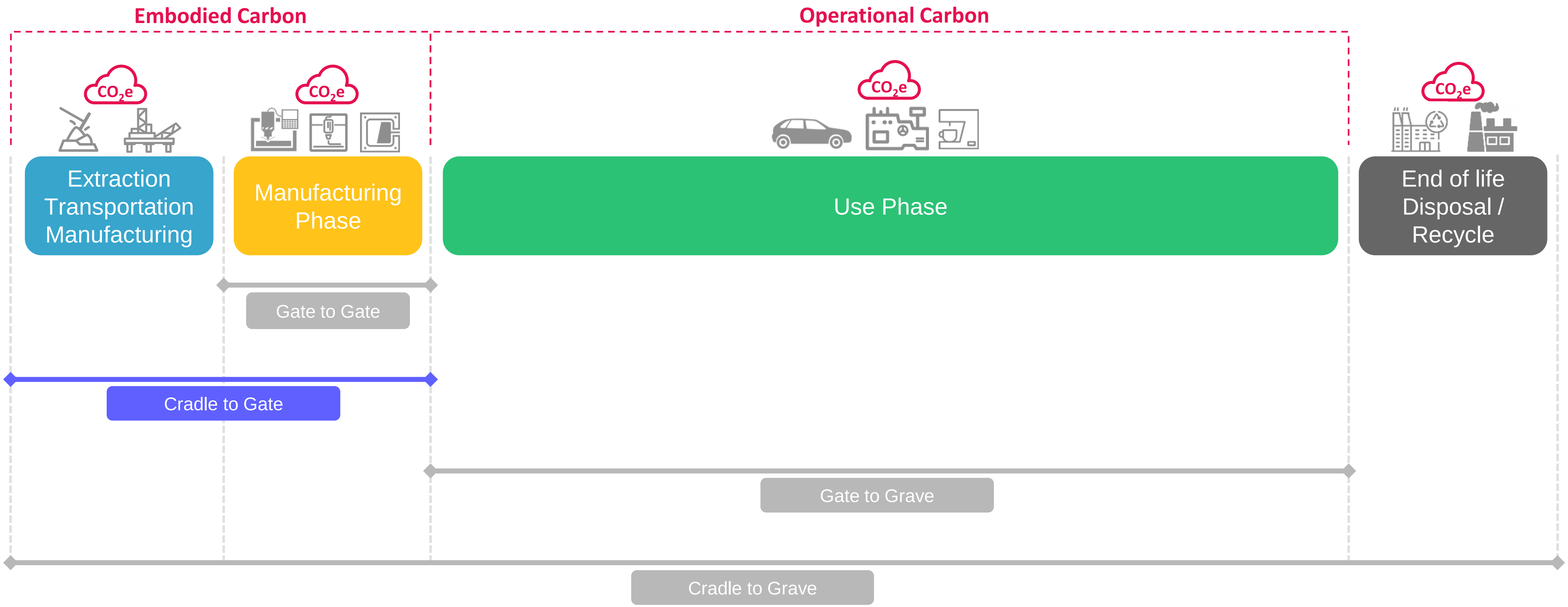
Evaluating and reducing manufacturing costs

Understanding and reducing manufacturing energy consumption

Minimising raw material consumption and reducing waste

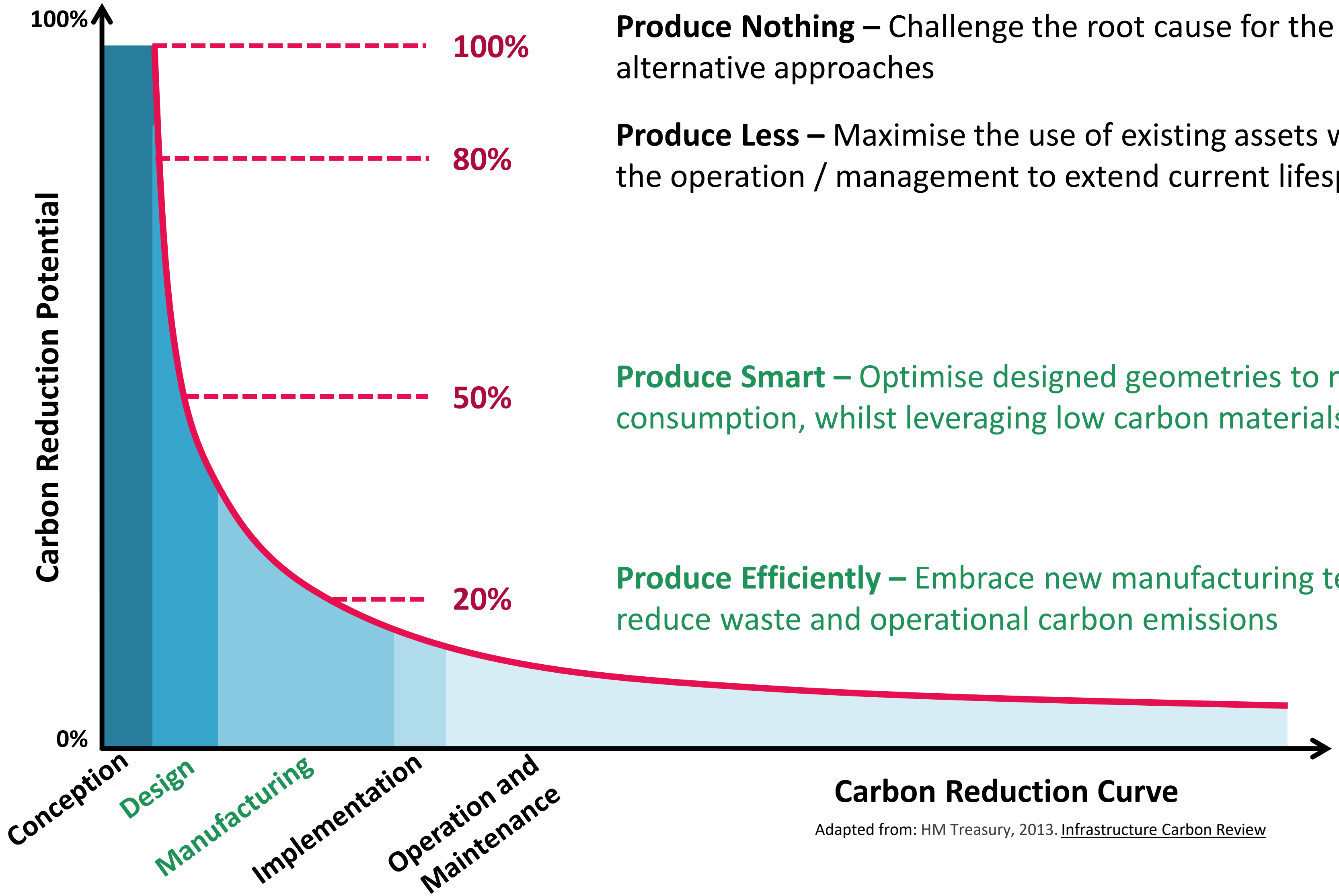
How to measure sustainability in manufacturing?

Leveraging an LCA to determine an embodied carbon value of a component



What problem are we trying to solve?

How do we Tackle Carbon Early with Smart and Efficient Production?



Produce Nothing – Challenge the root cause for the need and explore alternative approaches

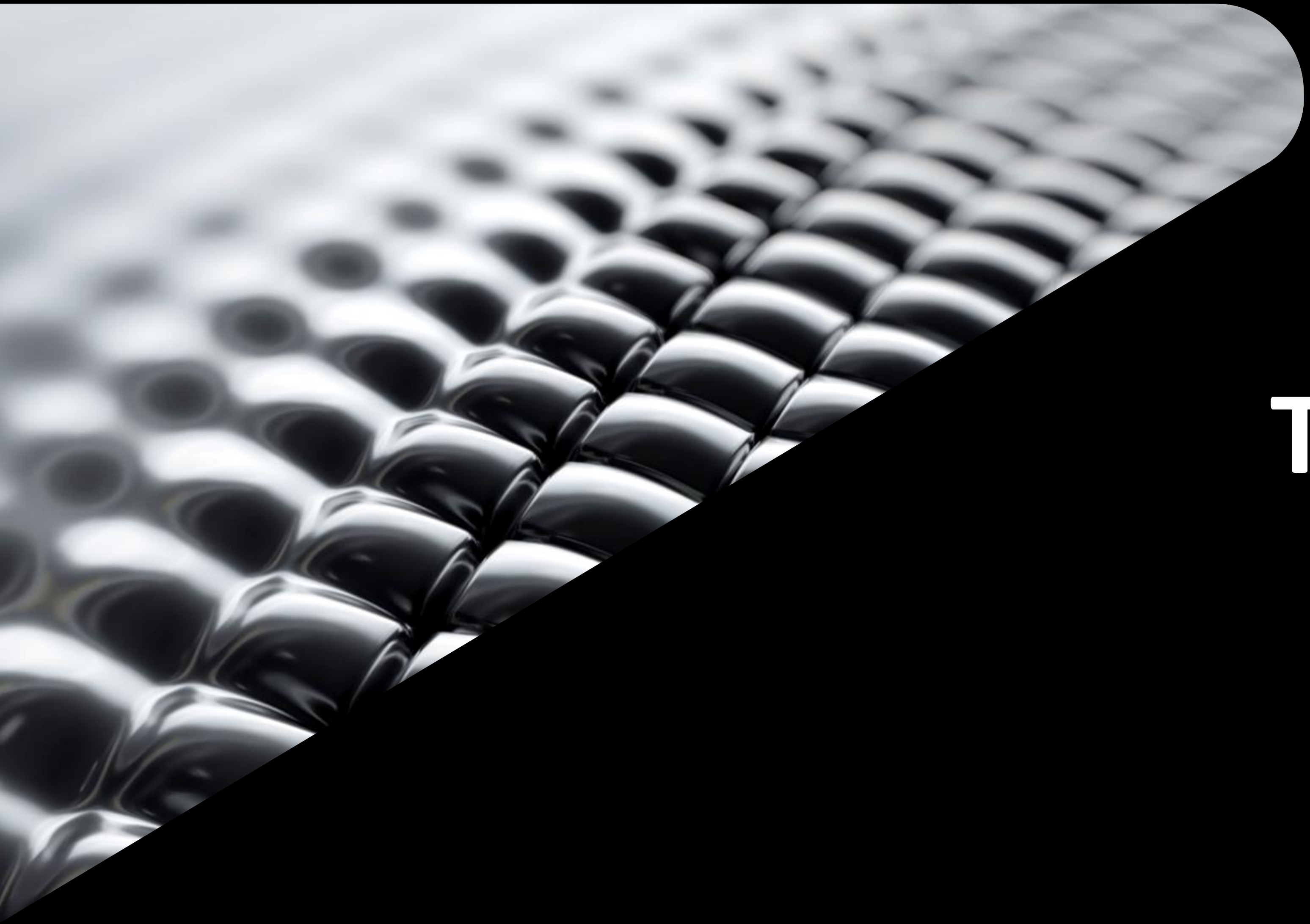
Produce Less – Maximise the use of existing assets whilst optimising the operation / management to extend current lifespans

Produce Smart – Optimise designed geometries to reduce resource consumption, whilst leveraging low carbon materials

Produce Efficiently – Embrace new manufacturing technologies to reduce waste and operational carbon emissions

Carbon Reduction Curve

Adapted from: HM Treasury, 2013. Infrastructure Carbon Review

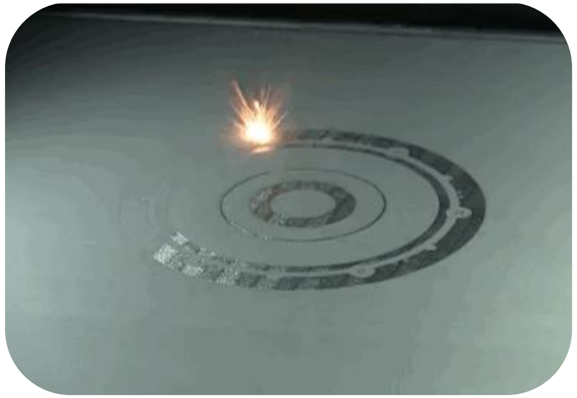


The Case study - Setup

Manufacturing Methods

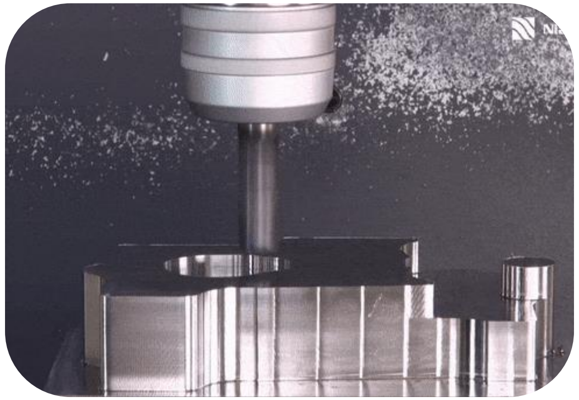
Manufacturing Technologies Used

Additive Manufacturing
Laser Powder Bed Fusion
(L-PBF)



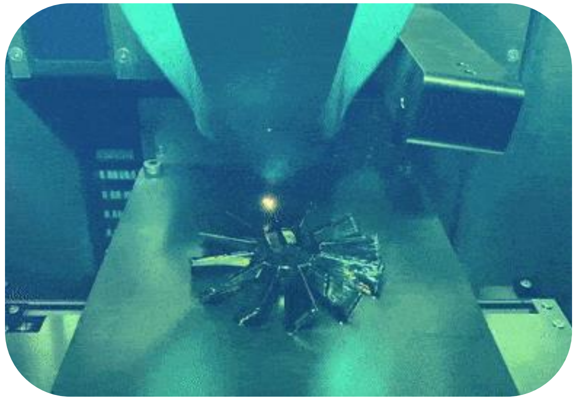
https://www.ge.com/news/reports/these-engineers-3d-printed-a-mini-jet-engine-then

Subtractive Manufacturing
CNC Milling



https://www.mmsonline.com/articles/rough-faster-with-better-tool-life-in-difficult-materials

Additive Manufacturing
Direct Energy Deposition

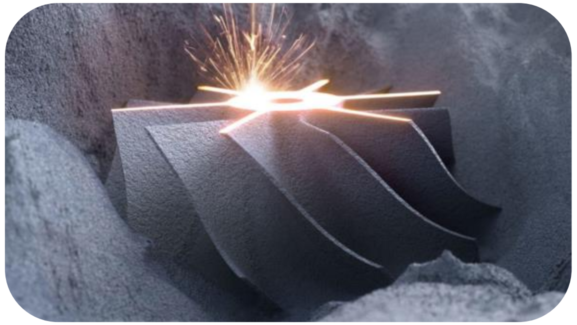


https://meltio3d.com/technology/

Manufacturing Methods

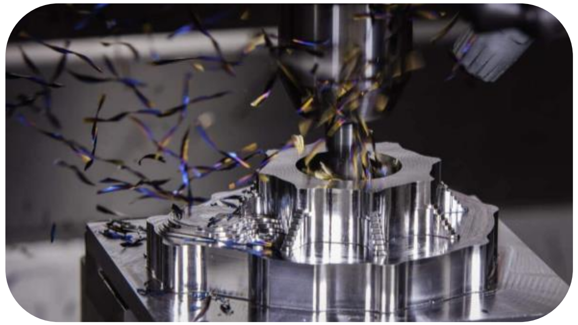
Manufacturing Machines Used

Additive Manufacturing
Laser Powder Bed Fusion (L-PBF)



https://www.3dnatives.com/en/direct-metal-laser-sintering100420174-2/

Subtractive Manufacturing
CNC Milling



https://www.3erp.com/services/cnc-machining/cnc-milling/

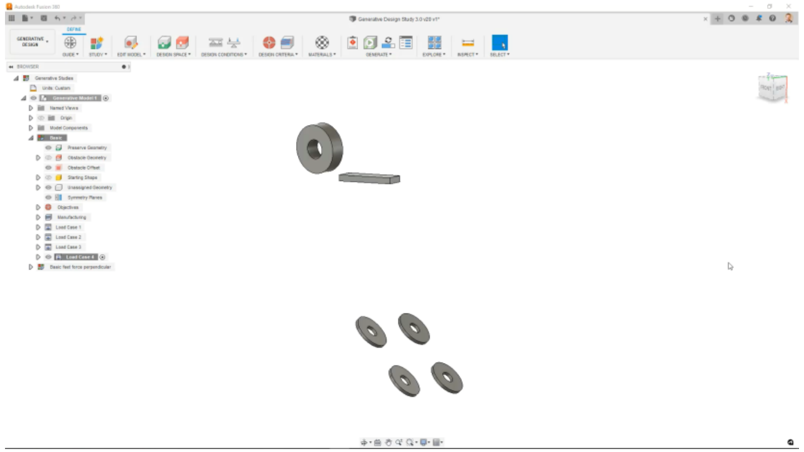
Hybrid Manufacturing
Direct Energy Deposition + CNC Milling

https://3dprint.com/276065/meltio-engine-jumps-over-the-limits-of-metal-3d-printing-by-enabling-hybrid-fabrication/

Generative Design

Geometry Optimisation for mass reduction

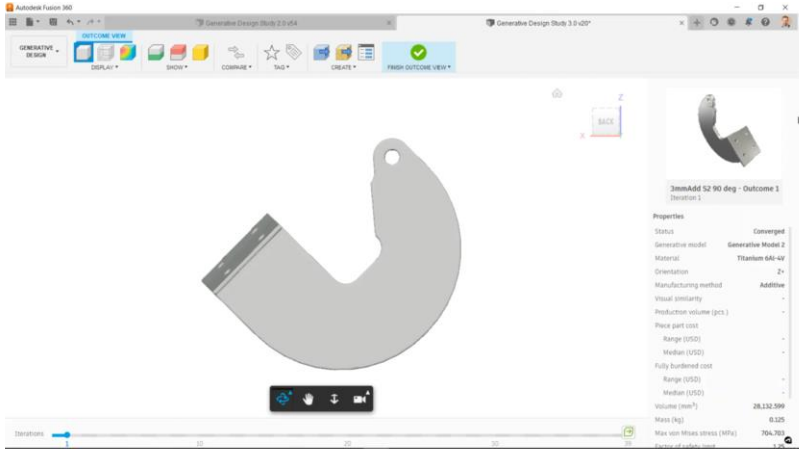
Define



Create a generative design set up by:

- Defining Preserve Regions
- Defining Obstacle Geometries
- Applying Load Cases
- Select Manufacturing Methods and materials
- Select Outcome Goals

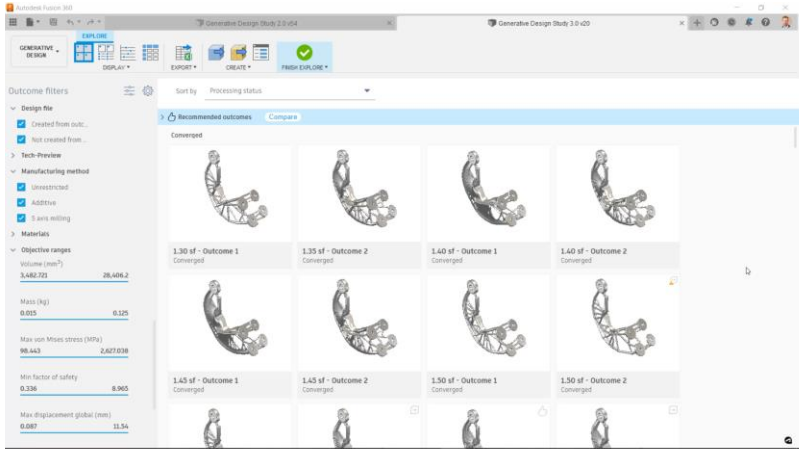
Generate



Wait for Generated Outcomes:

- Allow Generative Design to create optimized outcomes for your defined set up

Explore



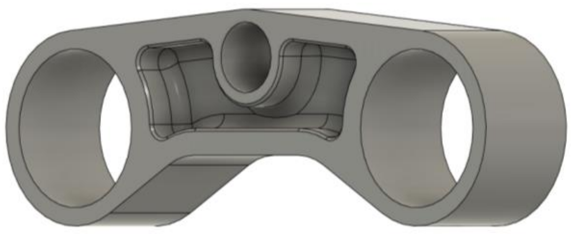
Explore Outcomes:

- Explore the different generated outcomes for different manufacturing methods and materials selected

The Component

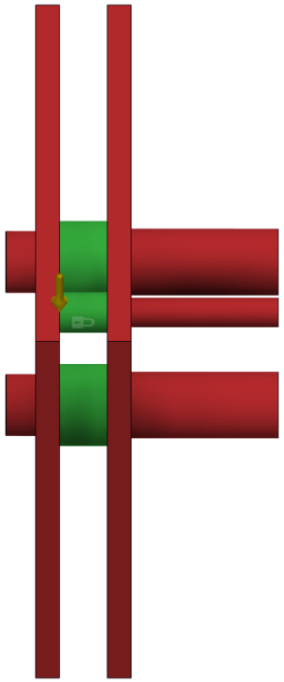
The Classic Triple Clamp Generative Example

Original Design



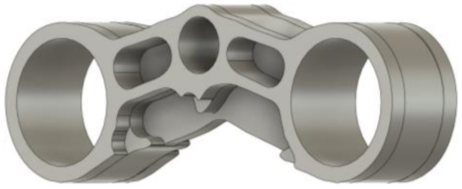
Material = Stainless Steel 316
Part Mass = 2.28 kg

Generative Design Set Up Defined



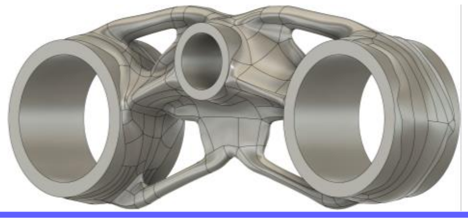
Generative Design Generated Outcomes Explored

2.5 Axis Outcome



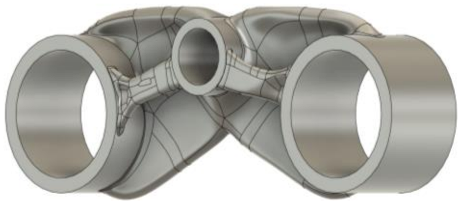
Material = Stainless Steel 316
Part Mass = 1.71 kg

3 Axis Outcome



Material = Stainless Steel 316
Part Mass = 1.62 kg

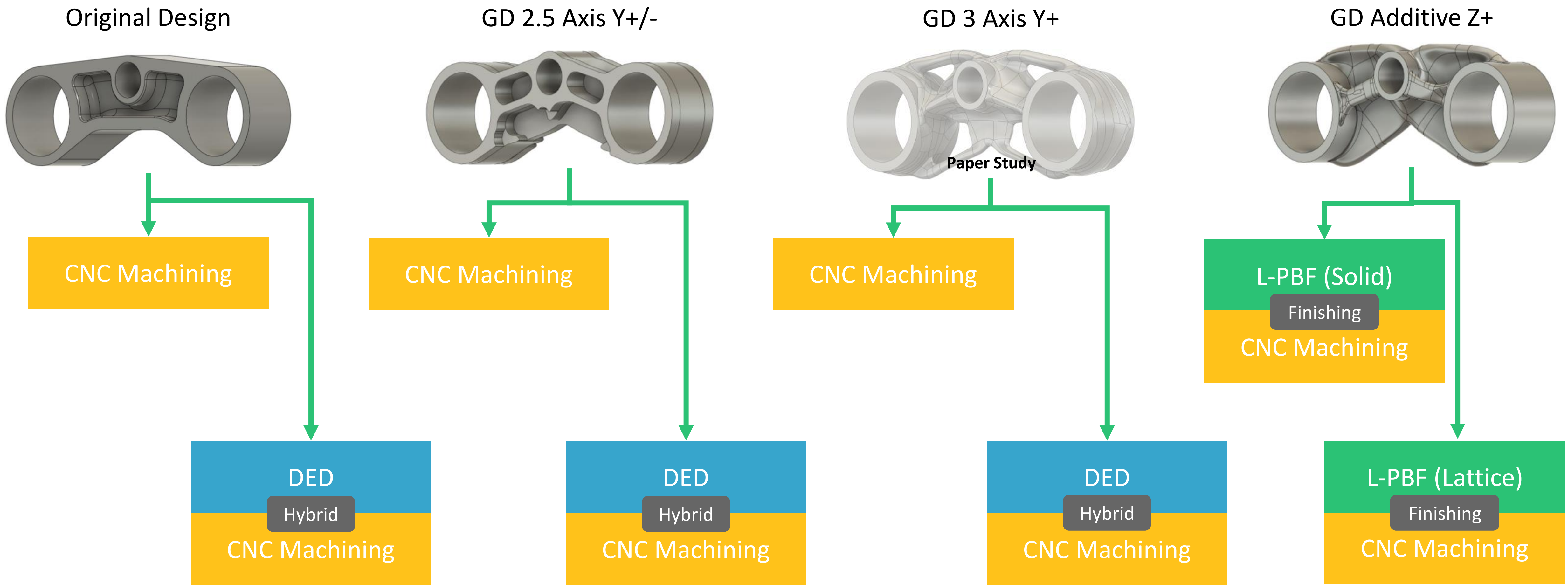
Additive Outcome



Material = Stainless Steel 316
Part Mass = 1.53 kg

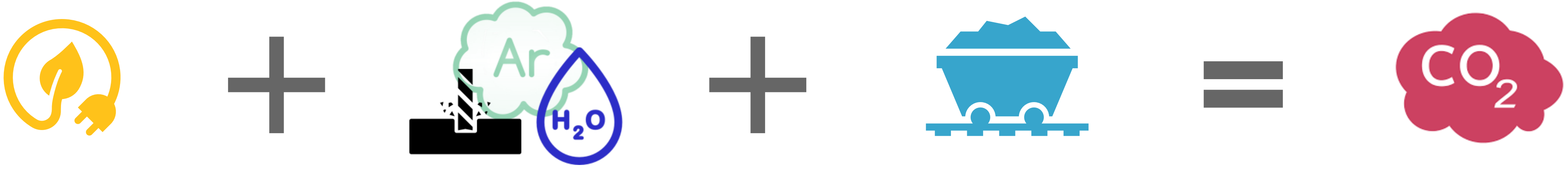
Component + Manufacturing Variations

Manufacturing processes



Evaluating the Manufacturing Outcomes

Tracking manufacturing consumption through a tailor-made LCA



Energy	Consumables	Materials	Total CO2
Operational energy consumption, monitored through IoT power monitors connected the power inputs of the different machinery	Volume of Argon gas, coolant liquid and tools consumed during the manufacturing of the finished component	Raw materials used for the manufacturing of the finished component.	Carbon equivalent values for Energy, Gas, Water and Materials identified through leveraging LCA data bases and research papers.

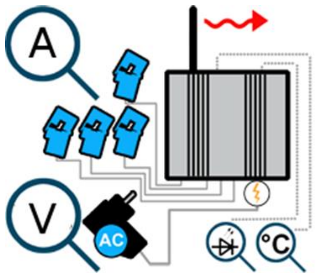
Evaluating the Manufacturing Outcomes

Tracking Operational Energy Consumption

HAAS UMC - 1000

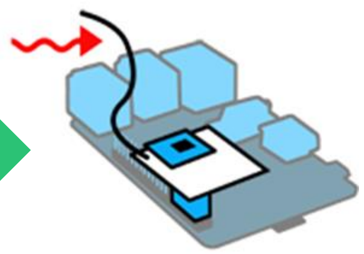
1

Power Monitor



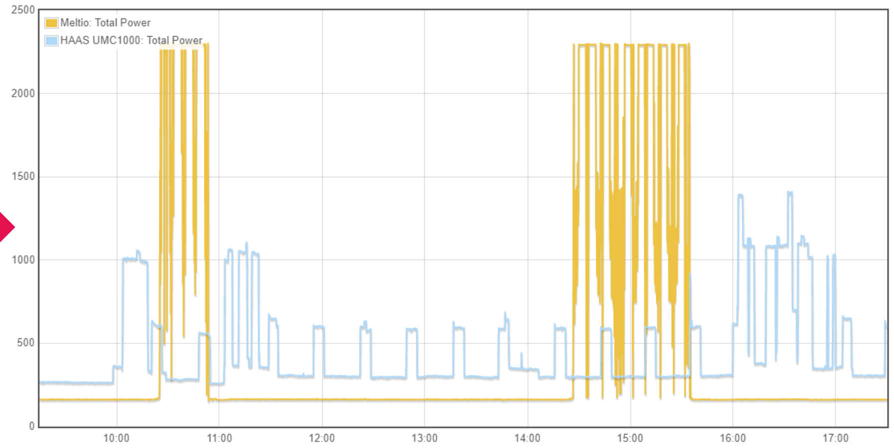
2

IoT Base Station



3

Power Consumption Dashboarding



1. Current clamps connected to the HAAS and Meltio Power Inputs

2. Power Monitor communicates and transfers power consumption data to the base station

3. Base station uploads live power data to cloud data visualisation platform

Evaluating the Manufacturing Outcomes

Tracking Manufacturing Consumables

Material Consumption

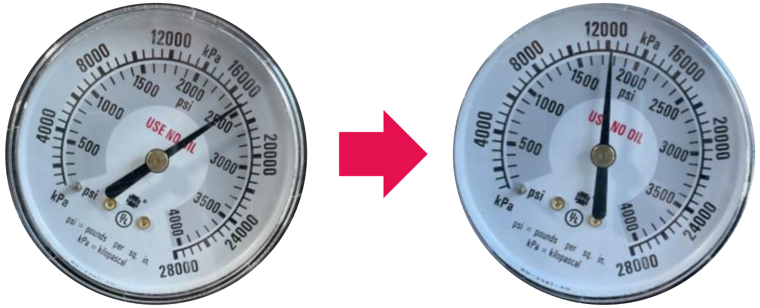
- Calculated the ‘unprocessed’ Stainless Steel 316 required to manufacture each operations stock material*
- Measuring total stock material required to manufacture the component (Waste)

Tool Consumption

- Number of tools worn through during the manufacturing process
- Measured number and size of tools and inserts replaced during the milling operations

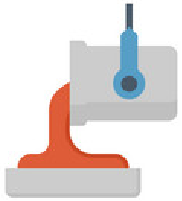
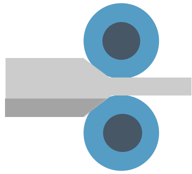
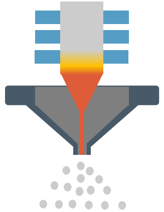
Argon Consumption

- Calculated the Argon consumption for the processing of steel to produce stock material*
- Measured Argon consumption during the manufacturing process



Evaluating the Manufacturing Outcomes

Calculating Embodied Carbon of Stock Materials

Material Processing	Continuous Casting	Hot Rolling	Wire Drawing	Gas Atomisation
				
Process Yield = 100% (Start)	Process Yield = 90%	Process Yield = 95%	Process Yield = 92%	Process Yield = 85%
CO_2 / kg Steel = 5.738 kg	CO_2 / kg Steel = 0.672 kg	CO_2 / kg Steel = 0.176 kg	CO_2 / kg Steel = 0.362 kg	CO_2 / kg Steel = 1.299 kg

CNC

Raw Material Required / kg = 1.17 kg

CO_2 / kg of Steel = 7.683 kg CO_2e / 316 Stainless kg

DED

Raw Material Required / kg = 1.27 kg

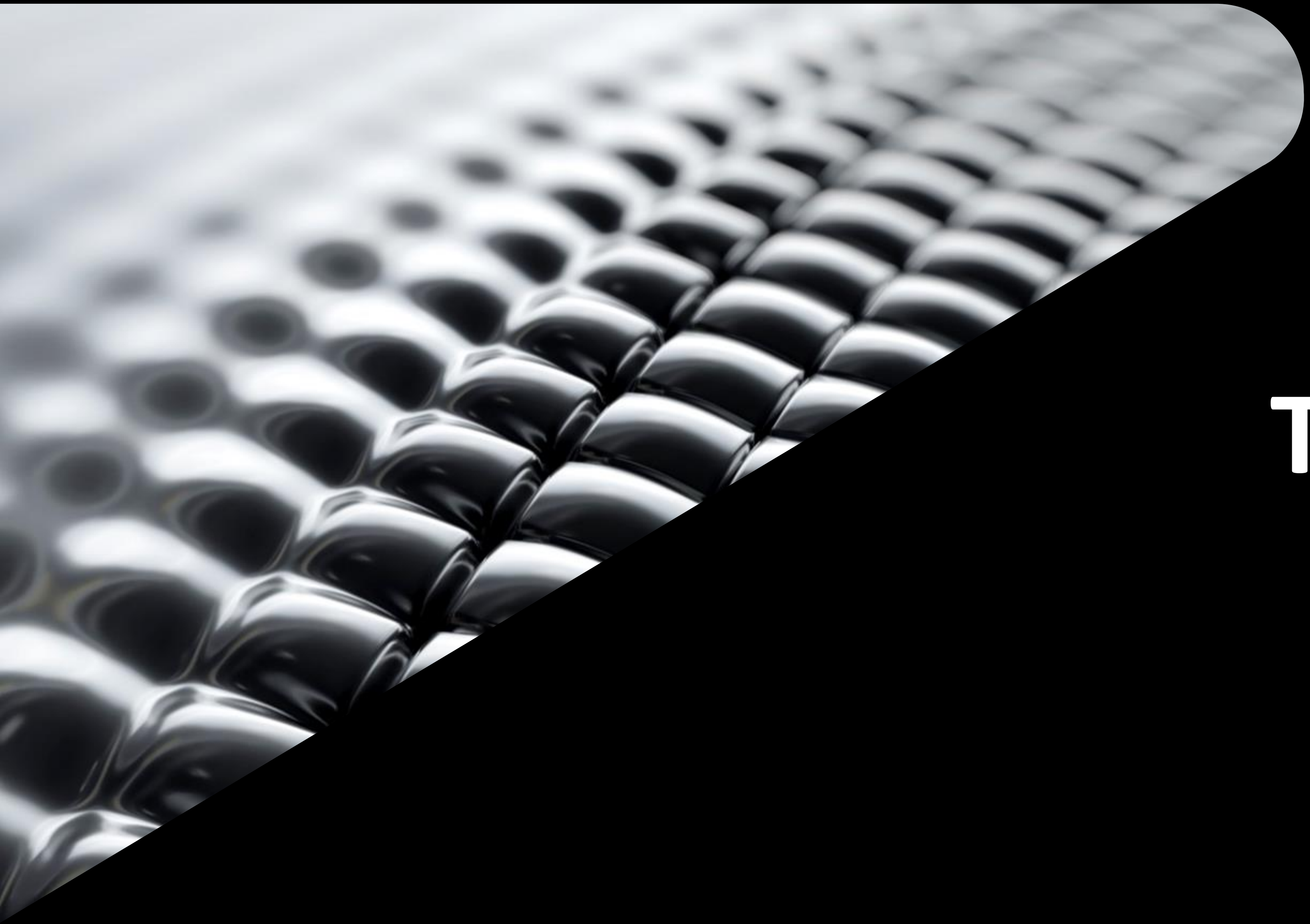
CO_2 / kg of Steel = 8.745 CO_2e / 316 Stainless kg

L-PBF

Raw Material Required / kg = 1.31 kg

CO_2 / kg of Steel = 9.907 CO_2e / 316 Stainless kg

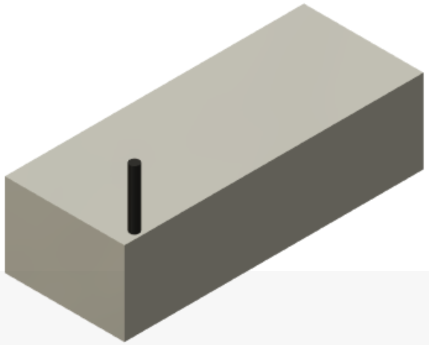
Values have been determined through collating research papers and accessing data from the LCA database 'Ecoinvent'



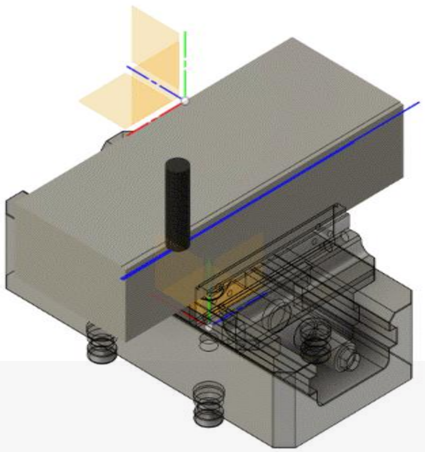
The Case study - Manufacturing

Design & Manufacturing

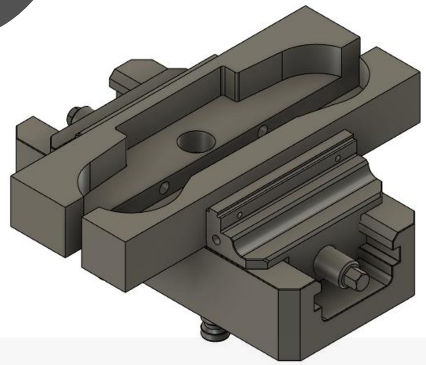
Generating Additive & Subtractive Tool Paths – Milling Manufacturing Plan



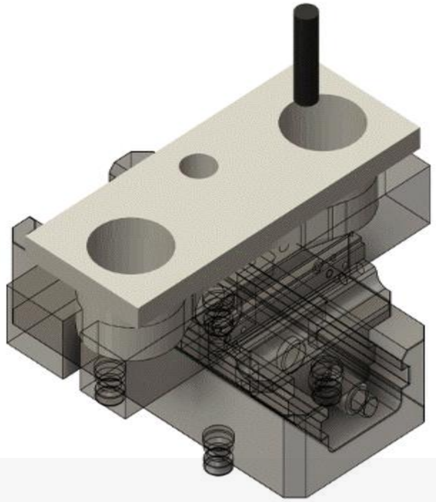
Starting stock



Milling setup 1



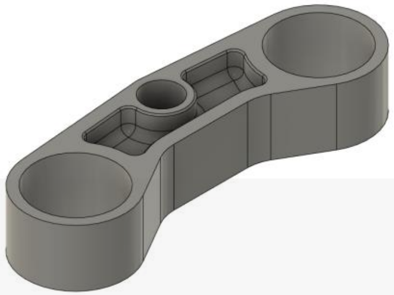
Soft jaw fixture



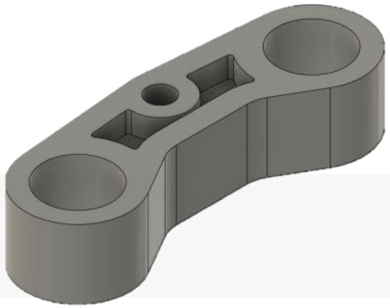
Milling setup 2

Design & Manufacturing

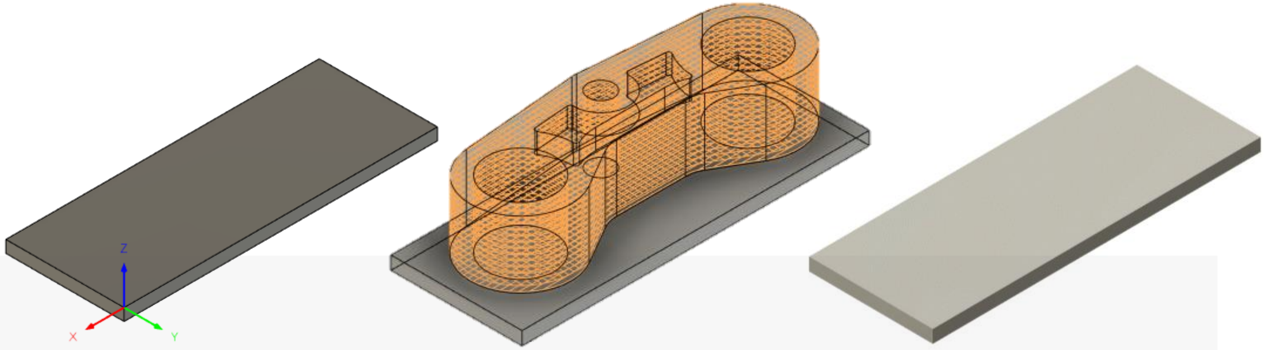
Generating Additive & Subtractive Tool Paths – Hybrid Manufacturing Plan



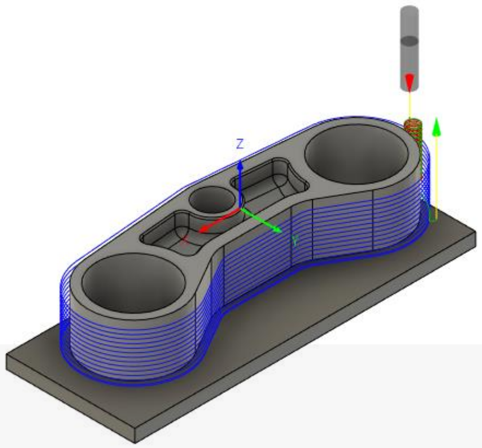
Original design



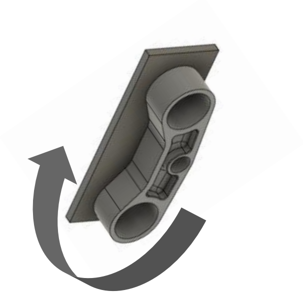
Manufacturing design

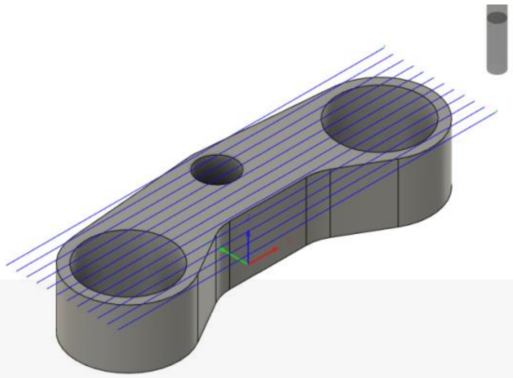


Deposition process



Milling setup 1



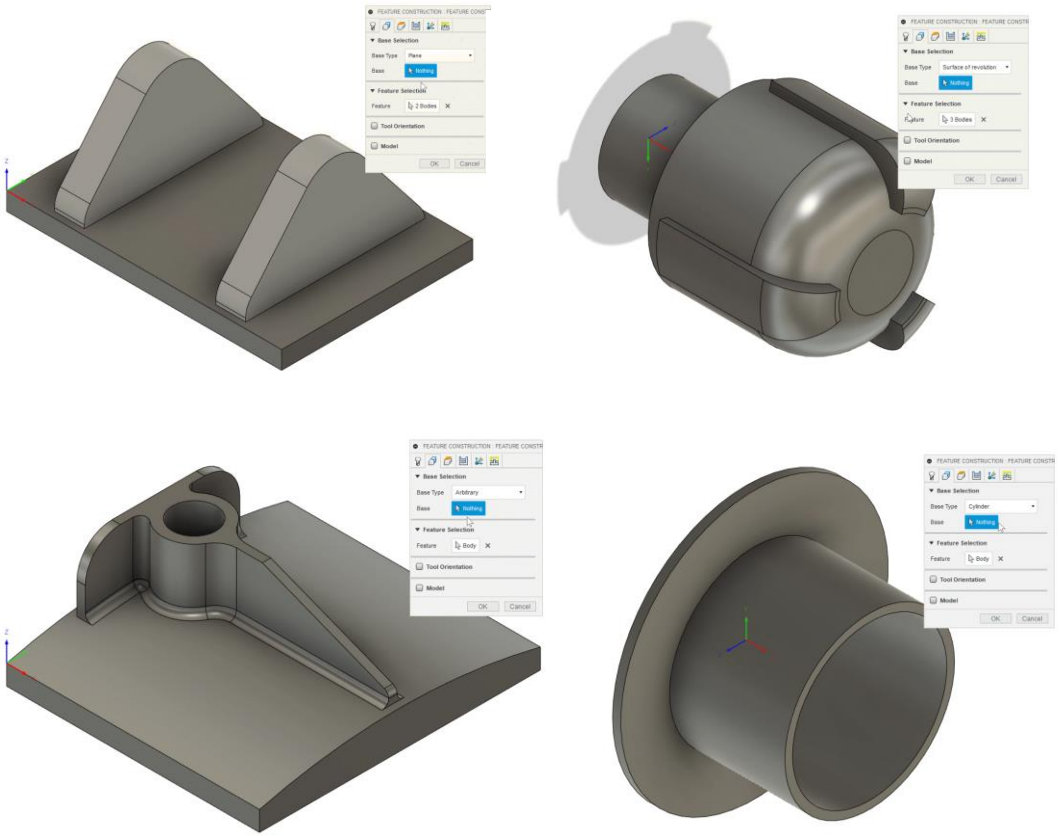


Milling setup 2

Design & Manufacturing

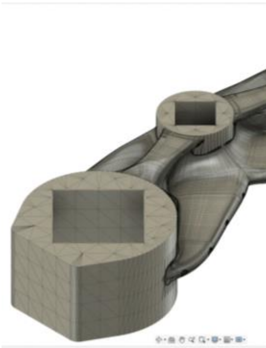
Generating Additive & Subtractive Tool Paths – Additive Toolpaths in Fusion 360

- Multi Axis Deposition Toolpaths – Tech preview released Nov. 2021
- Deposit entire components or add features to existing parts
- Create deposition conformal to planar, cylindrical, revolved or arbitrary surfaces
- Currently supports all major DED technologies
- Pass deposited stock forward to subsequent milling process

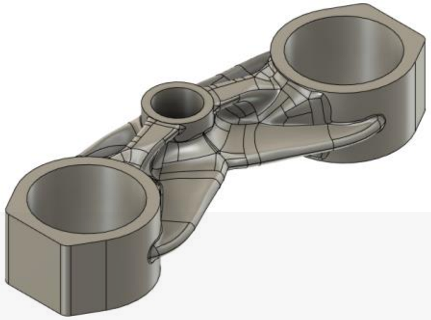


Design & Manufacturing

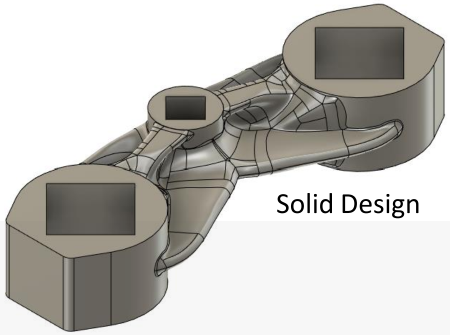
Generating Additive & Subtractive Tool Paths – Powder Bed Fusion Manufacturing Plan



Latticed Design in **Netfabb** with 0.75mm Beam 4 mm Cell Size

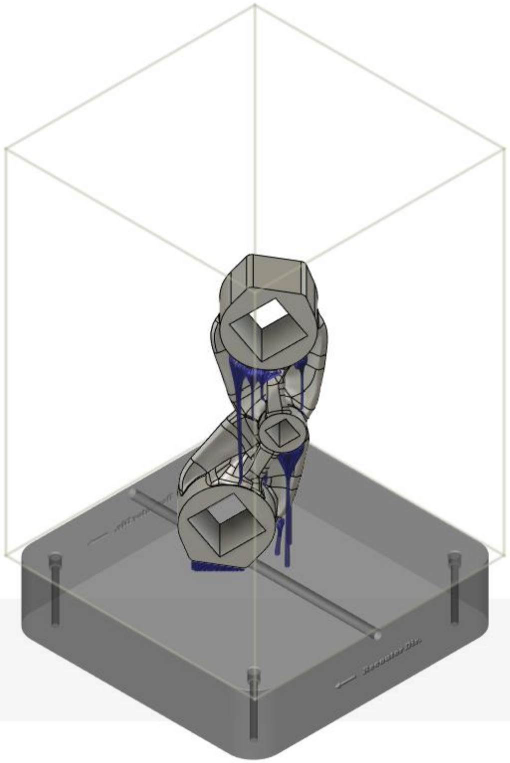


Original design

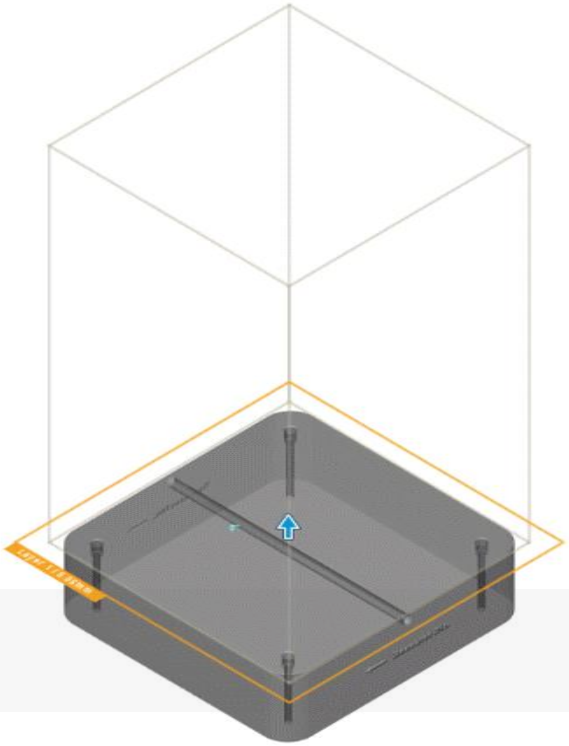


Solid Design

Manufacturing design



AM setup



AM process

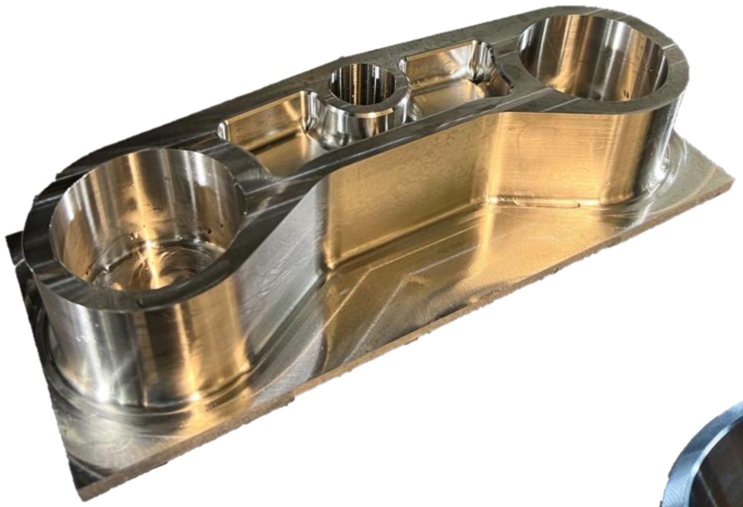
Design & Manufacturing

Original Design – Milling (Carbon Evaluation)

Manufacturing

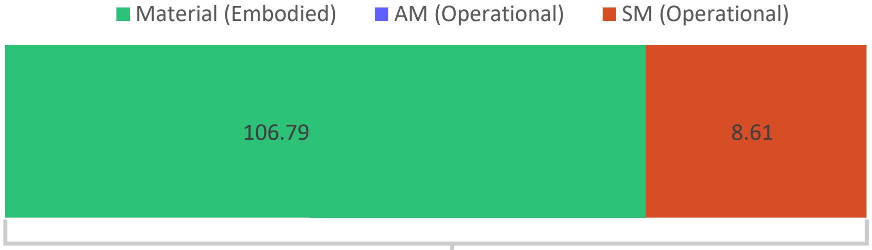
Step 1 : Subtractive (Machining)

Step 2: Subtractive (Machining)



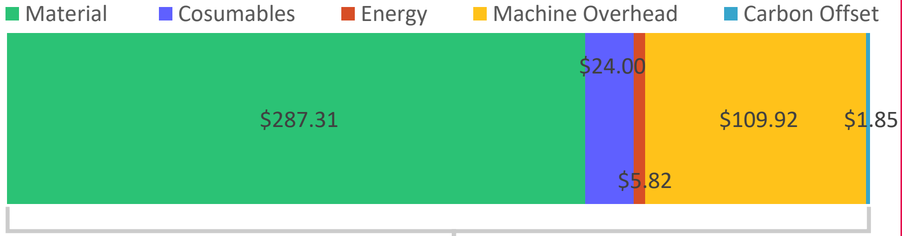
Carbon & Cost Evaluation

Total Carbon (kg CO2)



115.46 kg of CO_2

Total Cost ($)



$427.05

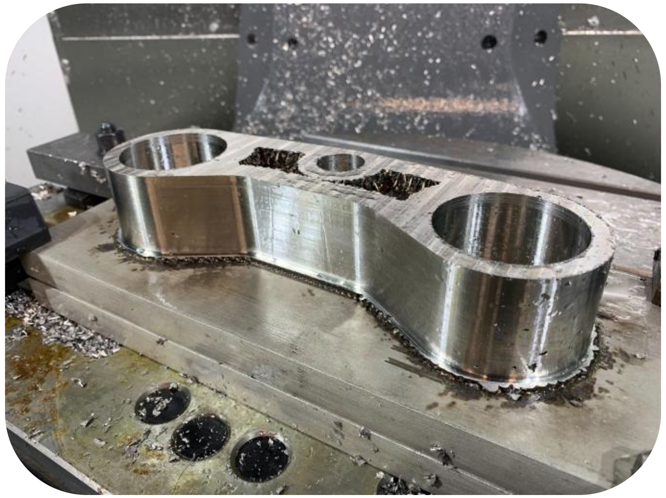
Design & Manufacturing

Original Design – Hybrid (Carbon Evaluation)

Manufacturing (WIP)

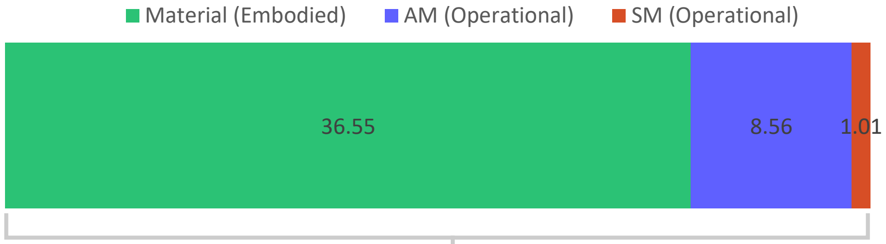
Step 1 : Additive (DED)

Step 2: Post Processing (Machining)



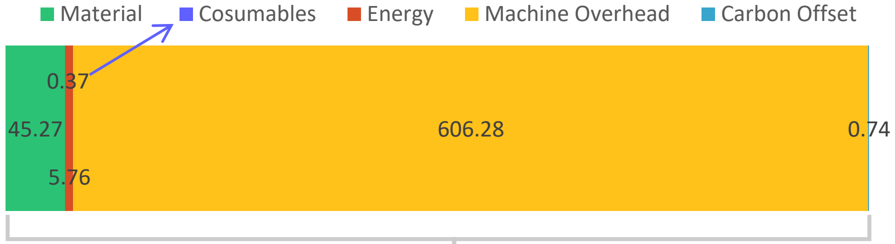
Carbon & Cost Evaluation*

Total Carbon (kg CO2)



46.12 kg of CO2

Total Cost ($)



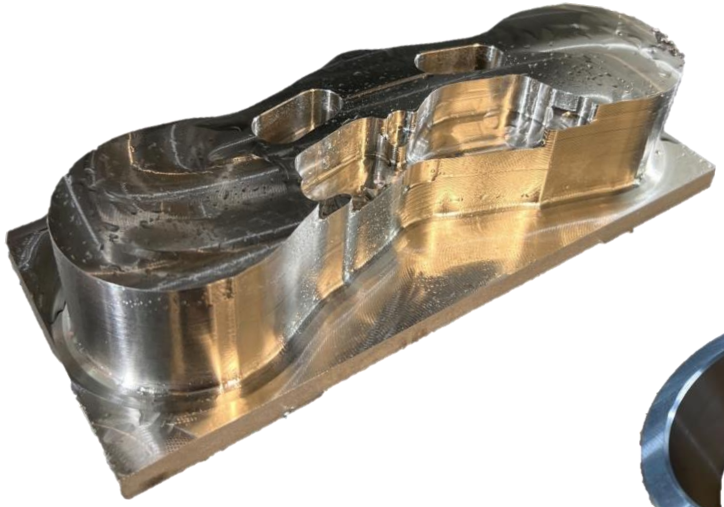
$657.68

Design & Manufacturing

2.5 Axis Outcome – Milling (Carbon Evaluation)

Manufacturing

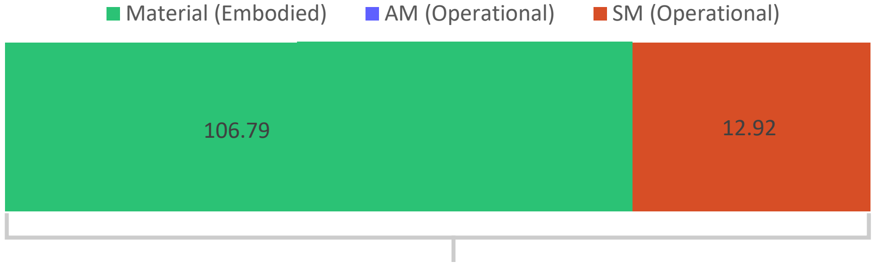
Step 1 : Subtractive (Machining)



Step 2: Subtractive (Machining)

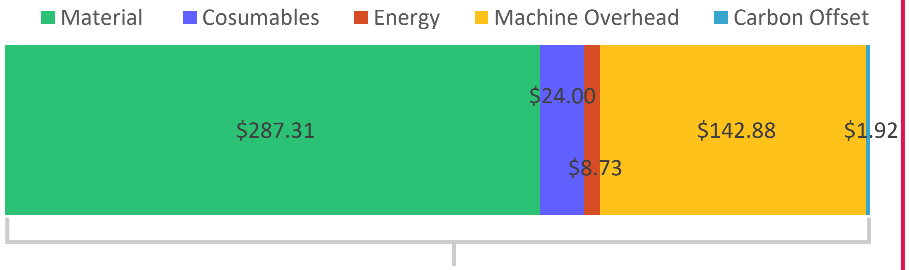
Carbon & Cost Evaluation

Total Carbon (kg CO2)



119.71 kg of CO2

Total Cost ($)



$462.92

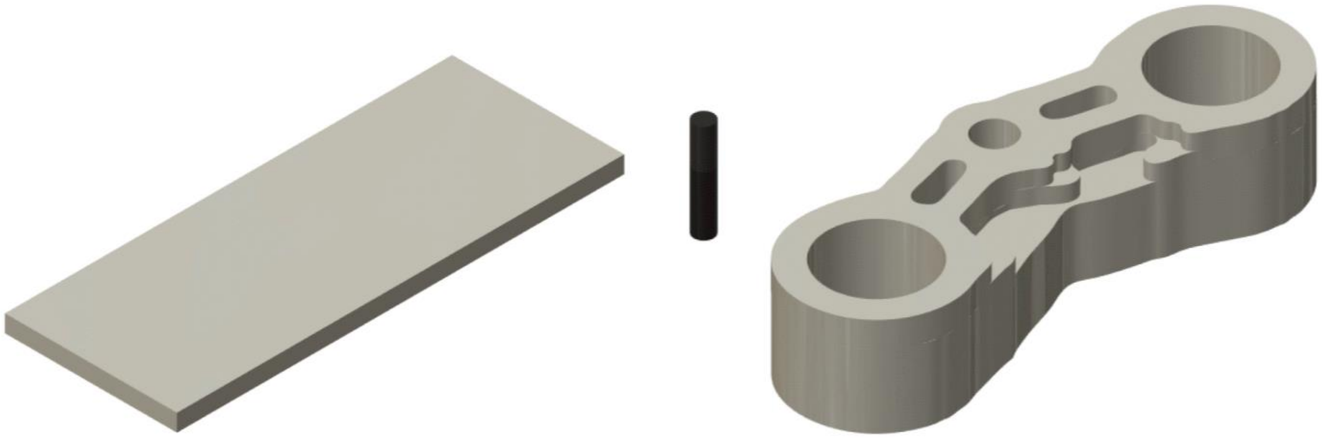
Design & Manufacturing

2.5 Axis Outcome – Hybrid (Carbon Evaluation)

Manufacturing (WIP)

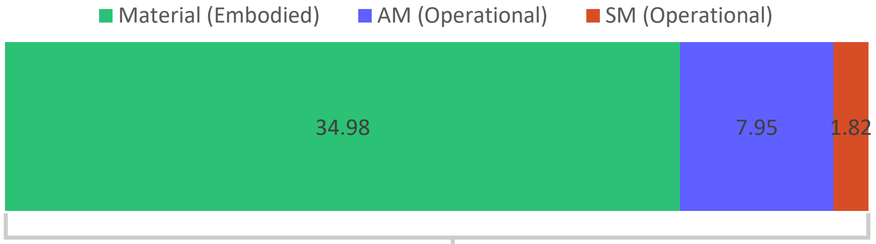
Step 1 : Additive (DED)

Step 2: Post Processing (Machining)



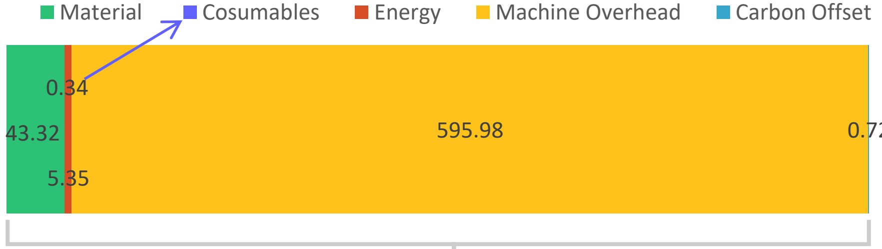
Carbon & Cost Evaluation*

Total Carbon (kg CO2)



44.74 kg of CO2

Total Cost ($)



$644.99

Design & Manufacturing

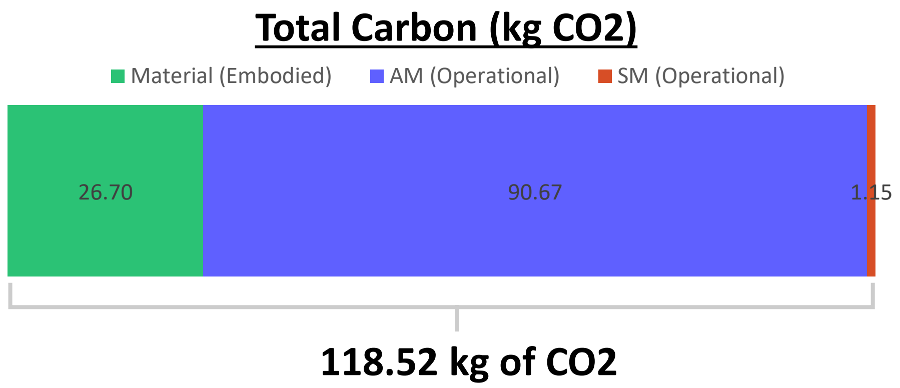
Additive Outcome – Solid (Carbon Evaluation)

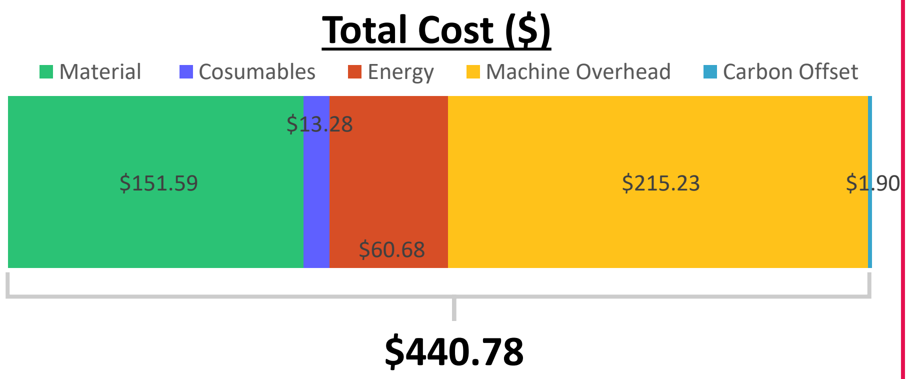
Manufacturing

Step 1 : Additive (L-PBF)

Step 2: Post Processing (Machining)

Carbon & Cost Evaluation



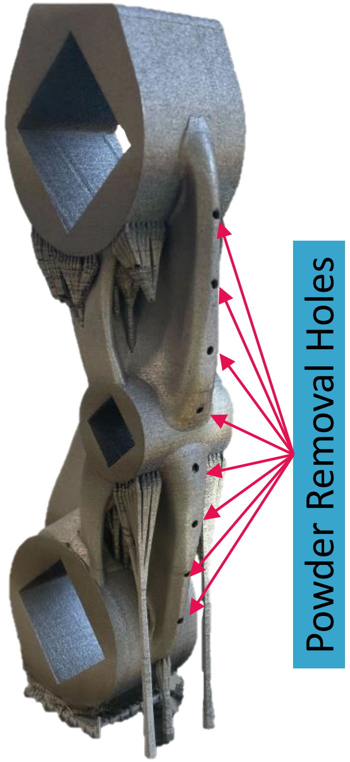


Design & Manufacturing

Additive Outcome – Latticed (Carbon Evaluation)

Manufacturing

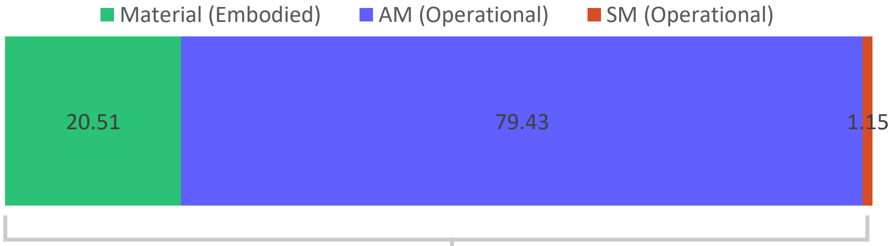
Step 1 : Additive (L-PBF)



Step 2: Post Processing (Machining)

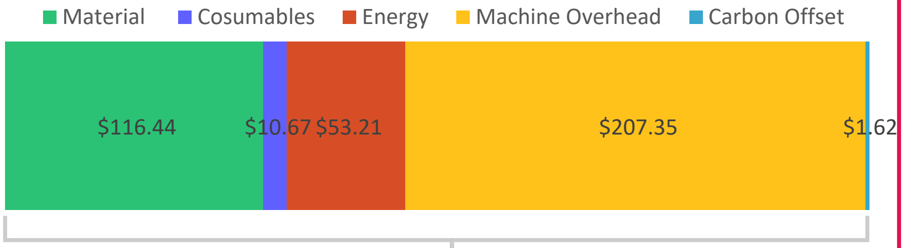
Carbon Evaluation

Total Carbon (kg CO2)

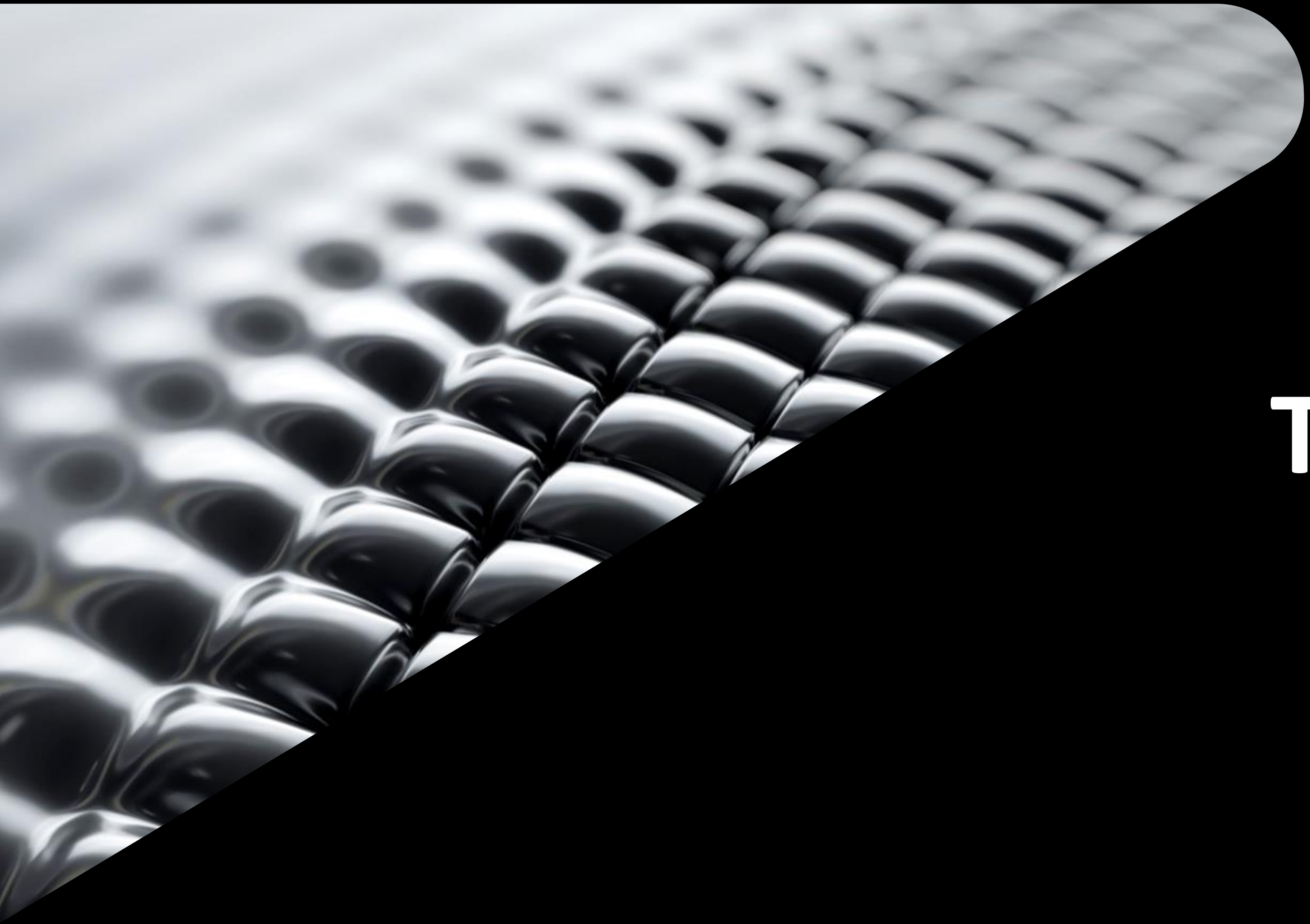


101.10 kg of CO2

Total Cost ($)



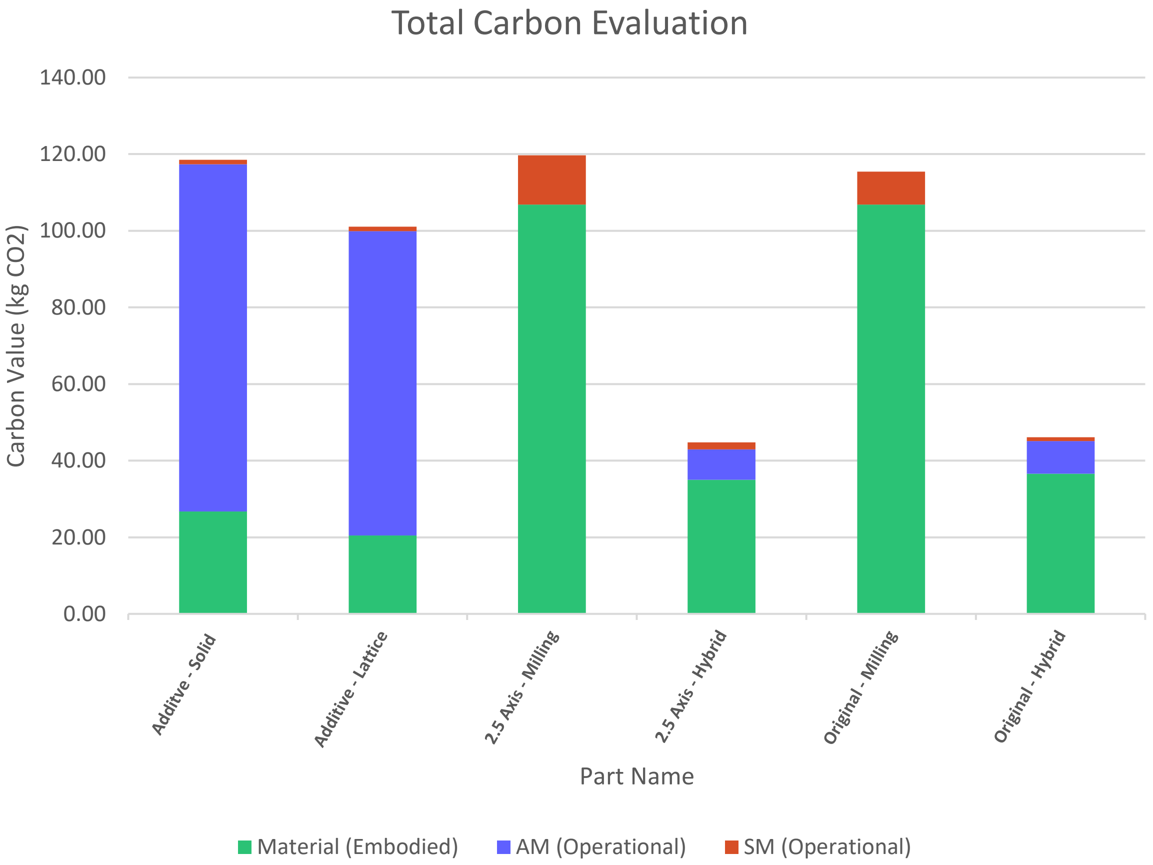
$387.67

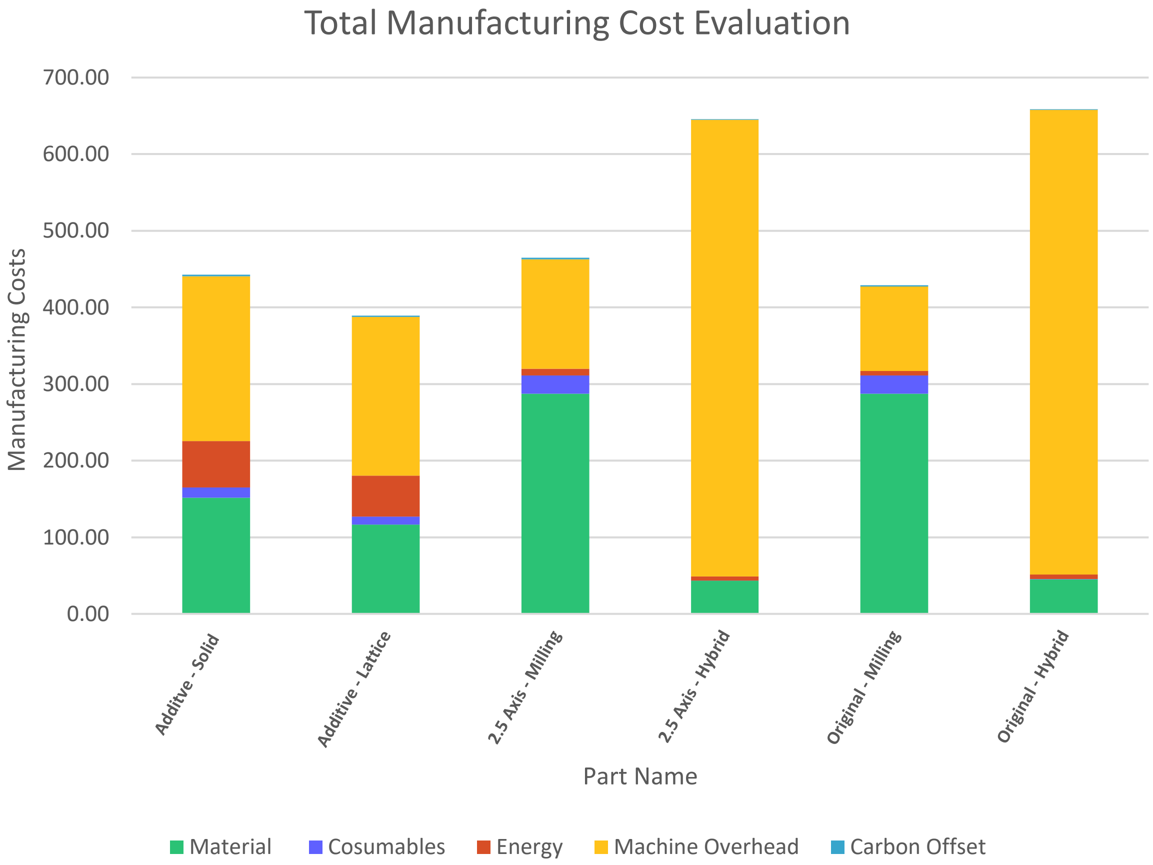


The Case study - Evaluation

Which Is The Most Sustainable Outcome?

From a Cradle to Gate Perspective

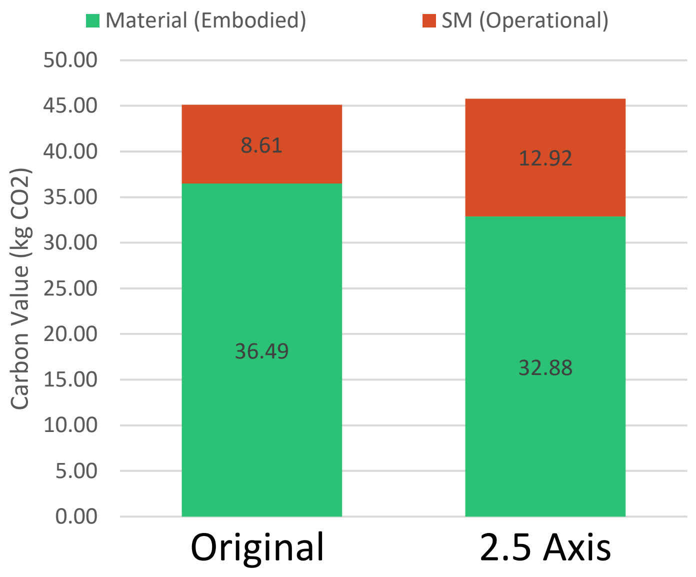




Which Is The Most Sustainable Outcome?

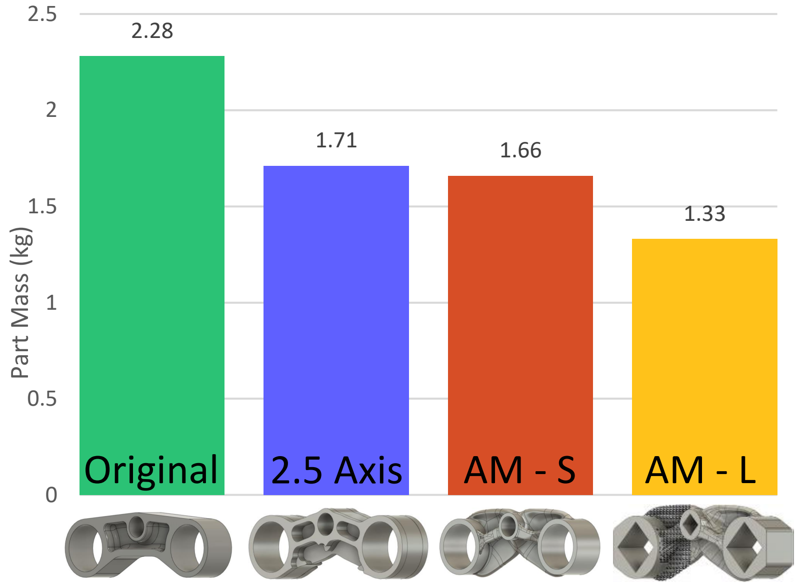
Extending the Scope…

Circular Economy Practices!



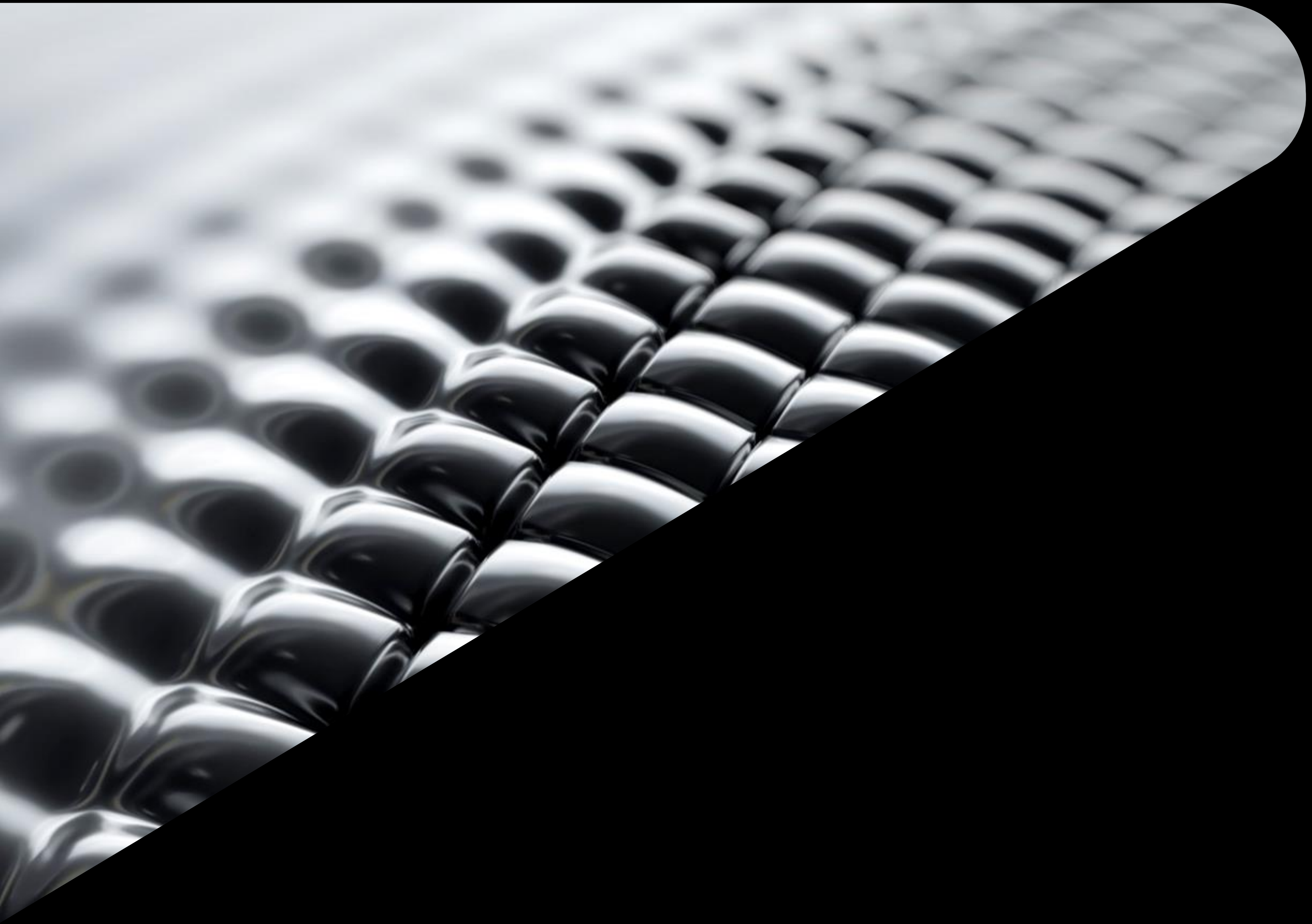
Recycling swarf from the milling operations leads to ~60% in Product Carbon

Including Operational Carbon



Light weighting is important for Fuel Efficiency!

Machines and Batching

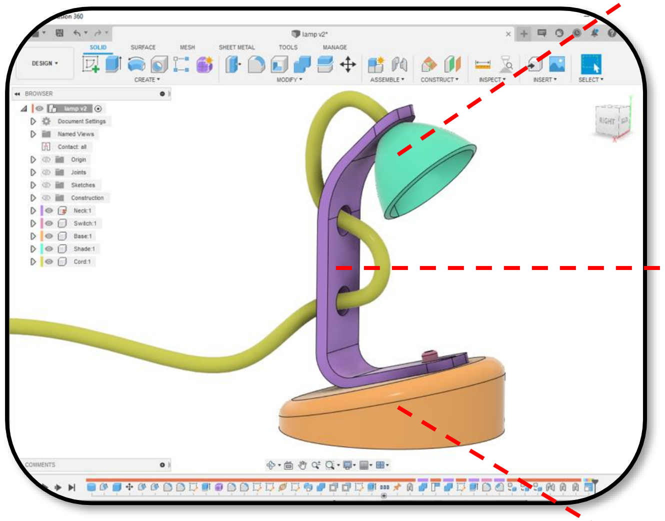


Predicting the Future

Making More Informed Manufacturing Choices

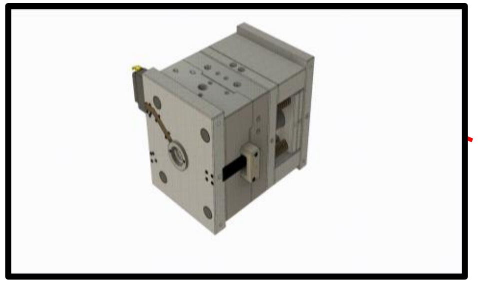
Our goal is to help you manufacture more sustainably

Design

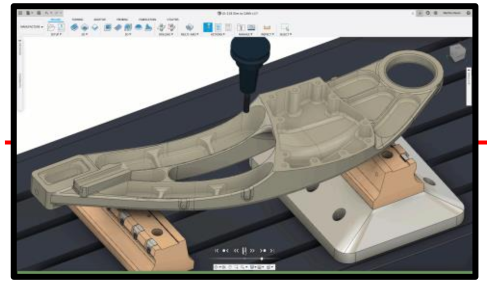


Estimate

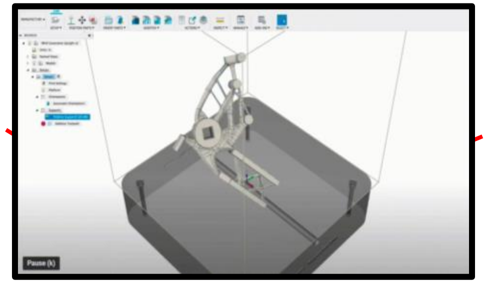
Molding



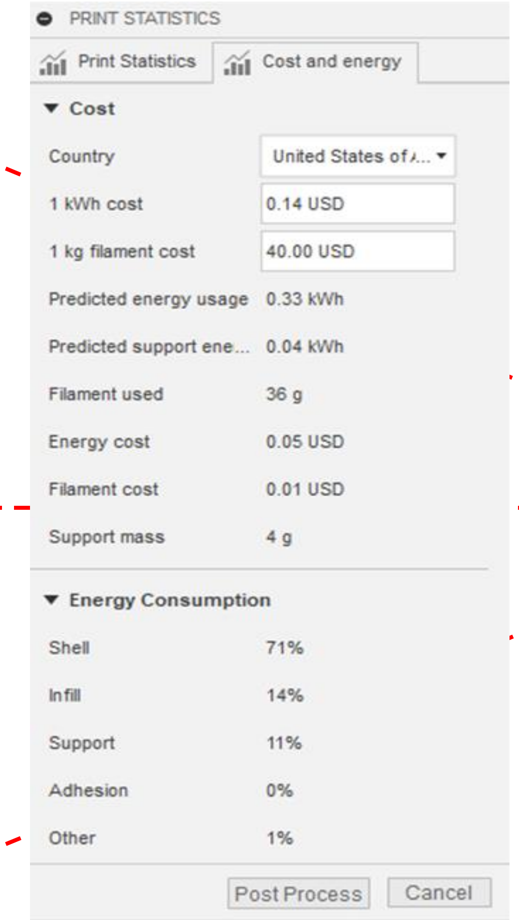
Subtractive



Additive

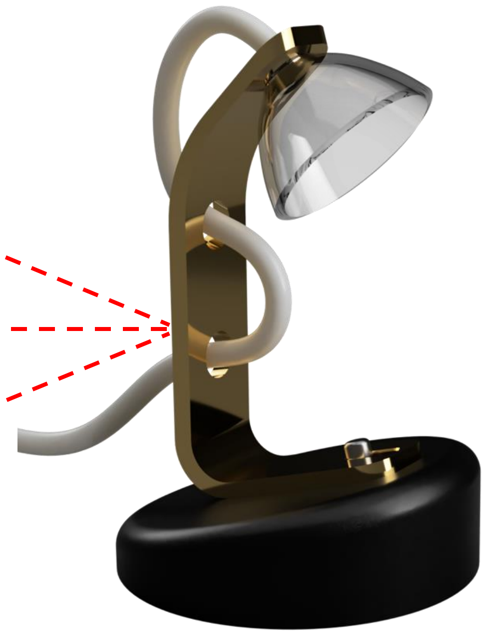


Manufacturing Energy Consumption



Customers are given predicted energy consumption insights based on their manufacturing simulations.

Create



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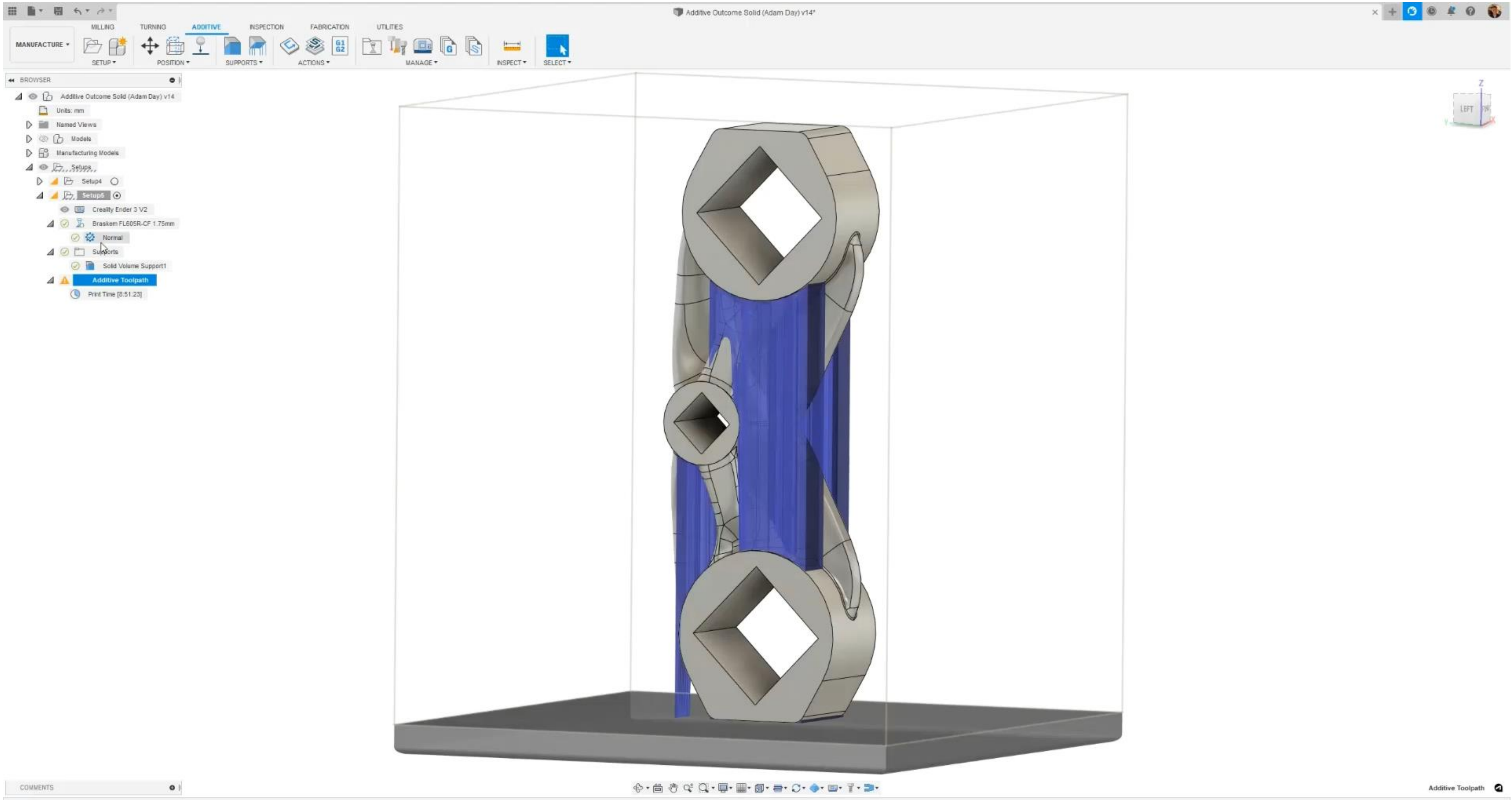
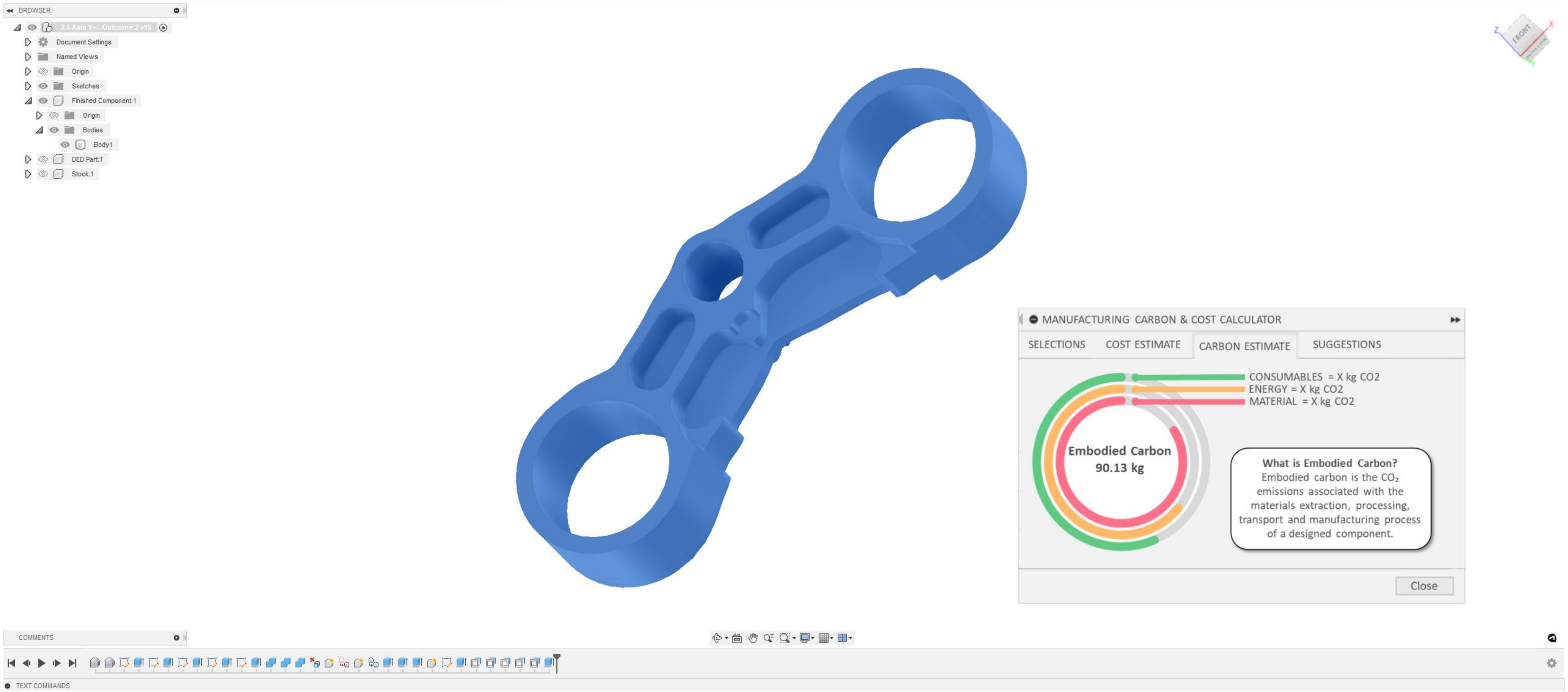
Making More Informed Manufacturing Choices

FFF Energy Prediction Tool



Manufacturing-Influenced Design Choices

How could we provide manufacturing sustainability Insights into your design phase?



How can you manufacture more sustainably?

Think about small changes in manufacturing operations, technology or materials which could save you money and help the planet!

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