

ASSESSMENT-BASED ECO-EFFICIENCY ESTIMATION OF COMPOSITE AND HYBRID STRUCTURES IN COMMERCIAL AIRCRAFT

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“Research & Innovation in Composites”

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Knowledge for Tomorrow

METHODOLOGY

SYSTEM BOUNDARY

MODELING & PARAMETERIZATION

EVALUATION RESULTS

OUTLOOK

DISCUSSION



METHODOLOGY

SYSTEM BOUNDARY

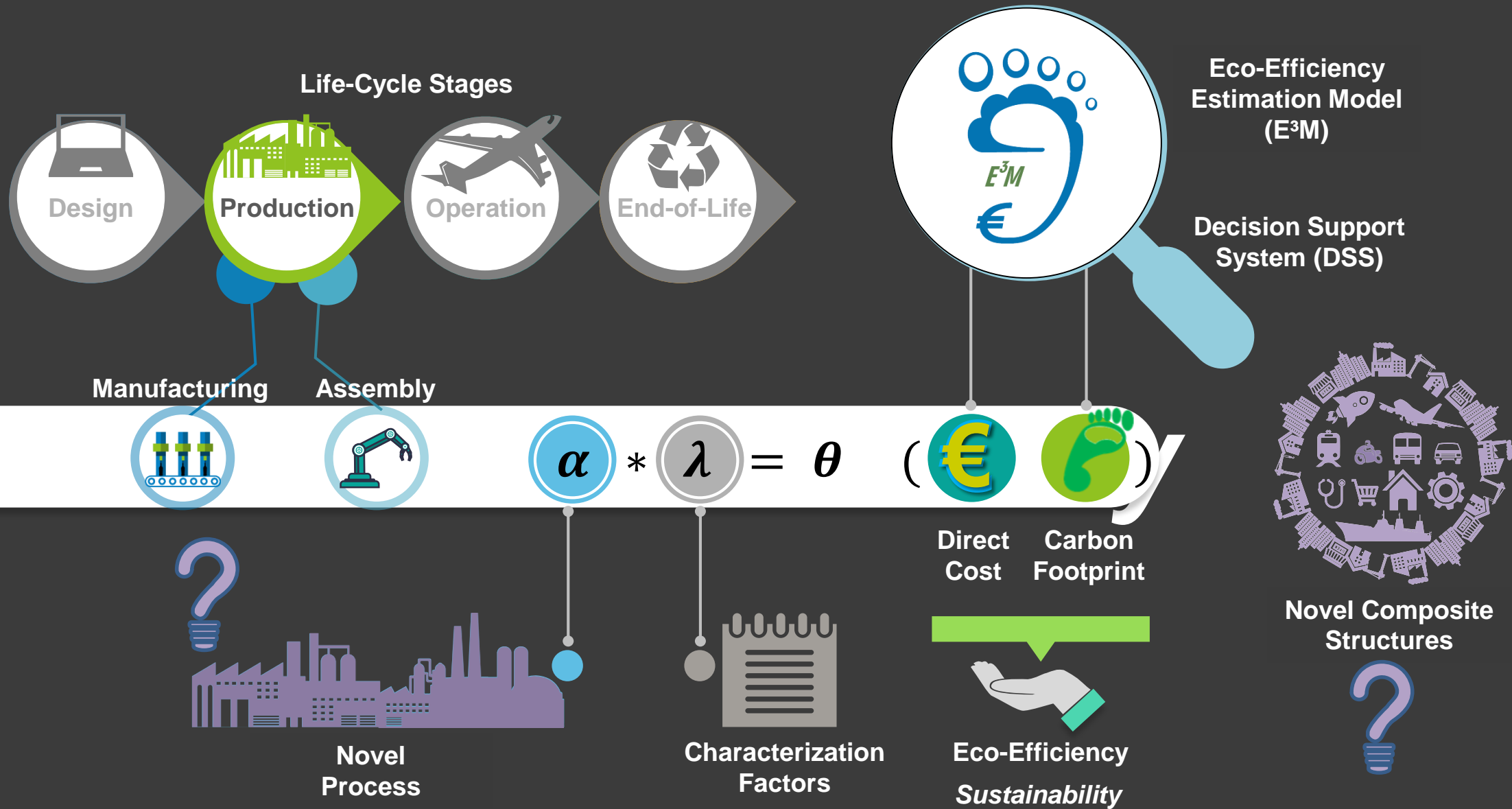
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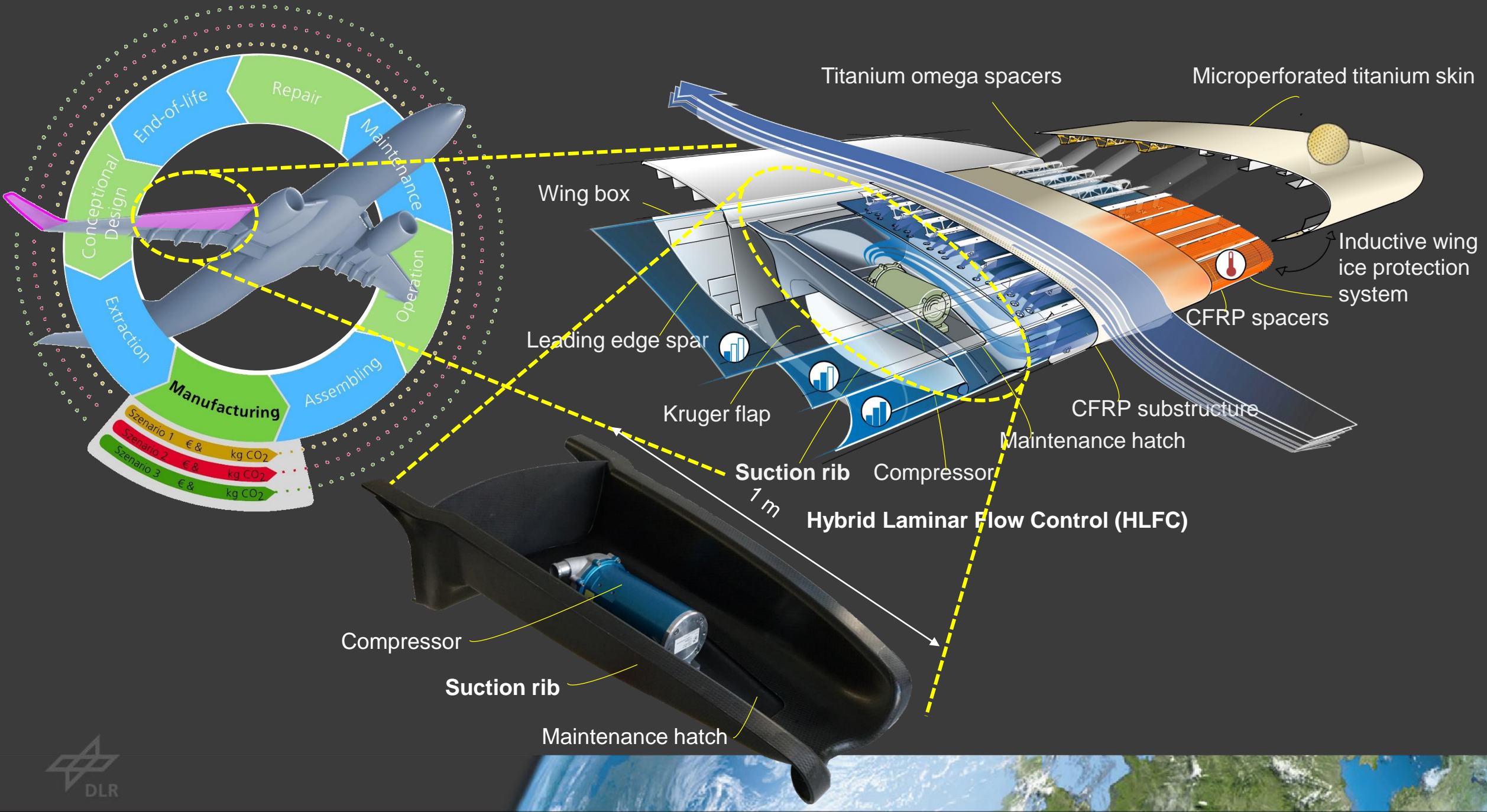
MODELING & PARAMETERIZATION

EVALUATION RESULTS

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Investment ~ 1 Mil €

Not necessarily sequential!

Annual Working Hours ~ 910

UP₁₁: Storage

UP₁₂: Cutting

UP₁₃: Preforming

UP₁₄: Set-up

UP₁₅: Curing

UP₁₆: Demolding

UP₁₇: Trimming

UP₁₈: Testing

Laboratories
DLR Brunswick



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- Labor
- Facility
- Energy
- Molds
- Fiber
- Fiber waste
- Matrix
- Matrix waste
- Ancillaries
- Equipment


Exemplary unit process (UP)

- Labor
- Facility
- Energy

ID₂₀₀₁

82.5 €/h
46 kg CO₂/h


Technician



ID₃₀₀₁

46.92 €/m²/month
71 kgCO₂/m²/year

Air-conditioned



ID₁₁₀₀₁

0.1445 €/kWh
0.428 kgCO₂/kWh

Energy mix



ID	Description	CostPerUnit	MassPerUnit	CO2PerKg
9001	Acetone (L)	2.49 €/L	0.7846 kg	2.19
9017	Release film (m ²)	3.8 €/m ²	0.0875 kg	2.67
9026	Vacuum film (m ²)	0.76 €/m ²	0.074 kg	2.4
9036	Sealing Tape (Tacky Tape) (m)	0.5 €/m	0.052069 kg	7.4966

- Ancillaries
- Equipment

ID	Description	Replacement Cost	Operating Life
4005	Iron Heater	50 €	2 years
4007	Central House Vacuum pump	15000 €	5 years
4015	Oven 1	13000 €	7.5 years



Investment ~ 4.6 Mil €

Not necessarily sequential!

Annual Working Hours ~ 3808

UP₁₁: Storage UP₁₂: Cutting UP₁₃: Preforming UP₁₄: Set-up UP₁₇: Trimming UP₁₅: Curing UP₁₆: Demolding UP₁₈: Testing

EVo-Platform
DLR Stage



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- Labor
- Facility
- Energy
- Molds
- Fiber
- Fiber waste
- Matrix
- Matrix waste
- Ancillaries
- Equipment

Exemplary unit process (UP)

- Labor
- Facility
- Energy
- Molds

ID₂₀₀₁

113.2 €/h
46 kg CO₂/h

Technician

ID₃₀₀₁

46.92 €/m²/month
71 kgCO₂/m²/year

Air-conditioned

ID₁₁₀₀₁

0.1445 €/kWh
0.428 kgCO₂/kWh

Energy mix

ID₅₀₂₉

50000 €
900 cycle/mold

Mold

ID	Description	CostPerUnit	MassPerUnit	CO2PerKg
9017	Release film (m ²)	3.8 €/m ²	0.0875 kg	2.67

- Ancillaries
- Equipment

ID	Description	Replacement Cost	Operating Life
40101	EVo-Lay up robot	175000 €	5 years
40102	EVo-Consolidation press	325000 €	7 years



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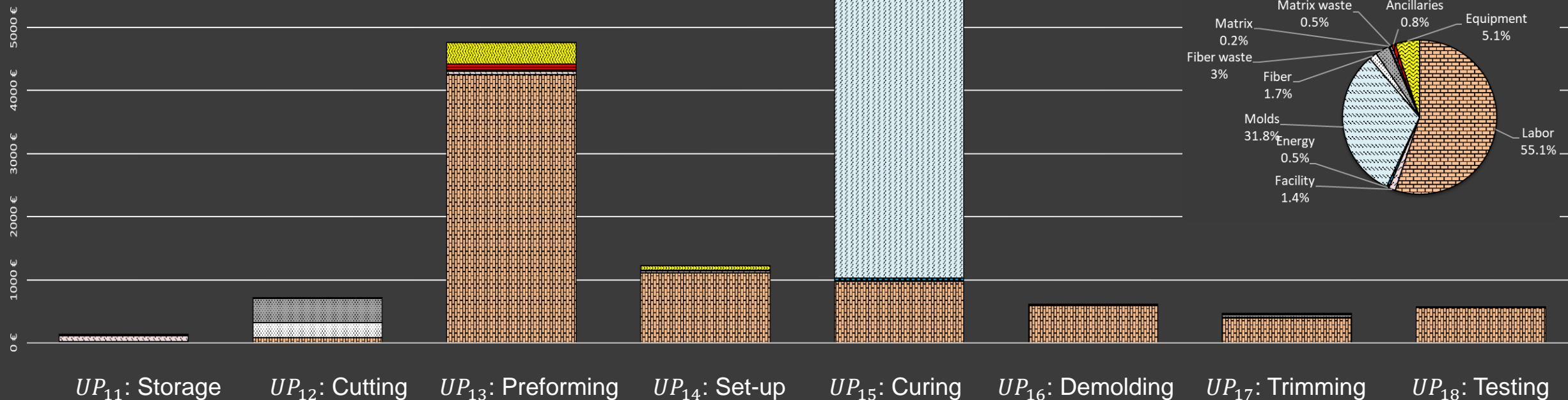
Direct Cost

Laboratories
DLR Brunswick



- Labor
- Facility
- Energy
- Molds
- Fiber
- Fiber waste
- Matrix
- Matrix waste
- Ancillaries
- Equipment

6000 €



Scenario 1 "as-is":
Laboratories DLR Brunswick



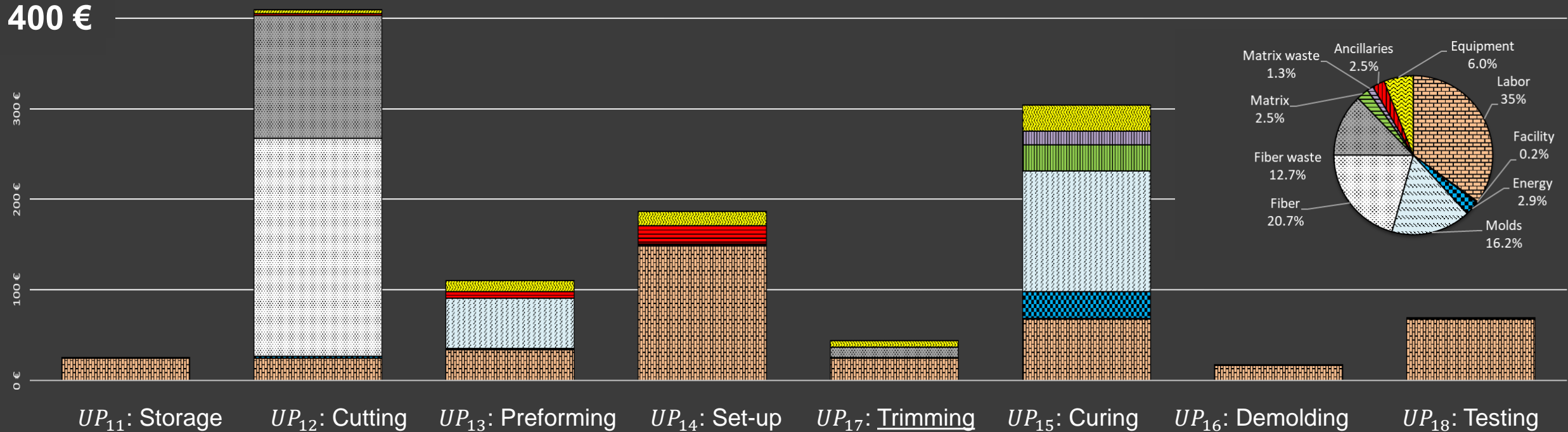


Direct Cost

Evo-Platform
DLR Stade



- Labor
- Facility
- Energy
- Molds
- Fiber
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- Equipment



Scenario 1 "as-if":
Evo-Platform-DLR Stade





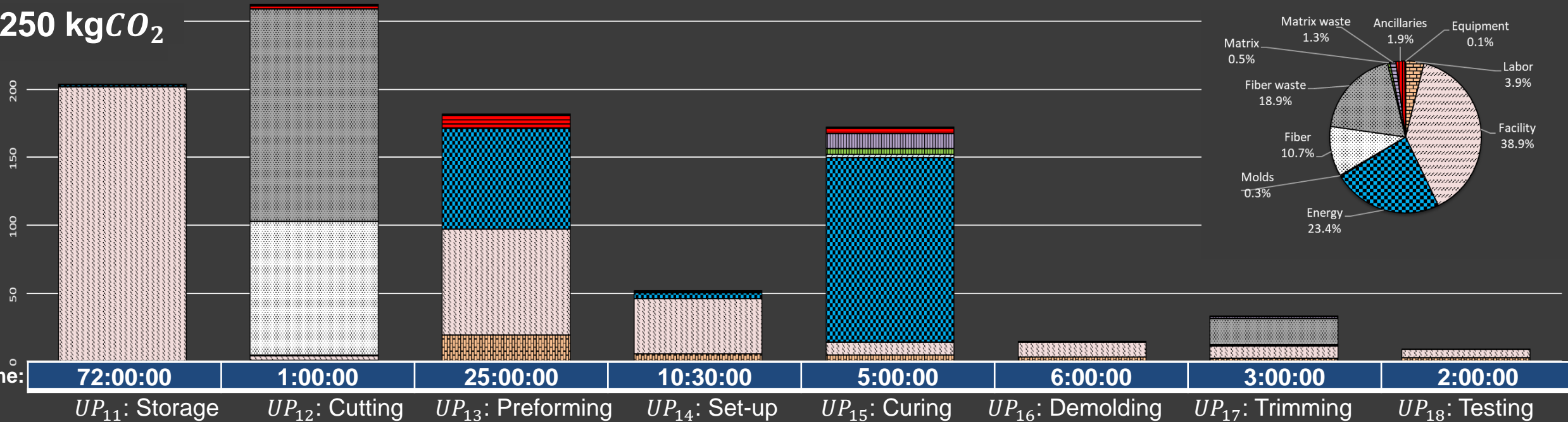
Carbon Footprint

Laboratories
DLR Brunswick



- Labor
- Facility
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- Equipment

250 kgCO₂



Scenario 1 "as-is":
Laboratories DLR Brunswick





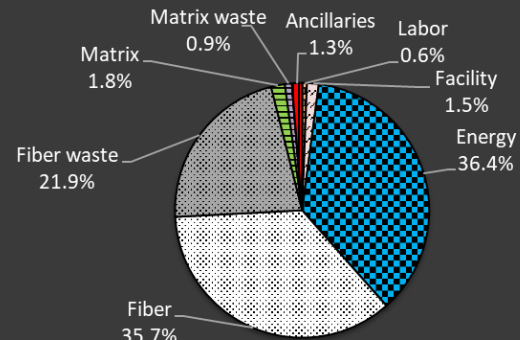
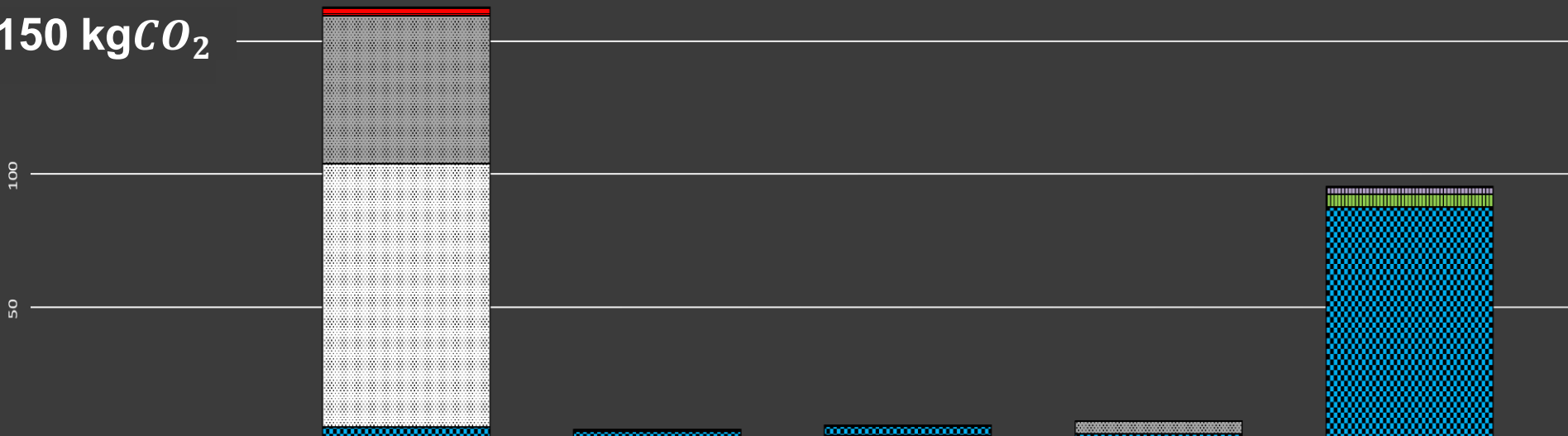
Carbon Footprint

Evo-Platform
DLR Stade



- Labor
- Facility
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150 kgCO₂



Scenario 1 "as-if":
Evo-Platform-DLR Stade



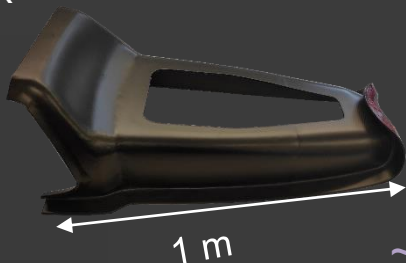


Direct Cost

Laboratories
DLR Brunswick

"as-is"

14.4 k€
~ 5 k€/kg



Direct Cost

EVo-Plattform
DLR Stade

"as-if"

1.2 k€
~ 0.4 k€/kg



Carbon Footprint

Laboratories
DLR Brunswick

"as-is"

925 kg CO₂
~ 314 kg CO₂ /kg



Carbon Footprint

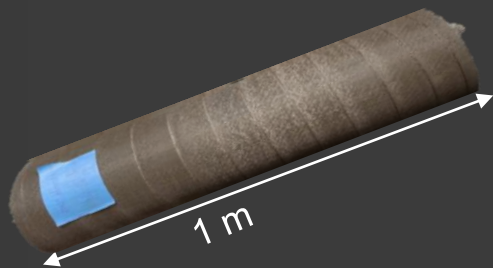
EVo-Plattform
DLR Stade

"as-if"

276 kg CO₂
~ 94 kg CO₂ /kg

Lucas Seifert,
Ali Al-Lami
2022

"filament winding"
~ 1.2 k€/kg

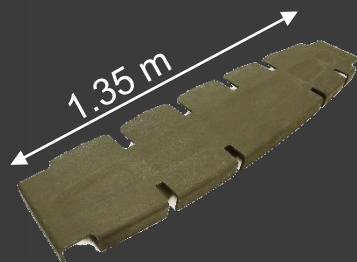


Lucas Seifert,
Ali Al-Lami
2022

"filament winding"
~ 214 kg CO₂ /kg

Ali Al-Lami et al.
2018

"autoclave, single-
line-infusion"
~ 0.6 k€/kg



Ali Al-Lami et al.
2018

"autoclave, single-
line-infusion"
~ 116 kg CO₂ /kg



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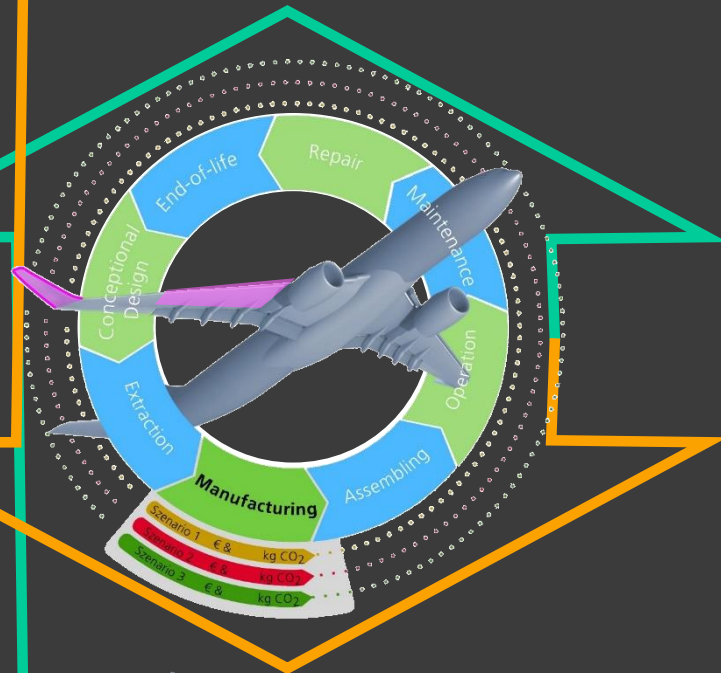
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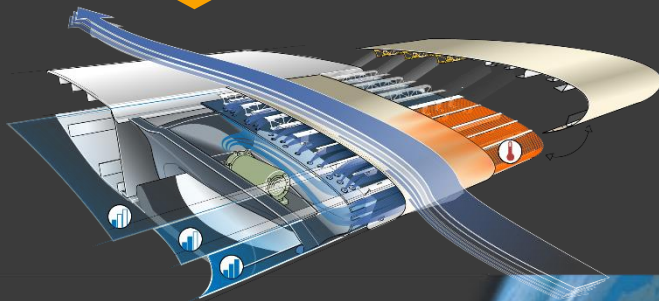
DISCUSSION









Top-Down



Bottom-Up



Smart-Work-Station (SWS)

-  Labor
-  Facility
-  Equipment
-  Fiber
-  Fiber waste
-  Matrix waste

ReCiPe 2008

DC	€
CED	MJ oil-Eq
ALOP	m ² ·a
GWP	kg CO ₂ -Eq
FDP	kg oil-Eq
FETP	kg 1.4-DCB
FEP	kg P-Eq
HTP	kg 1.4-DCB
IRP	kg U235-Eq
METP	kg 1.4-DB.
MEP	kg N-Eq
MDP	kg Fe-Eq
NLTP	m ²
ODP	kg CFC-11
PMFP	kg PM10-Eq
POFP	kg NMVOC
TAP	kg SO ₂ -Eq
TETP	kg 1.4-DCB.
ULOP	m ² ·a
WDP	m ³
.....	

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Thank You!

Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)

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Publications

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Patents

