CHALLENGES IN THE LIFE CYCLE ASSESSMENT OF FIBRE REINFORCED POLYMERS USING THE EXAMPLE OF A COMPOSITE AIRCRAFT INTERIOR SHELL

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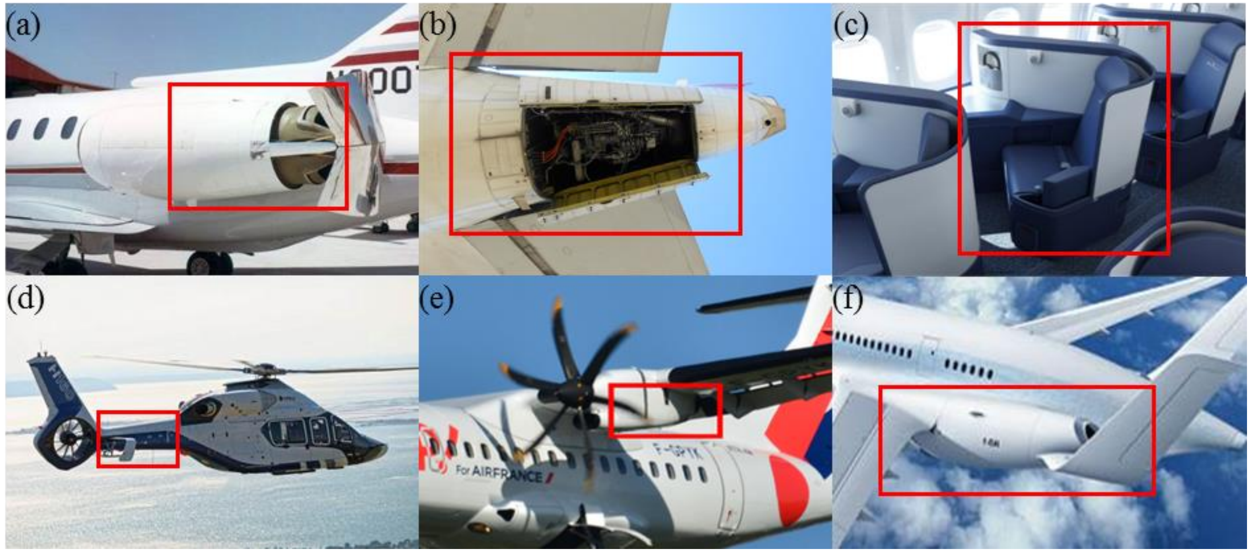
SuCoHS

SUSTAINABLE & COST EFFICIENT
HIGH-PERFORMANCE COMPOSITE STRUCTURES
DEMANDING TEMPERATURE
AND FIRE RESISTANCE

- Several aeronautical applications demanding high temperature and fire conditions
- Maintain industrial leadership through expanded use of composites for:
  - Reduced weight
  - Improved performance
  - Increased efficiency
  - Reduced costs
  - Improved sustainability



www.sucohs-project.eu

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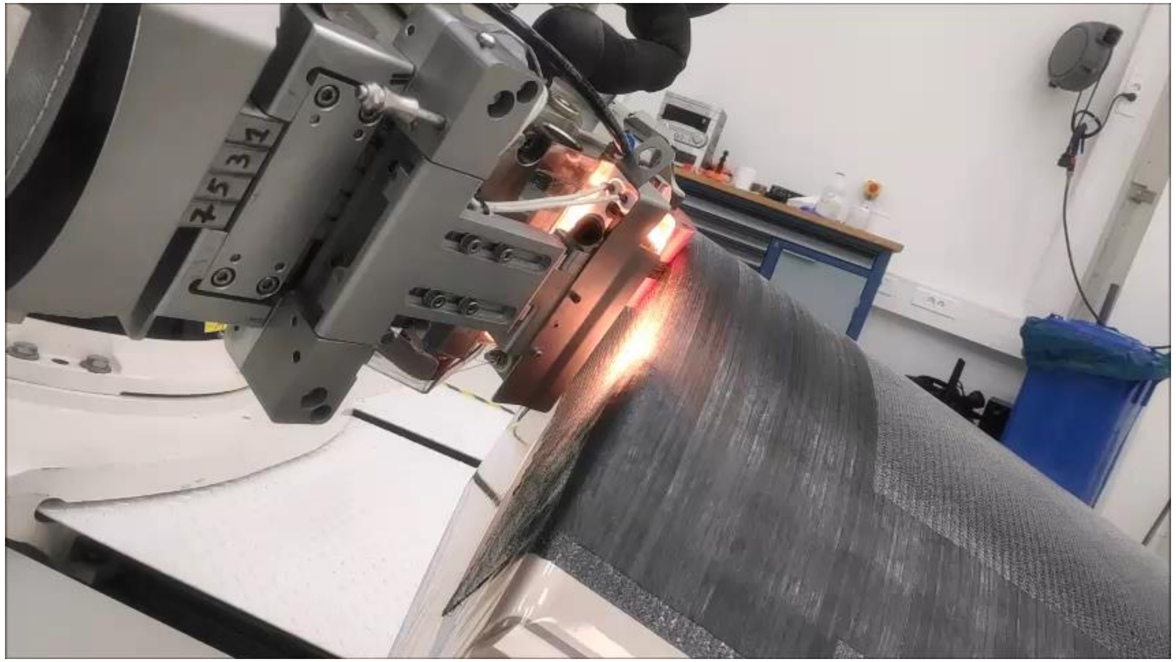
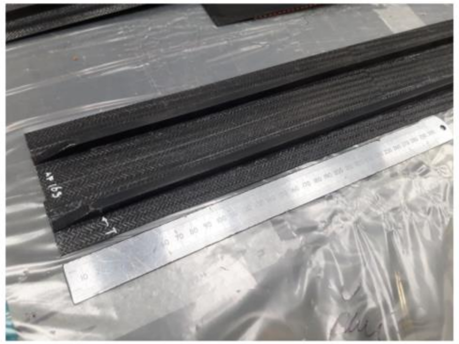
SuCoHS
Industrial Demonstration and Use-Cases



Equivalent

Weight
Stiffness
Strength



Sandwich structure – 2 C 2
Carbon fibre epoxy woven fabric
Nomex core

UD or woven fabric skin
Automated tape laid-up carbon fibre UD stringers

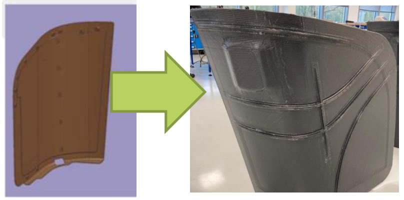
LCA

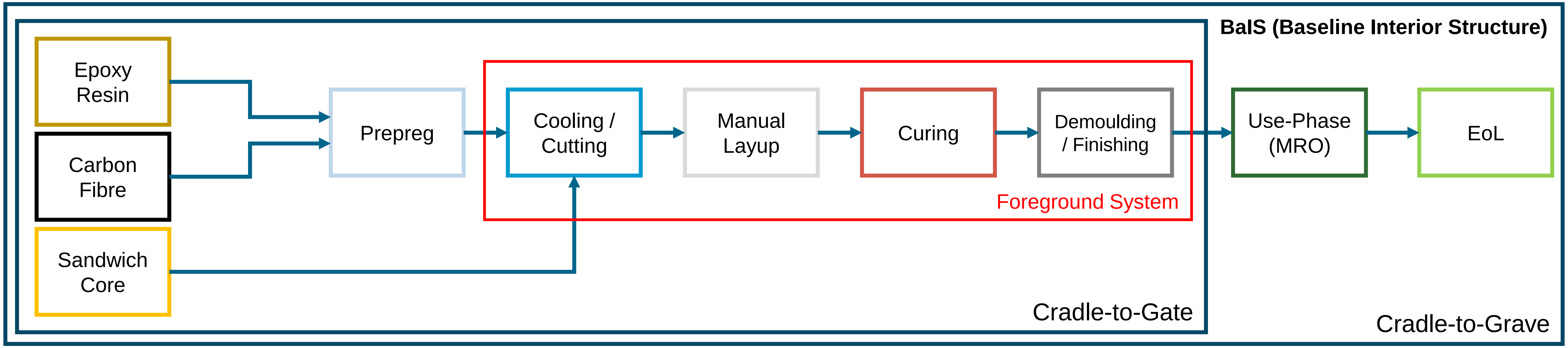
Interior Shell
Collins Aerospace

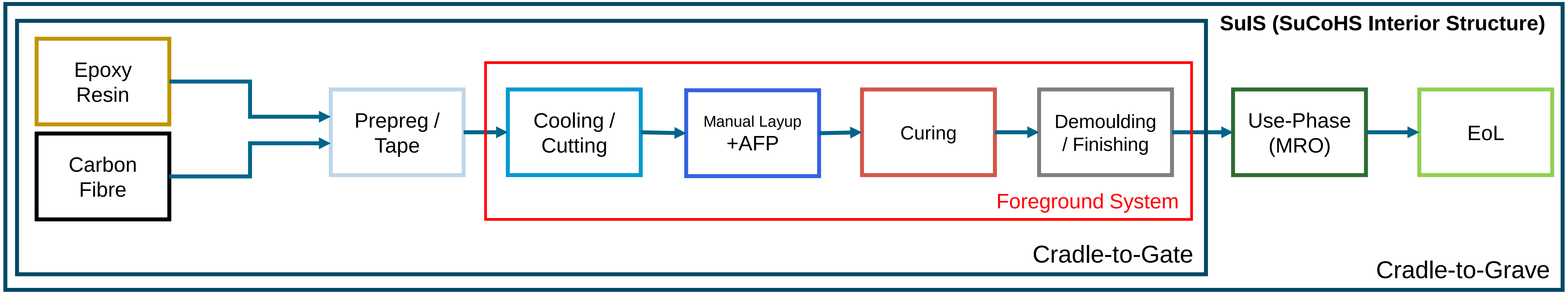
Collins Aerospace

Goal and Scope

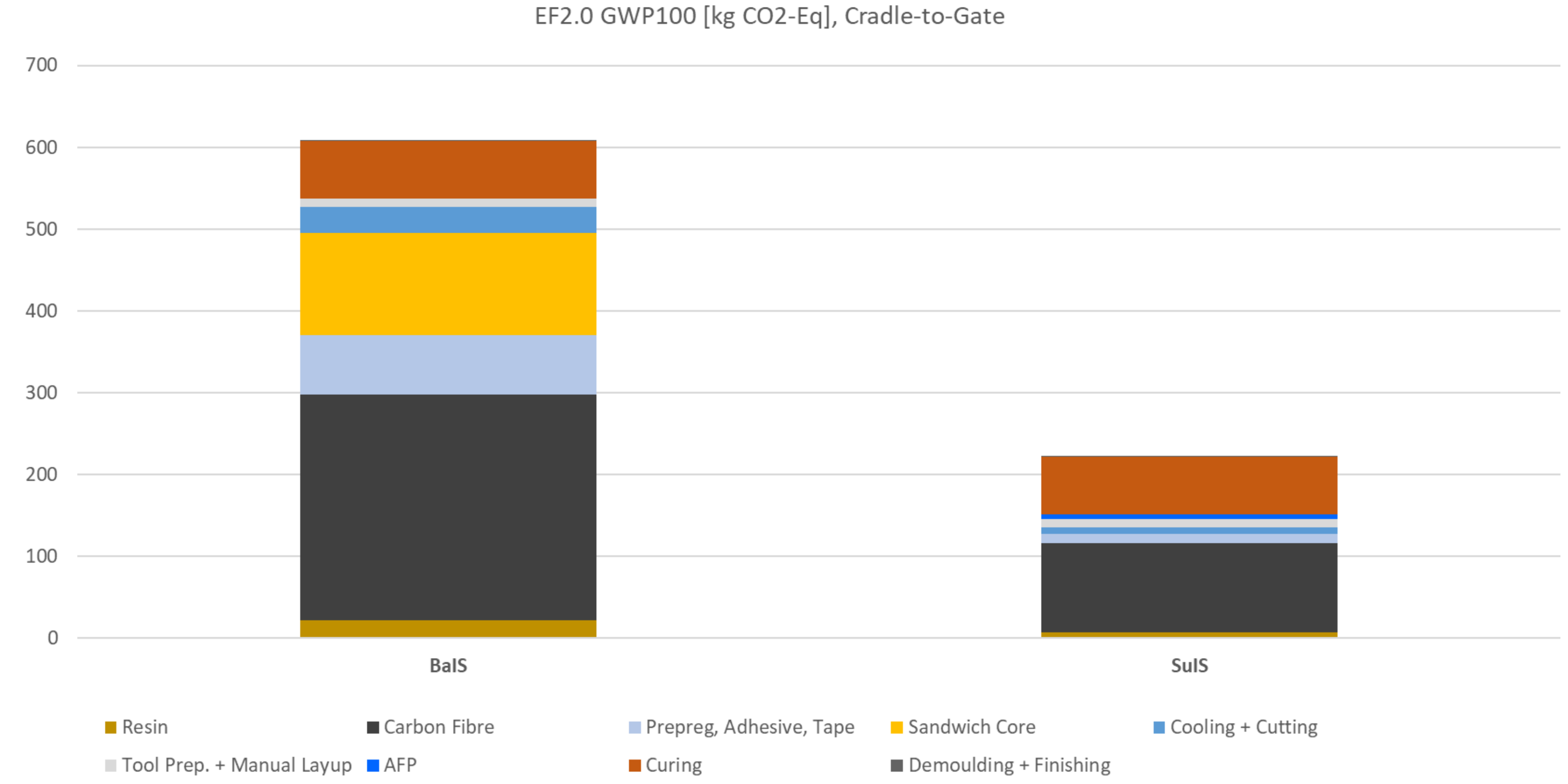
- fU = finished Interior Shell
- Foreground data: Different TRL level, partly laboratory data
- Background data: Ecoinvent v3.8cut-off (RER), Literature
- Software: Umberto LCA+ Version 10.0 (build 10.0.3.200)
- LCIA Method: EF2.0, all categories







(Preliminary) LCIA Interior Shell, Cradle-to-Gate



Preliminary Results Life Cycle Assessment, SuCoHS Interior Shell with Epoxy resin (SuIS) compared to Baseline Interior Shell (BaIS)
Functional Unit = one interior shell, System Boundary: Cradle-to-Gate
Assumption: Foreground processes use average European Electricity Mix (RER) for Medium Voltage. Backkground data = RER.
Modelled in Umberto LCA+ Software (v10.0.3) and Ecoinvent Database (v3.8 Cut-Off), EF2.0 2018 Midpoint LCIA Method.
Model: DLR-SY-MFW with data from SuCoHS project partners, updated for EASN2023 conference (2023-09-05, Salerno)

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Life Cycle Inventory
Example 1: Carbon Fibres

- Today: PAN based Carbon Fibres
  - Different grades of CF, e.g. HT, HM
- No primary data available
- No CF data in Ecoinvent
  - Other databases only aggregated, if any…

- Published LCIA results?
  - e.g. „Carbon-Footprint“ in EPD

- Literature?
  - Wide range of energy consumption reported
  - Specifications often unclear
- Cradle-to-Gate or Gate-to-Gate LCI?
  - Precursor Line included?
  - What form of energy?
  - Equipment / Periphery included?
  - …

Table 1: Reported energy intensities for PAN-based precursor manufacturing

	Das, 2011	Liddell et al., 2016	Liddell et al., 2017
Polymerisation [MJ/ kg PAN]	N/A	199	118
Spinning [MJ/ kg PAN]	N/A	195	194
Total [MJ/ kg PAN]	245	394	312
System boundary	cradle-to-gate, primary energy	gate-to-gate	gate-to-gate

Table 2: Reported energy intensities for carbon fibre manufacturing

	De Vegt and Haije, 1997	Suzuki and Takahashi, 2005b	Griffing and Overcash, 2009	Das, 2011	Liddell et al., 2016	Liddell et al., 2017	Arnold et al., 2018
Stabilization [MJ/ kg CF]	N/A	N/A	N/A	N/A	316	195	N/A
Carbonization [MJ/ kg CF]	N/A	N/A	4.47	N/A			N/A
Surface Treatment [MJ/ kg CF]	N/A	N/A	0.05	N/A	25	24	N/A
Total [MJ/ kg CF]	7.56	286-478	4.52	704	341	219	255.02
Fibre properties	N/A	N/A	high strength	N/A	N/A	N/A	N/A
System boundary	gate-to-gate	N/A	gate-to-gate	primary energy	gate-to-gate	gate-to-gate	gate-to-gate

[Dér et al. 2021] https://doi.org/10.1016/j.jclepro.2021.127105

Table 1 Total energy consumption per kg carbon fibre

Source	Total Energy [MJ/kg]	Data origin	Comment
Arnold et al. [16]	255	Experimental data, simulation	Heat and electricity
Das [3]	459	Experimental data, databases	Little details about system
Suzuki et al. [17]	286	unclear	No details about system
Liddell et al. [18]	219	Experimental data, databases, estimations	US industry average
Liddell et al. [19]	195	Experimental data, databases, estimations	“State of the art” average
Dér et al. [15]	1150	Experimental data	Incl. peripheral processes

[Groetsch et al. 2021] https://doi.org/10.1016/j.procir.2021.01.146

VCF

- Material conversion yield of PAN precursor to VCF is 58%. Electricity, natural gas, and steam consumption include 150 MJ, 178 MJ and 31.4 kg per kg VCF produced.[5] Emission data for CF production obtained from literature.[6]

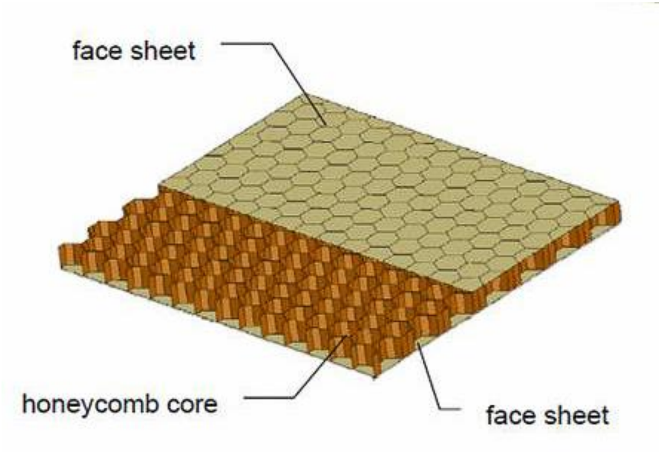
[Meng et al. 2021] https://doi.org/10.1021/acs.est.1c05462

Life Cycle Inventory
Example 2: Sandwich Core

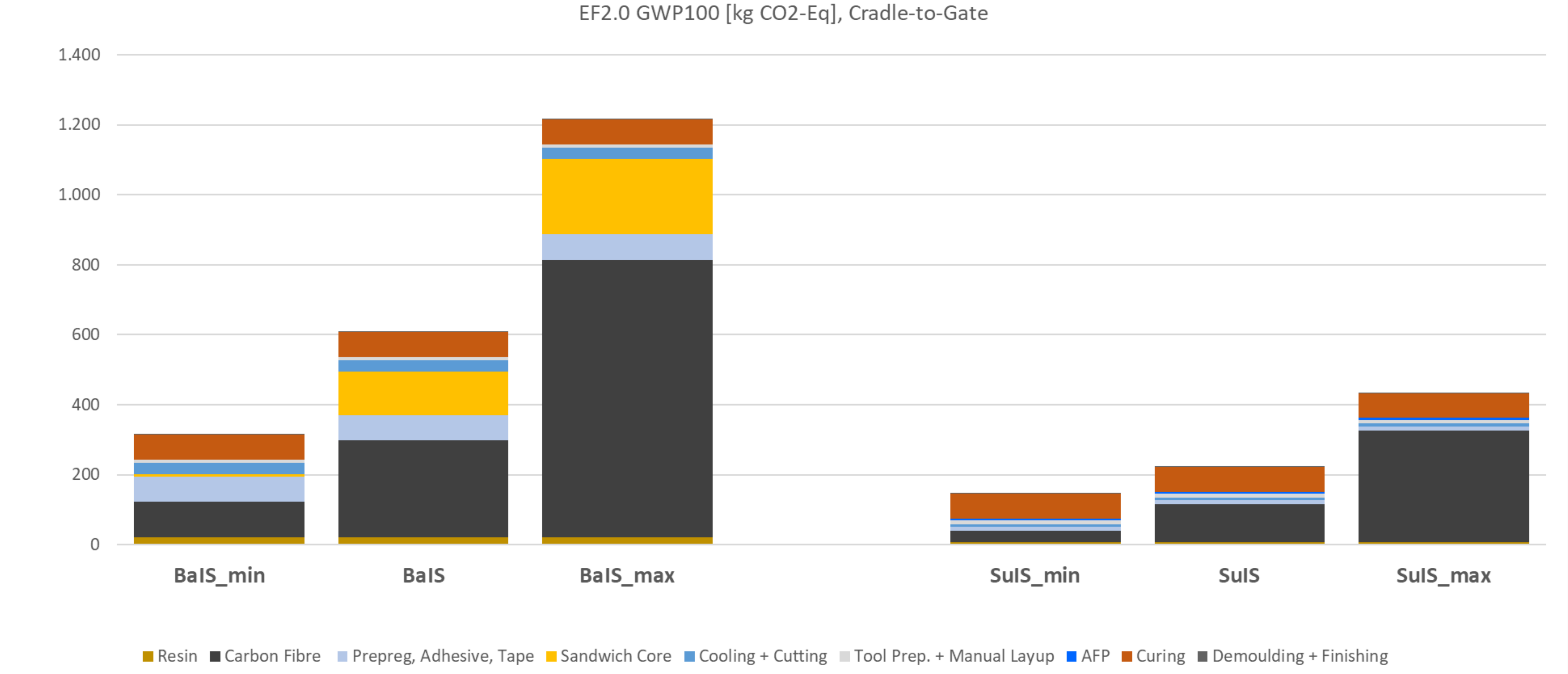
- Aramid fibre and phenolic resin
- Energy intensive production process

- No data in any LCA database

- Literature survey
  - Example
    - Proxy fibre: Nylon 6-6
    - Other processes neglected!



(Preliminary) LCIA Interior Shell, Cradle-to-Gate
Uncertainty Analysis for Carbon Fibre and Sandwich Core



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Conclusion and Outlook

- Relative differences of similar composite systems can be modelled in LCA
- Absolute values are not reliable

→ **LCI data is crucial LCA decision making**

→ **Unit Processes with Material and Energy I/O data**

→ **Transparent Data Quality Rating (DQR)**

- Further Challenges
  - Allocation / EoL Formulas
  - Most databases incompatible
  - LCIA Methods and their implementation in the software
  - Aviation Use-Phase not fully represented in LCA
  - Missing Characterisation Factors (e.g. indirect Hydrogen impact on GWP)

ALICIA
Aviation Life Cycle
and Impact Assessment

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