Environmental Improvement Potential of Flexible Polyurethane Foam for Aviation Applications

- A Case Example Analysis

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Conference Session on ecoDESIGN and Sustainable Productivity
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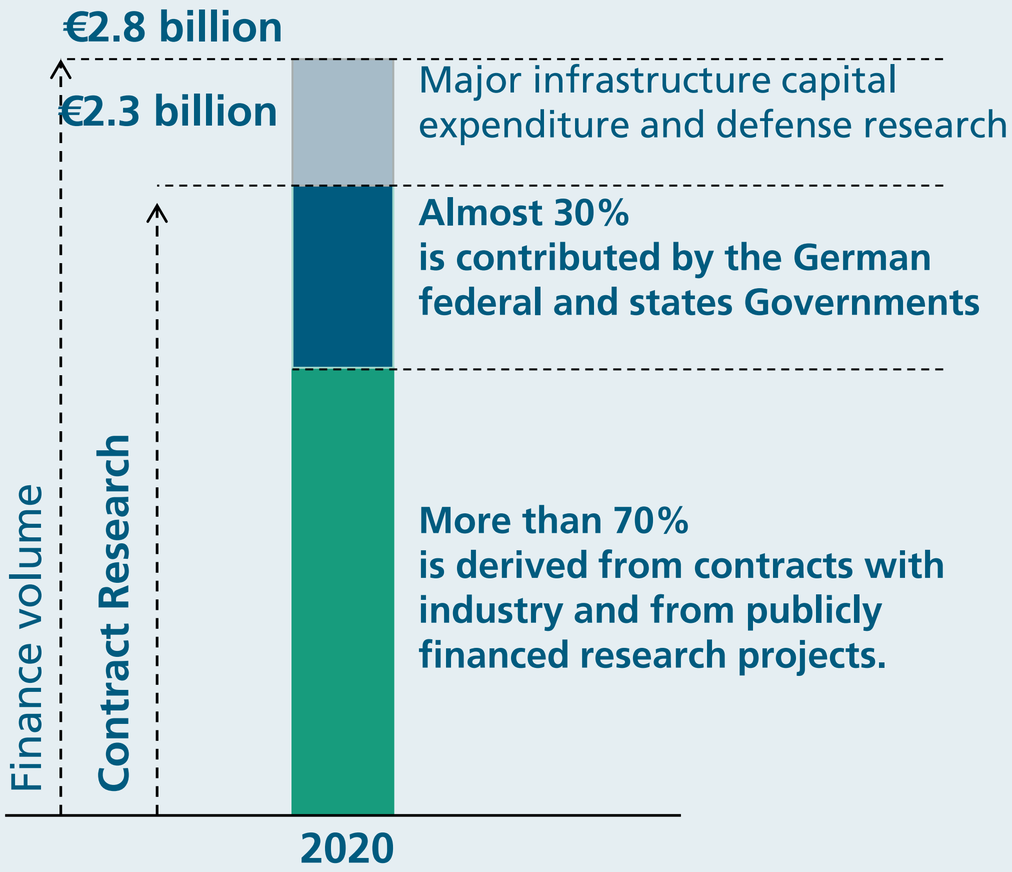
The Fraunhofer-Gesellschaft at a Glance

Fraunhofer

30,000 staff

76 institutes and research units



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Fraunhofer Institute for Chemical Technology ICT

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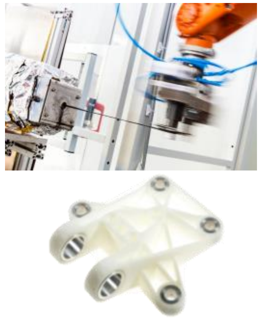
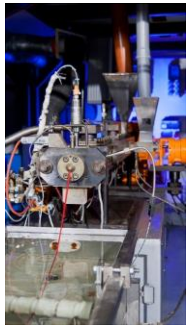
- Established in 1959
- 580 employees
- Total site area 210.000 m²
  → Laboratories, offices, etc. >27.000 m²
- Core Competences
  - Explosives technology, safety and security
  - Polymer Engineering
  - Chemical processes
  - Energy and drive systems





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AIR C-2 - Eco-Design FOR AIRFRAME Objectives and WBS

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Objectives C-1

Air C Management and Link to the transversal activity (TA) by support to CCM Delegate, to VEES/EDAS mapping, setting up of LCI data collection teams, synthesis reports and management of the outputs to ECO TA

Objectives C-2

to make available to the aerospace industry and its supply chain a set of new technologies reducing the environmental footprint of the aircraft production from the global life cycle point of view

C - Eco-Design
FHG

- WP C-1 — Eco-Design Management and ECO TA Link — *FHG, AIB, DAV, CASA*
- WP C-2 — Eco-Design for Airframe — *DAV, FHG, AIB, ecoTECH*
  - WP C-2.0 — ecoTECH management — *IAI, ALTRAN (ecoTECH)*
  - WP C-2.1 — Technology Development — *DAV, FHG, AIB, ecoTECH*
    - WP C-2.1.1 — Materials and Surface Treatments — *FhG, DAv, ecoTECH*
    - WP C-2.1.2 — Manufacturing process — *AIB, FHG, DAV, ecoTECH*
    - WP C-2.1.3 — Maintenance and Repair — *AIB, FHG, DAV, ecoTECH*
    - WP C-2.1.4 — End of Life — *FhG, DAv, ecoTECH*
    - WP C-2.1.5 — LCA data collection — *FHG, AIB, DAV, ecoTECH*
  - WP C-2.2 — Life Cycle Assessment — *FHG, DAV*
  - WP C-2.3 — Demonstration — *FHG, ecoTECH*
    - WP C-2.3.1 — Development of a composite aircraft wheel — *FHG*
    - WP C-2.3.2 — Hybrid Aircraft Seating Structure — *FHG*
    - WP C-2.3.3 — TP Fuselage Panel Demonstrator — *ecoTECH*
    - WP C-2.3.4 — TS Fuselage Panel Demonstrator — *ecoTECH*
    - WP C-2.3.5 — Metallic Fuselage Panel Demonstrator — *ecoTECH*
    - WP C-2.3.6 — Biomaterial a/c Interior Demonstrator — *ecoTECH*

2022 - 2023

WP	Title	Partners	FSD
WP C-2.3	Demonstration	*FHG, ecoTECH, AIB*	
WP C-2.3.2	Hybrid Aircraft Seating Structure	*FHG*	FSD AIR01 Cabin Interior – Seat Bank
WP C-2.3.3	TP Fuselage Panel Demonstrator	*ecoTECH*	FSD AIR02 Thermoplastic Fuselage / Wing
WP C-2.3.4	TS Wing Panel Demonstrator	*ecoTECH*	FSD AIR03 Thermoset Wing
WP C-2.3.5	Metallic Fuselage Panel Demonstrator	*ecoTECH*	FSD AIR04 Metallic Fuselage
WP C-2.3.6	Biomaterial a/c Interior Demonstrator	*ecoTECH*	FSD AIR01 Cabin Interior - Drawer box and Handrail
WP C-2.3.7	Generic Coating Demonstration	*AIB*	

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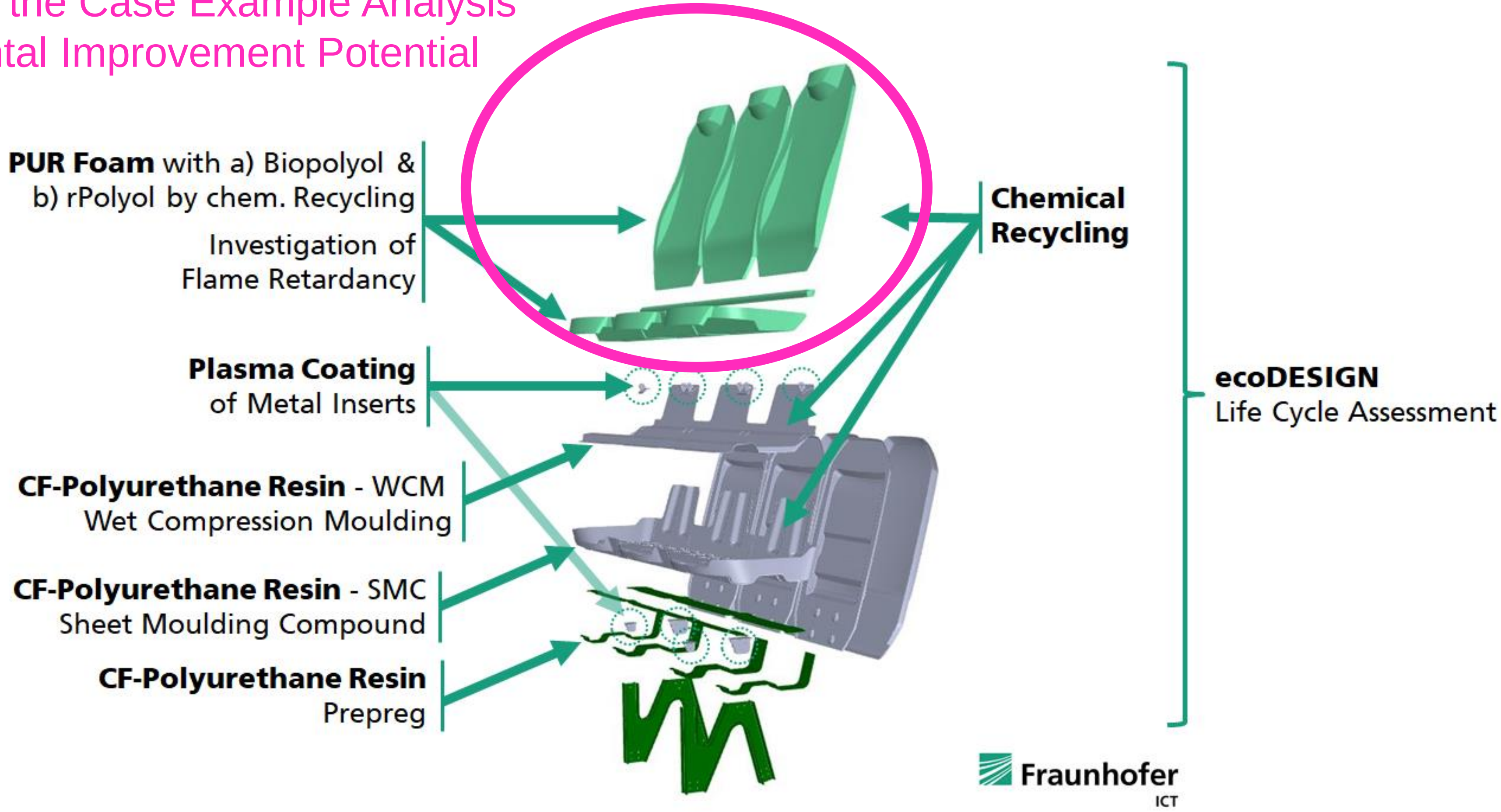
Polyurethane Flexible Foam (PUR-FF)
Component of the Case Example Analysis of Environmental Improvement Potential

Focus of the development

- Use of bio-based feedstock to reduce GWP
- Substitution of hazardous tin(II)-based catalysts (**REACh**)
- Elimination of hazardous flame retardants (**REACh**)
- Use of recycled material to avoid incineration / landfilling (**Recycling**)
- Chemical recycling of polyurethane flexible foam (**Recycling**)



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Goals

Perfomance of an eco-screening for the innovative polyurethane flexible foam for aircraft seating cushions based on three perspectives/analysis:

- Different **biopolyols** instead of fossil-based polyols
- Replacement of **hazardous chemicals** like heavy metal catalysts and flame retardants
- Use of **recovered polyol** obtained by chemical solvolysis of flexible polyurethane foam

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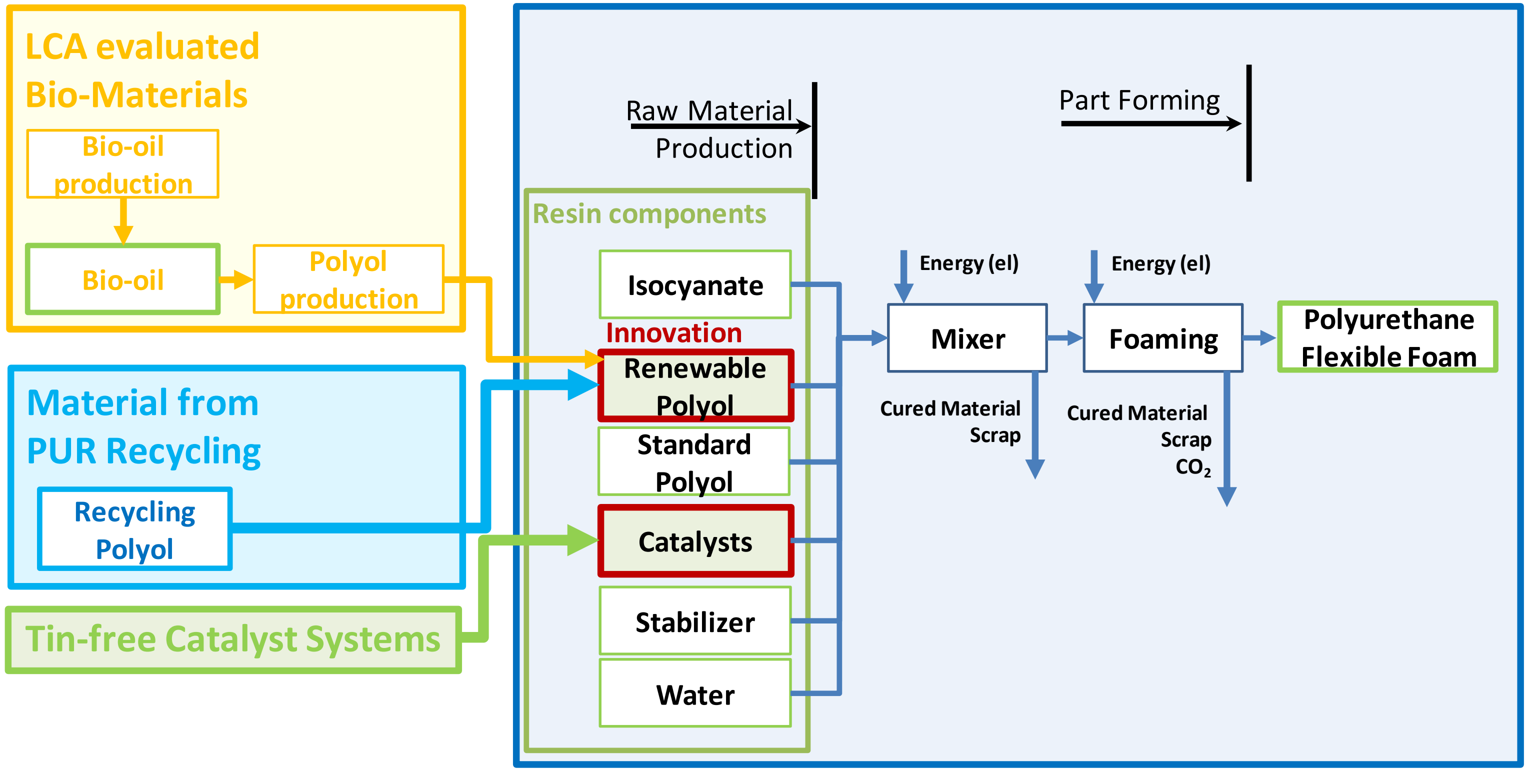
System boundaries analyzed

1	**Use of biopolyols instead of fossil-based polyols**
2	**Reduction and replacement of hazardous chemicals**
3	**Use of recovered polyol obtained by chemical solvolysis**

Flow Chart of the polyurethane flexible foam manufacturing



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Use of biopolyols instead of fossil-based polyols
- Analysis of the Environmental Burdens of Polyols -

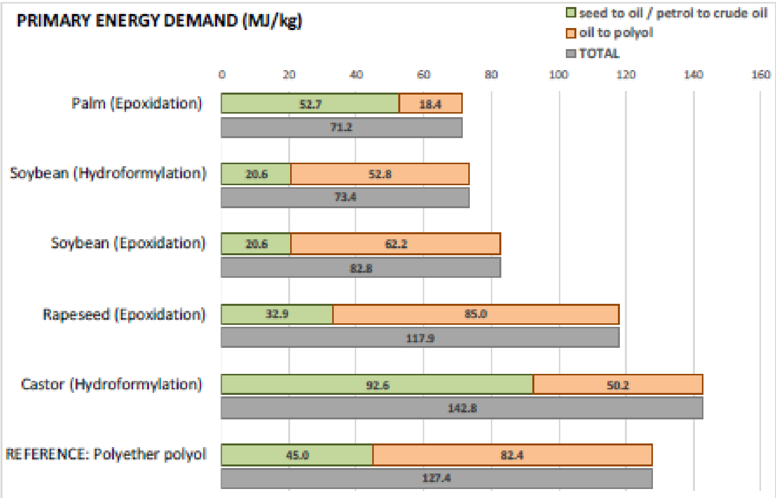
System boundary:

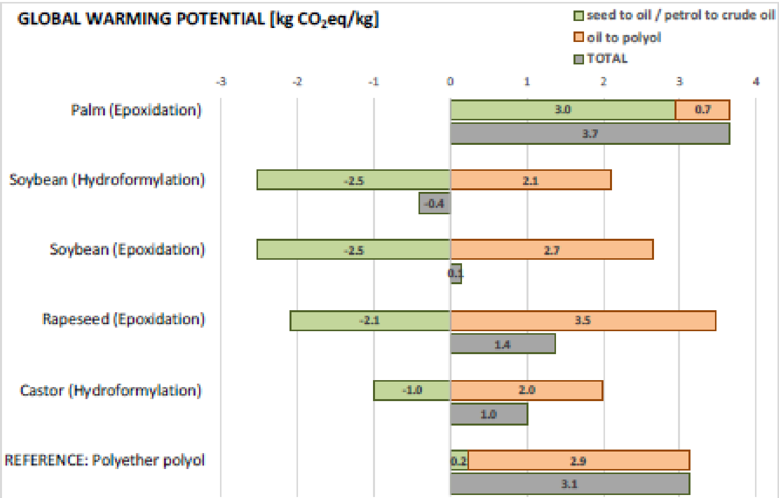
Land use change → Seeds cultivation → Harvesting → Oil production → Polyol production

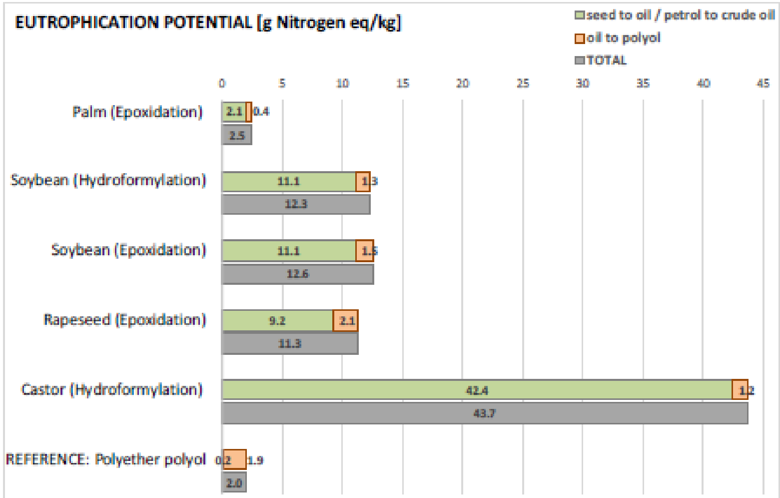
Results

- **Primary Energy Demand:** Palm and soybean polyols show the lowest impact due to high production yield (conversion of raw material into oil) and low energy consumption during the whole production of the polyol.
- **Global Warming Potential:** Soybean, rapeseed, and castor polyols show lowest impact mainly due to the consideration of the carbon cycle during land use change and sowing. Negative GWP values are caused by CO_2 uptake by the crop during cultivation. The high impact of palm oil is a consequence of deforestation, especially by rainforest burning.
- **Eutrophication Potential:** Palm polyol shows lowest impact due to low consumption of fertilizer during cultivation.

➔ **ecoDESIGN Candidate for bio-based polyurethane flexible foam: Soybean polyol**







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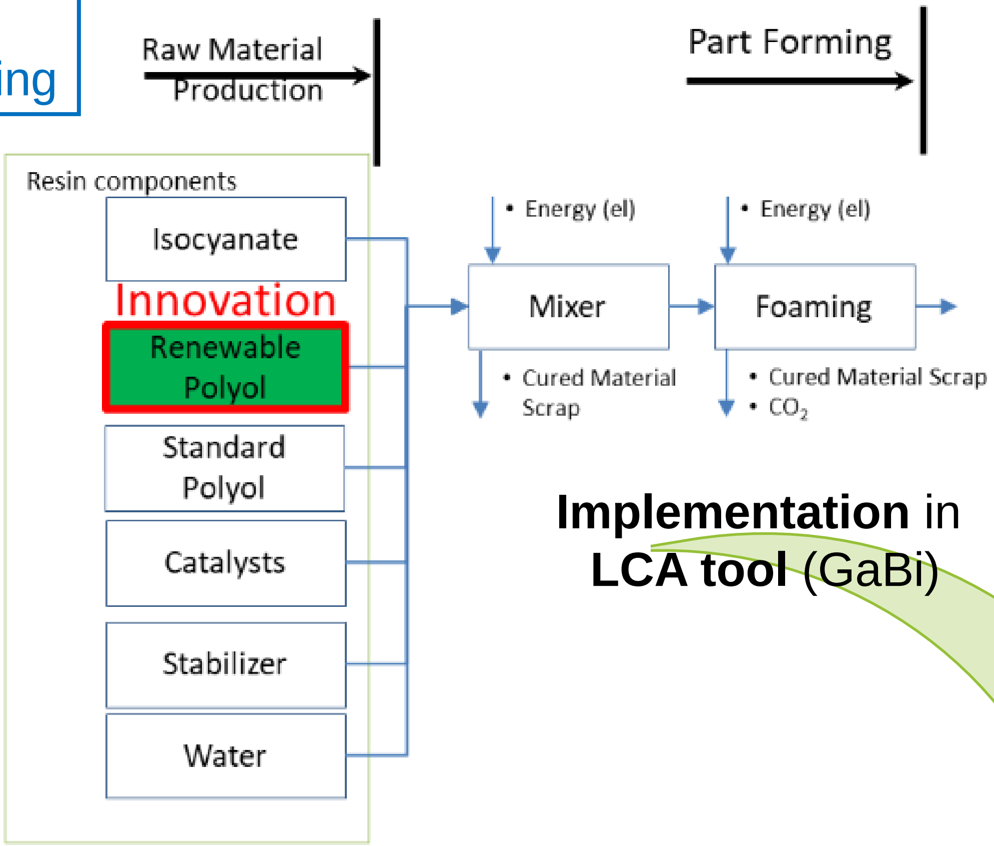
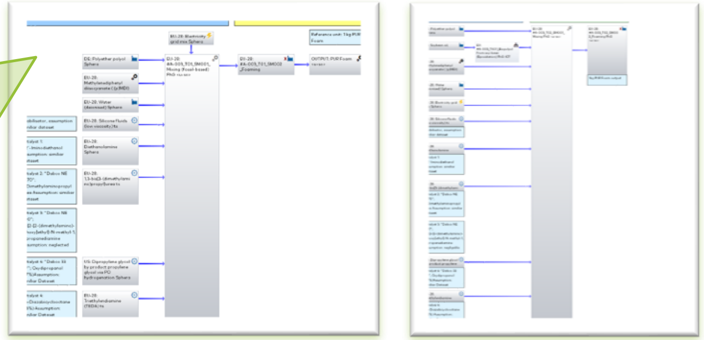
Part manufacturing



Implementation in **LCA tool** (GaBi)



Scenarios for Analysis

Parameter	Variation
1. Material	1. Fossil based polyol 2. Soybean based polyol
2. Manufacturing	1. PUR foaming

#	Scenario name
Sc.01	Polyurethane Flexible Foam made from **standard polyol** (non-renewable) [1.1 + 2.1]
Sc.02	Polyurethane Flexible Foam made from **soybean-based polyol** [1.2 + 2.1]

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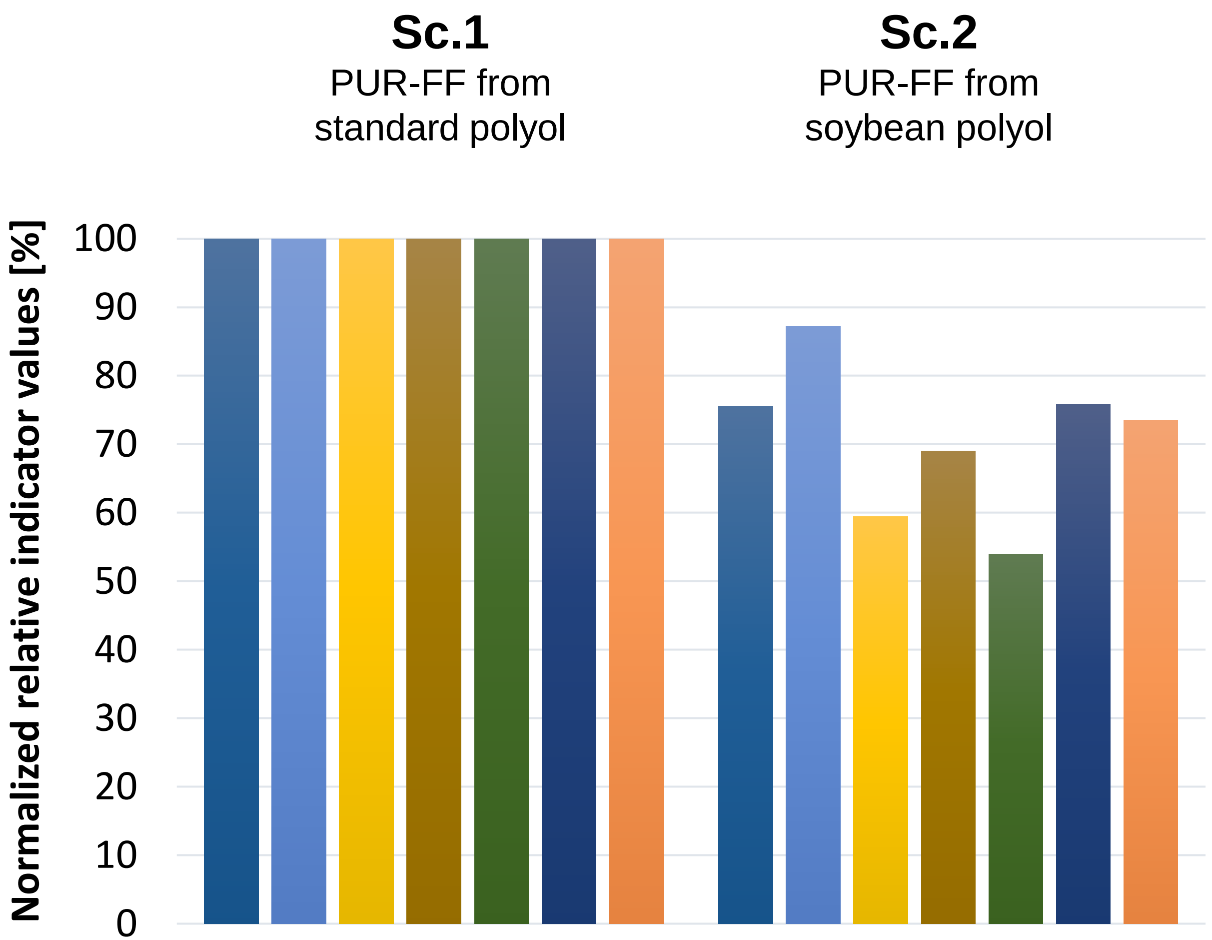
Use of biopolyols instead of fossil-based polyols
- Analysis of the Environmental *Benefits* of PUR-FF -

- CML2001 - Aug. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]
- PED - Primary Energy Demand [MJ] (Indicator of energy resources)
- CML2001 - Aug. 2016, Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB eq.]
- USEtox 2.12, Human toxicity, cancer (recommended and interim) [CTUh]
- USEtox 2.12, Human toxicity, non-canc. (recommended and interim) [CTUh]
- DALY - EI99, EA, Human health, Respiratory (organic)
- CML2001 - Aug. 2016, Abiotic Depletion (ADP elements) [kg Sb eq.]



- Main benefits are mainly driven by less energy consumption during the bio-polyol production

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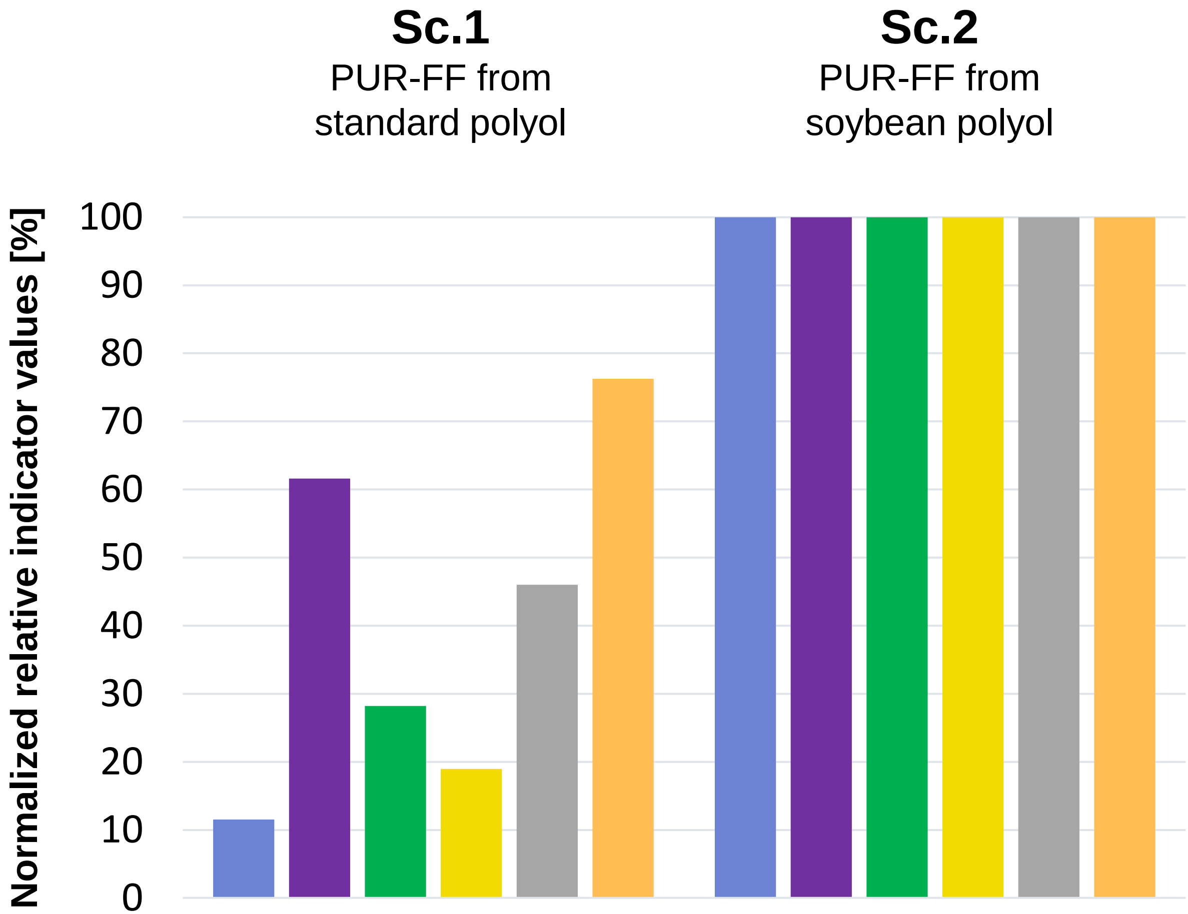
Use of biopolyols instead of fossil-based polyols
- Analysis of the Environmental *Burdens* of PUR-FF -

- Water pollution [m3]
- CML2001 - Aug. 2016, Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB eq.]
- LANCA v2.5, Biotic Production Loss Potential (Occupation) [kg]
- LANCA v2.5, Physicochemical Filtration Reduction Potential (Occupation) [mol*a]
- CML2001 - Aug. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]
- CML2001 - Aug. 2016, Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]



- Main drivers of environmental burdens are the land use change for the bio-material plantation and water consumption during its cultivation

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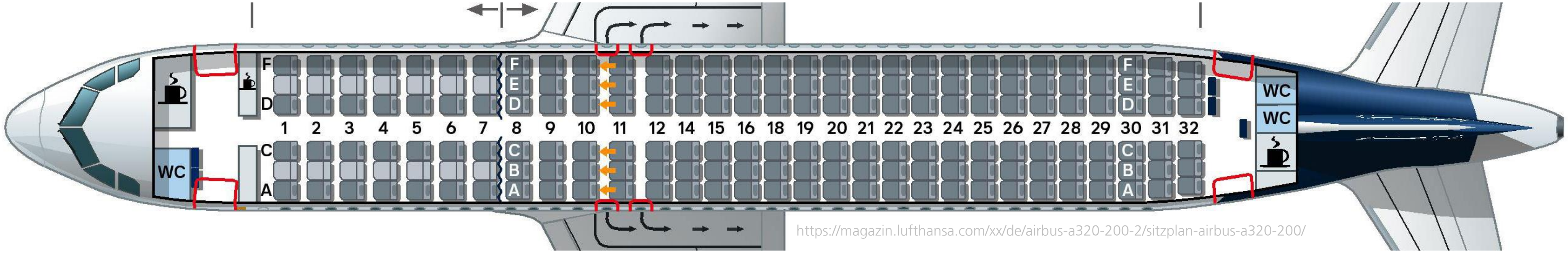
Reduction and replacement of hazardous chemicals
- Impact of Hazardous Materials on Aircraft Fleet Level -



https://magazin.lufthansa.com/xx/de/airbus-a320-200-2/sitzplan-airbus-a320-200/

Assumption for A320:

- 6 kg PUR Foam per Seating Structure
- approximately 60 Seating Structures per a/c
- 6x exchange of all Seating Structures per a/c life time

→ 2 t PUR Foam per a/c over life time

Global: **35,076 t PUR-FF** per A220/320 fleet

	A300/A310	A220/A320	A330/A340/A350	A380	Total
Total orders	816	16239	3103	251	20409
Total deliveries	816	10139	2333	248	13536
Aircraft in fleet	287	9562	2089	243	12181

https://www.airbus.com/aircraft/market/orders-deliveries.html (August 2021)

Hazardous Materials

Tin(II) Catalyst
Typically 0.1 % tin(II) catalyst in an a/c PUR foam formulation:

Assumed to be **neglectable** in a typically LCA study!

35 t Tin(II) Catalyst Savings

Flame Retardant
Typically 5-10 % Flame Retardant in an a/c PUR foam formulation:

1,750-3,500 t
Flame Retardant Savings

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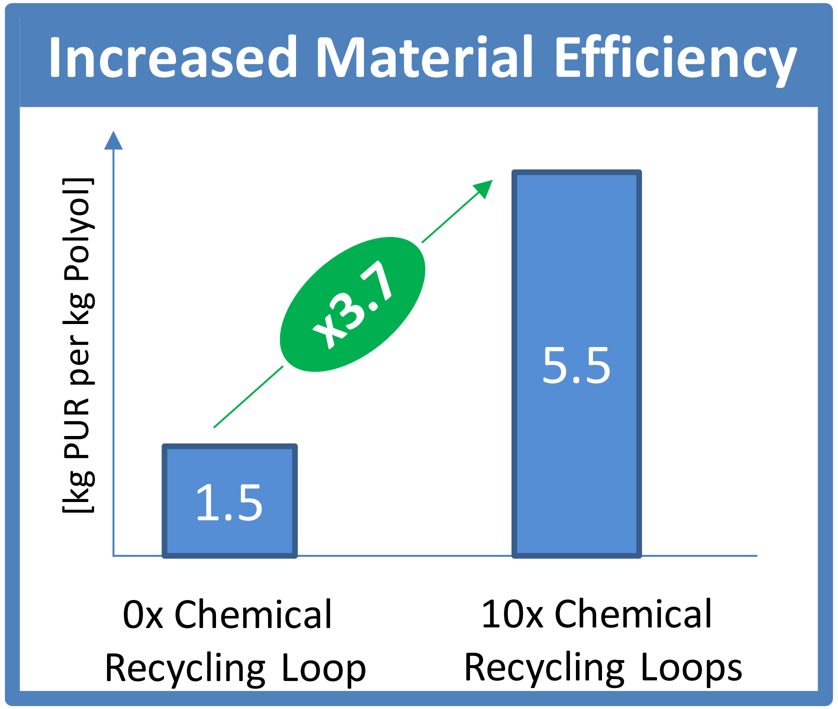

Recycling in the context of bio-based polyols:

- Recycling technologies (e.g. chemical recycling) for PUR-FF enables the recovery of polyols
- **Recovery of polyols increases** the **yield of PUR-FF** over the entire life-time in respect to the **cultivated seeds**

- **Thought experiment:**
  - **(1) 1 kg** bio-based / fossil-based **polyol** leads to **1.5 kg PUR-FF**
  - (2) If **PUR-FF** is **recycled 10 times** (polyol recovery: 95%; recovered polyol usage: 75% of PUR-FF polyol fraction)
    ➔ **1 kg** of **polyol** leads to **5.5 kg PUR-FF**

➔ Particular importance to **minimize environmental impact** as land use change, eutrophication, etc. **due to oil seed plantation**

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Conclusions – Eco-screening

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Eco-screening performed for the innovative polyurethane flexible foam for aircraft seating cushions

Analysis of three perspectives:

- Use of biopolyols instead of fossil-based polyols
  ecoDESIGN Candidate for bio-based polyurethane flexible foam: **Soybean polyol**

- Reduction and replacement of hazardous chemicals like heavy metal catalysts and flame retardants
  1,750-3,500 t flame retardant savings

- Use of recovered polyol obtained by chemical solvolysis of polyurethane flexible foam
  Chemical recycling technology increases **material efficiency** by **3.7 times**

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Conclusions

- For **ecoDESIGN of an aircraft, several impacts on the environment** must be considered - not only in the use phase - but also during the production stage and the end-of-life stage of an aircraft.

- Within this eco-screening, we achieved a deep ecological understanding with the differentiation of the three case examples on PUR-FF for aircraft seating cushions

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Thank you for your Attention!

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Further Information and Acknowledgement

Acknowledgement

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