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25/10/2017



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CTC
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AN AIRBUS COMPANY

Life cycle analysis for Carbon Composite Structures in different branches

25.10.2017

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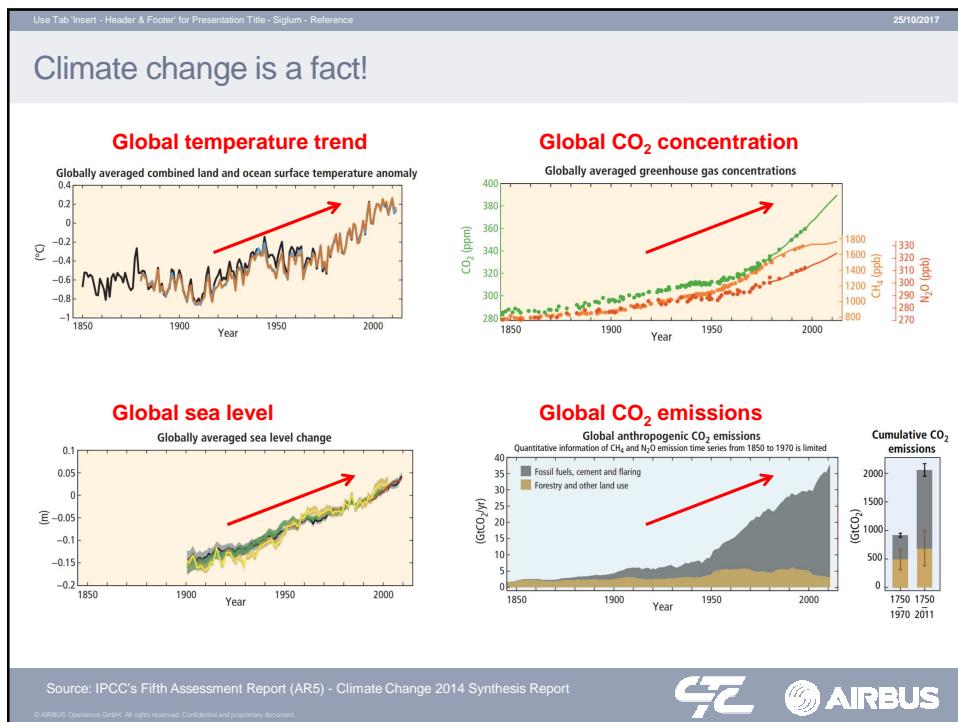
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Life cycle analysis for Carbon Composite Structures in different branches

- Motivation of life cycle analysis in transportation
- How to compare the three modes of transportation?
- Actual comparison
- Results and Conclusion

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Life cycle approaches – compared

Accounting for	Assessment criteria
...common criteria	Resource consumption, environmental exposure, humane toxicity, greenhouse effect, ozone depletion, acidification, eutrophication, ecotoxicity, summer smog, noise pollution
... ISO 14044	General requirements for life cycle assessment (with scope for definition of separation criteria)
... MIPS	Abiotic material, biotic material, soil movement in agriculture and forestry, water and air
... Method of ecological shortage	Comparison of the environmental impact (actual quantity) with the load (tolerance quantity), which is regarded as permissible in terms of society policy. The ratio of actual quantity to tolerance quantity is referred to as ecological shortage
... Carbon footprint	Emitted CO ₂ in the course of the production of a product
... cumulative energy consumption	Total energy required for the production of a product/raw material per kg
... Company directives ???Unternehmensvorgabe	energy consumption, CO ₂ emissions, Recyclability, Use of hazardous substances , water consumption, material shortage, ...

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Life cycle approaches – compared How to define the frame?

Production Process of a Product

```

graph LR
    A[Herstellung] --> B[Handel]
    B --> C[Nutzer/Verbraucher]
    C -- Entsorgung --> D[Entsorgung]
    A -- Betriebs- und Hilfsstoffe --> E[Produkt z. B. Kühlschrank]
    E --> B
    
```

The diagram illustrates the production process of a product. It starts with 'Herstellung' (Manufacturing) at the top left, which leads to 'Handel' (Trade) in the center. From 'Handel', the product is delivered to the 'Nutzer/Verbraucher' (User/Consumer) at the bottom right. An arrow labeled 'Entsorgung' (Waste disposal) points from the consumer back towards the manufacturing stage. Additionally, there is a feedback loop from the consumer back to the manufacturing stage, labeled 'Betriebs- und Hilfsstoffe' (Operating and auxiliary materials).

*Source: modified, Original aus: "Ökobilanzen populär", Senatsverwaltung für Wirtschaft und Technologie, Berlin 1995

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Life cycle approaches – compared How to define the frame?

LCA - Method 1

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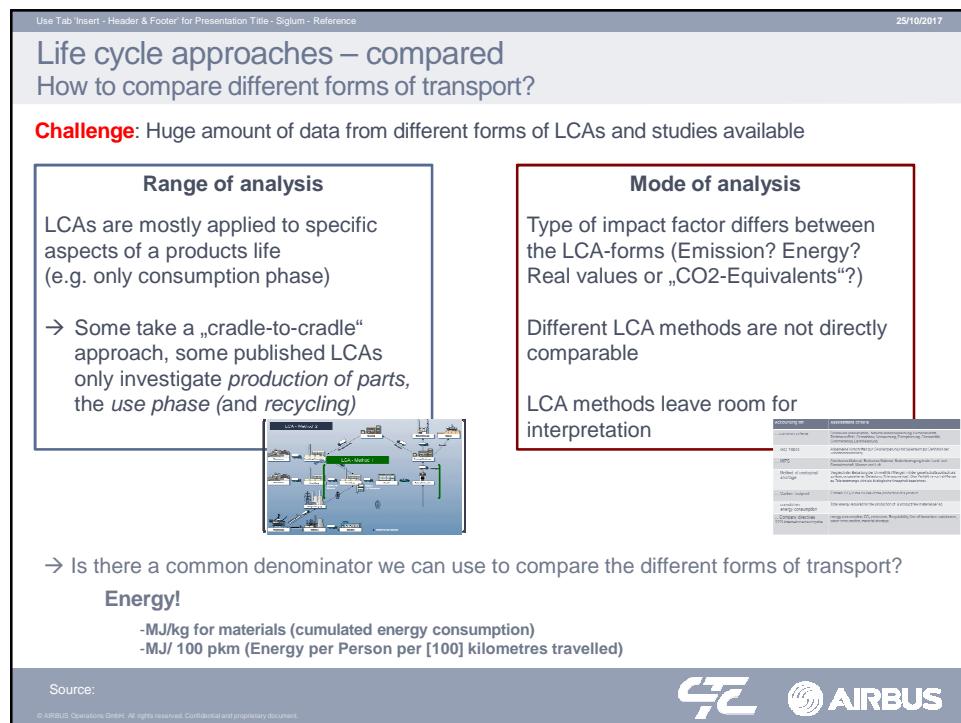
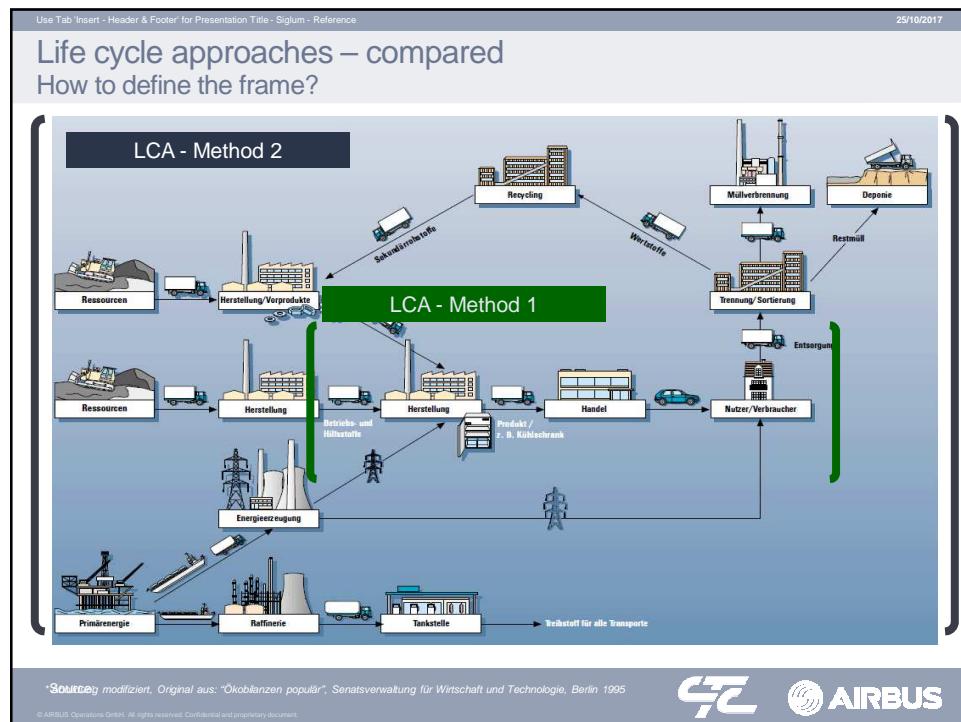
graph LR
    A[Herstellung] --> B[Handel]
    B --> C[Nutzer/Verbraucher]
    C -- Entsorgung --> D[Entsorgung]
    A -- Betriebs- und Hilfsstoffe --> E[Produkt z. B. Kühlschrank]
    E --> B
    
```

The diagram illustrates the production process of a product, similar to the one above. It shows the flow from 'Herstellung' (Manufacturing) to 'Handel' (Trade) to 'Nutzer/Verbraucher' (User/Consumer). An arrow labeled 'Entsorgung' (Waste disposal) points from the consumer back towards the manufacturing stage. A green bracket encloses the entire sequence from manufacturing to waste disposal, representing the scope of the Life Cycle Assessment (LCA) method being demonstrated.

*Source: modified, Original aus: "Ökobilanzen populär", Senatsverwaltung für Wirtschaft und Technologie, Berlin 1995

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Life cycle approaches – why we need a cradle to cradle approach

Production			
Use phase			

Focus of company provided LCAs are the production of individual units of transport

- Energy and emissions during production
- Consumption (and derived emissions) during use

Source: Wikipedia; Hamburger Abendblatt; www.motor-talk.de; taz.de; Wirtschaftswoche; Spiegel.de

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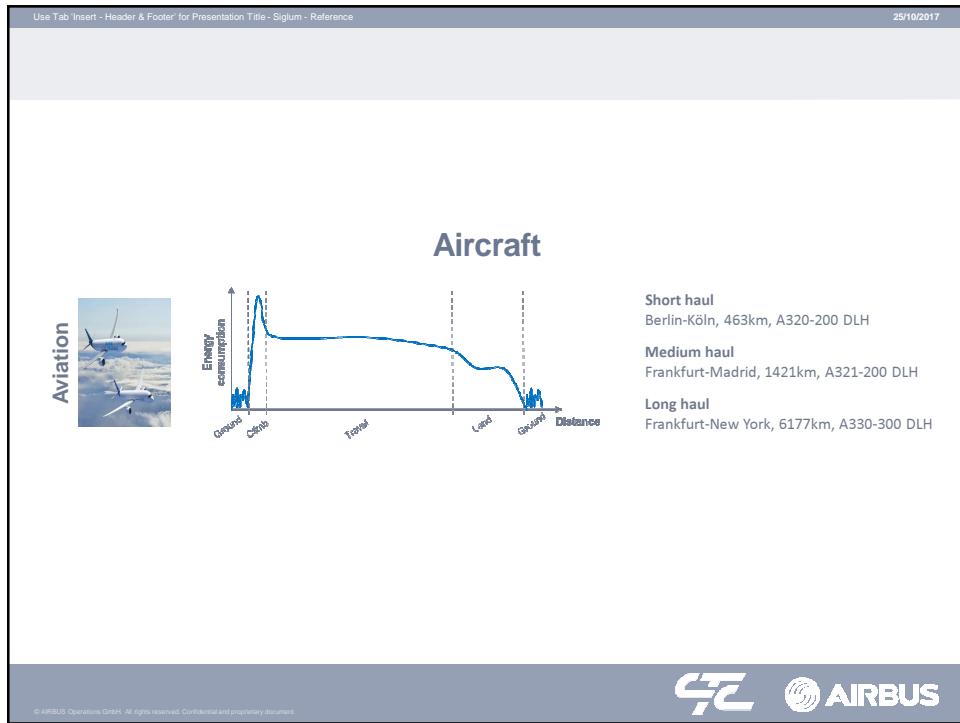
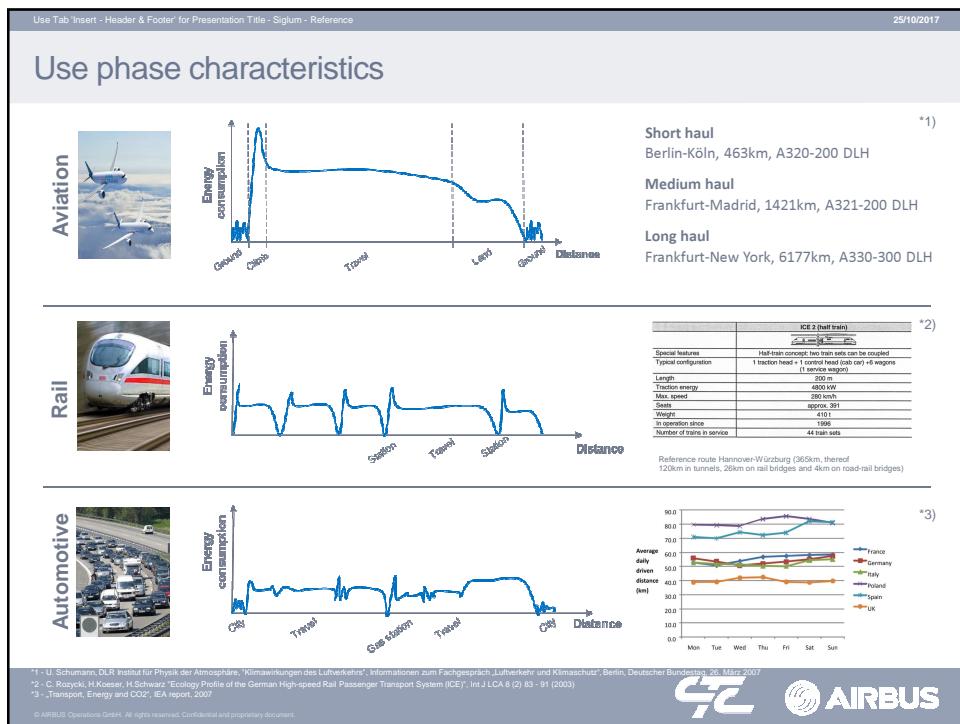
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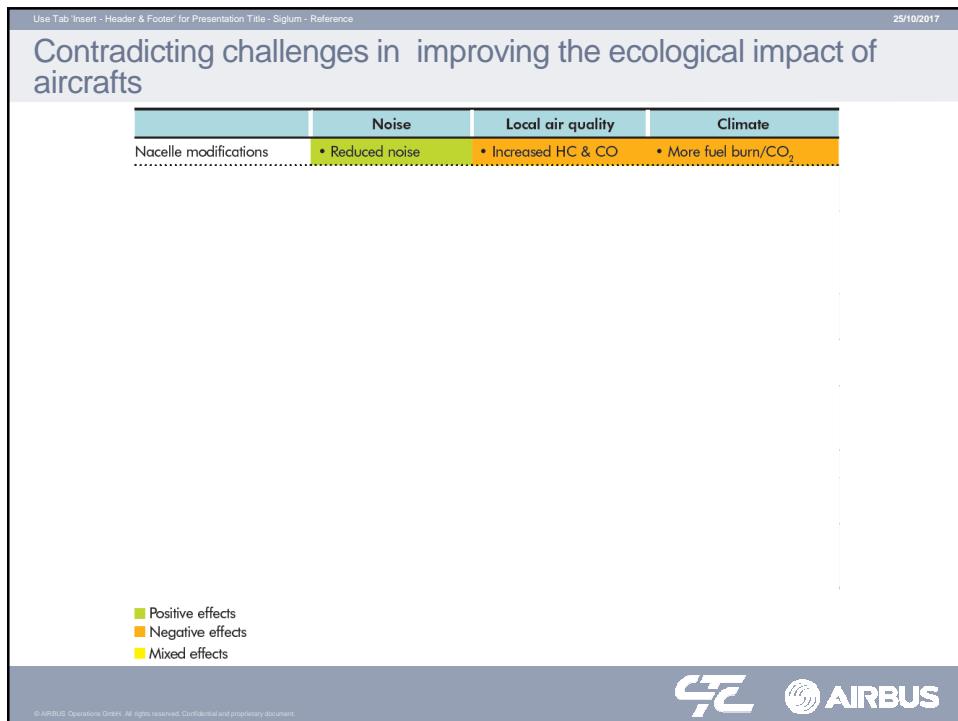
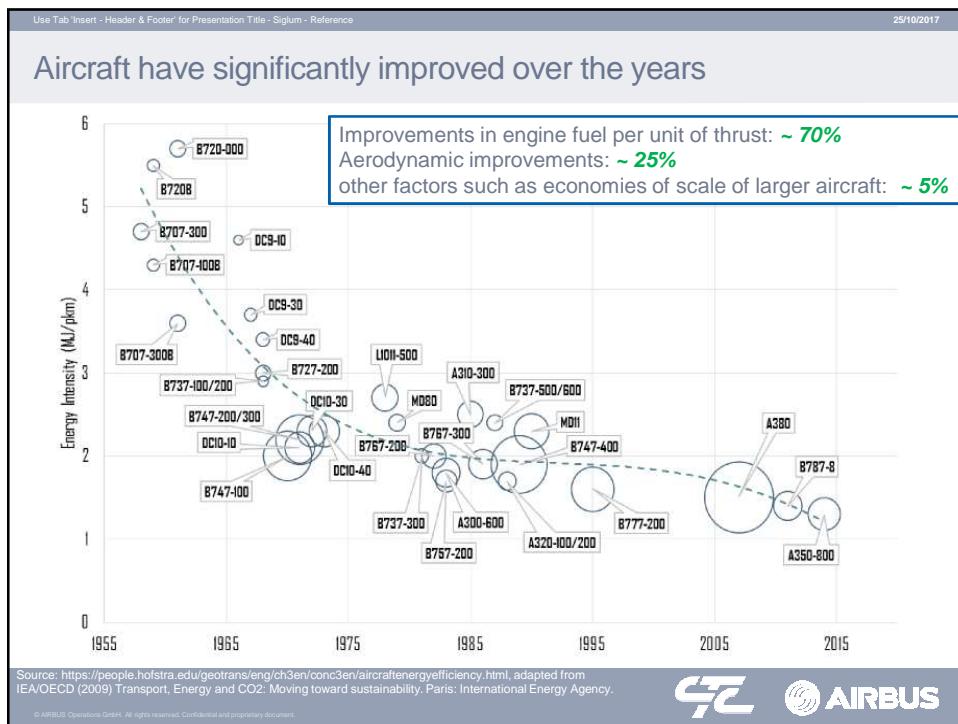
Life cycle approaches – why we need a cradle to cradle approach

Production			
Infrastructure			
Use phase			

Source: Wikipedia; Hamburger Abendblatt; www.motor-talk.de; taz.de; Wirtschaftswoche; Spiegel.de

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Contradicting challenges in improving the ecological impact of aircrafts

	Noise	Local air quality	Climate
Nacelle modifications	• Reduced noise	• Increased HC & CO	• More fuel burn/CO ₂
Increased engine pressure ratio & temp		• Increased NO _x • Reduced HC & CO	• Reduced fuel burn/CO ₂
Reduce cruise altitude			• Increased fuel burn/CO ₂ • Increased NO _x • Less increase in ozone • Reduced contrails
Increase engine bypass ratio	• Reduced noise	• Increased NO _x	• Reduced fuel burn/CO ₂
New runways	• New noise exposures	• Reduced delay (fuel burn)	
Reduce polar flights	• Potentially increased noise exposures		• Less effects on stratosphere • More fuel burn/CO ₂
Steep climb	• Reduced noise	• More fuel burn	• More fuel burn/CO ₂
Continuous descent approach (CDA)	• Reduced noise	• Reduced delay (fuel burn)	• Reduced fuel burn/CO ₂
Reduced thrust takeoffs	• Reduced noise	• Reduced NO _x • Reduced PM • Increased SO _x	• More fuel burn/CO ₂

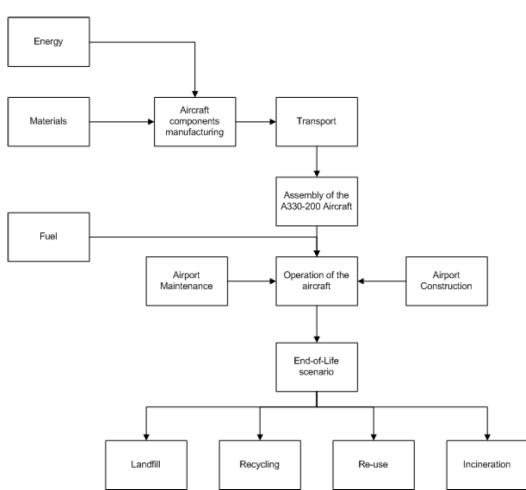
Legend:
■ Positive effects
■ Negative effects
■ Mixed effects

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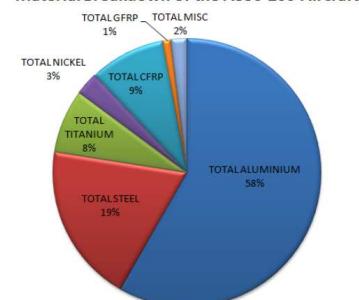


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Basis for comparison - Aviation



Material Breakdown of the A330-200 Aircraft



Material	Weight (in Kg)	Weight contribution (in %)
Aluminium	61903	58,3
Steel	20388	19,2
Titanium	8161	7,7
Nickel	2948	2,8
CFRP	9743	9,2
GFRP	1059	1,0
Miscellaneous	2015	1,9
TOTAL	106218	100

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Actual per person consumption of different flights

Dataset 1

Short haul	Medium haul	Long haul
Berlin-Köln, 463km, A320-200 DLH, 5,39l/ 100 pkm	Frankfurt-Madrid, 1421km, A321-200 DLH, 4,55 l/ 100 pkm	Frankfurt-New York, 6177km, A330-300 DLH, 4,03l/ 100 pkm

Dataset 2

Range type	Directions	Fuel consumption, L/PAX	Fuel consumption L/PAX/100 km
Short haul	Berlin-Köln, A320-200	25	5,4
Medium haul	Frankfurt- Madrid, A321-200	65	4,6
Long haul	Frankfurt-Peking, A340-600	310	4,0

Source: Deutsche Lufthansa, 2007; M.Schaefer, DLR-Institut für Antriebstechnik, 2007.

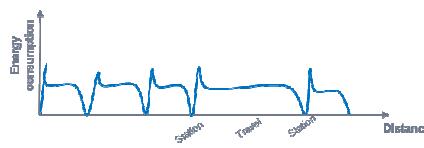
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Train

Rail

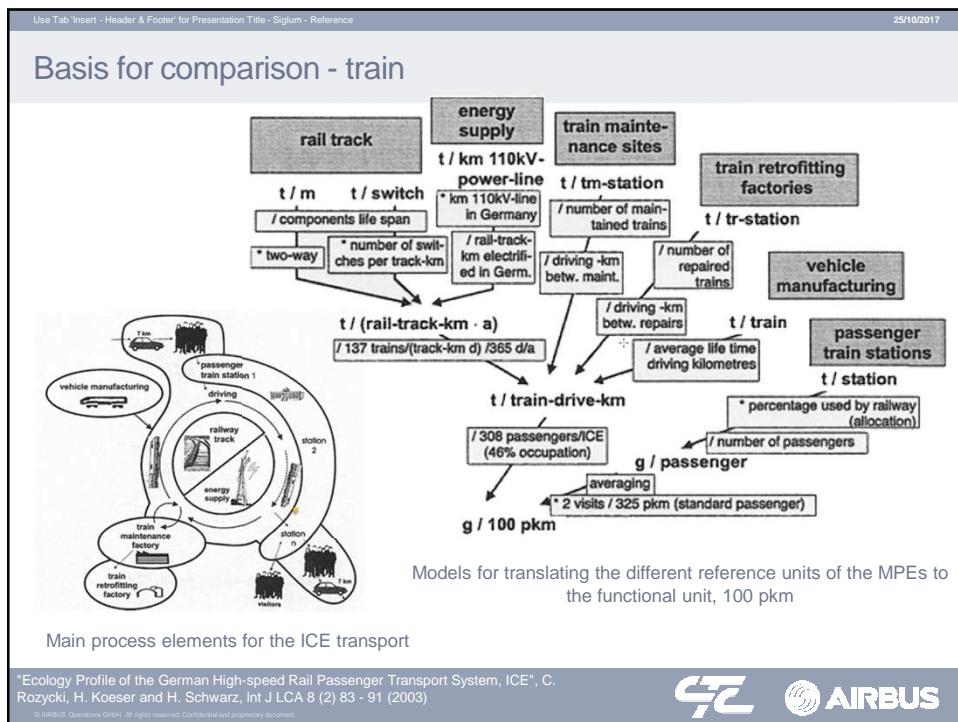



ICE 2 (half train)	
Special features	Half-train concept: two train sets can be coupled
Type/Configuration	1 traction head + 1 intermediate car + 8 service wagons
Length	200 m
Traction energy	4800 kW
Max. speed	280 km/h
Seats	approx. 391
Weight	141 t
In operation since	1998
Number of trains in service	44 train sets

Reference route Hannover-Würzburg (365km, thereof 120km in tunnels, 26km on rail bridges and 4km on road-rail bridges)

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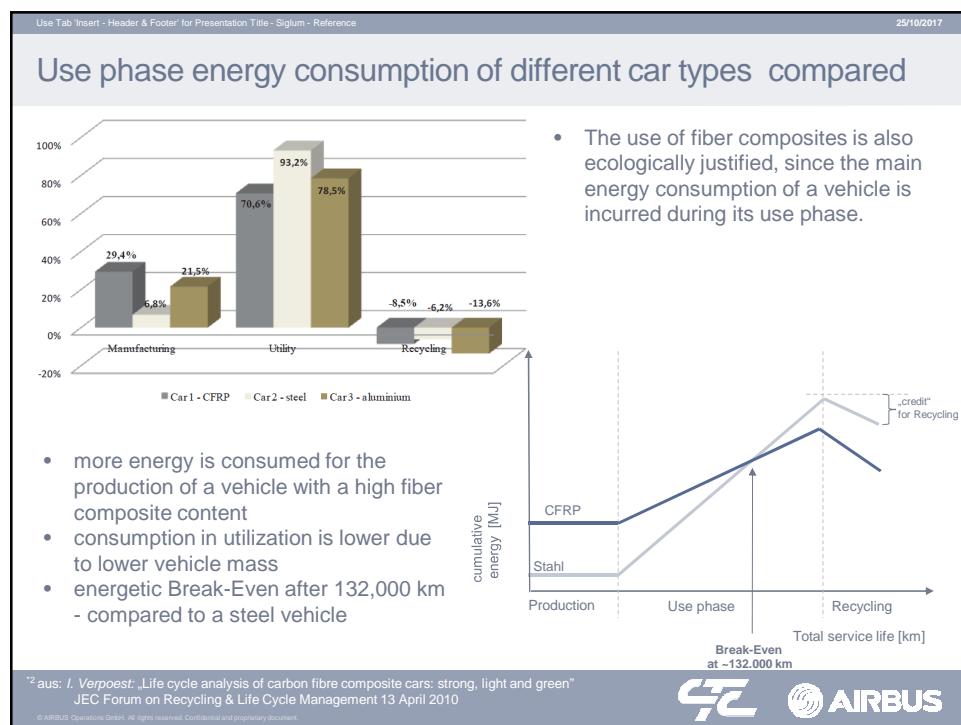
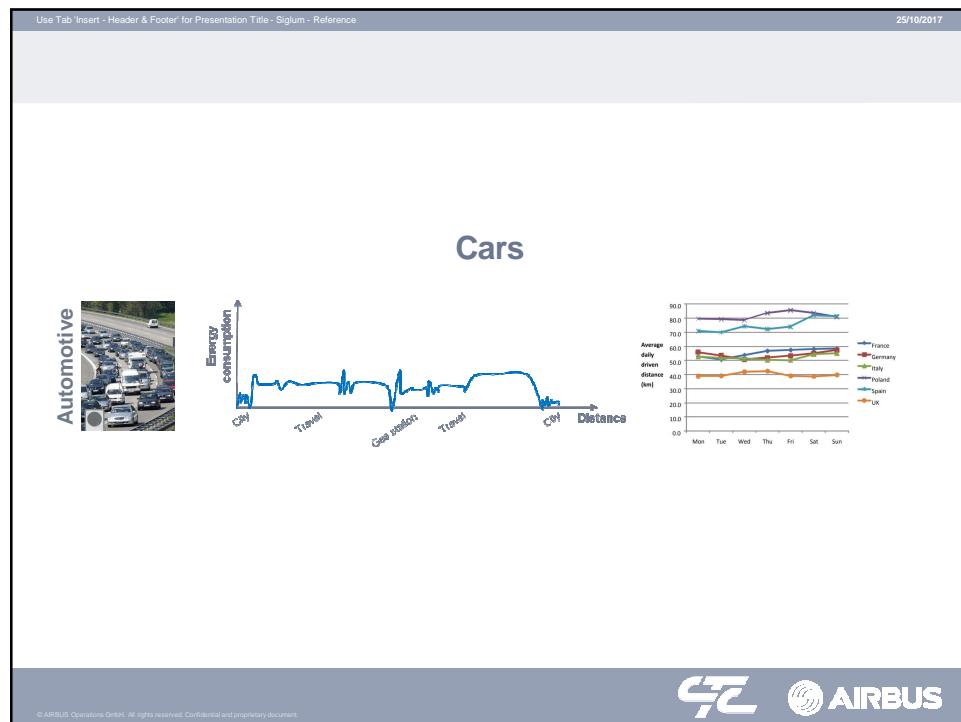
Total energy consumption of an ICE (German high speed train)

Input	Direct masses / end energies		CED
	[kg / 100 pkm (ICE)]	[MJ / 100 pkm (ICE)]	
Rail electricity	8.18	83.8	
Grid electricity	0.124	1.33	
Thermal energy	0.521	1.10	
[kg / 100 pkm (ICE)]		[MJ / 100 pkm (ICE)]	
Drinking water	2.51	0	
[kg / 100 pkm (ICE)]		[MJ / 100 pkm (ICE)]	
Petrol (passenger overhead)	0.422	18.4	
Gravel (ballast)	3.76	0.902	
Concrete	2.11	2.10	
Sand/grit	0.812	0.0760	
Glass	0.00110	0.0157	
Insulation material (mineral wool)	0.000677	0.00861	
Plastics	0.00755	0.269	
Soil/rock excavation	15.5	0.415	
Steel	0.210	5.14	
Iron	0.0113	0.190	
Aluminum	0.00597	0.855	
Copper	0.00627	0.293	
Non-ferrous metals (unspec.)	0.00106	0.0266	
primary energy for construction		2.11	
Output		CED	
waste water	2.27	0	
waste/secondary raw materials	0.0028	0	
Σ		117 MJ / 100 pkm	

Energy balance for high speed train
117 MJ / 100 pkm
(→ 1,17 MJ / pkt)

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Use phase and production is clear, but infrastructure for cars and busses – how?

Complex LCA model has to be used to cover all of the three life cycle elements

The diagram illustrates the life cycle assessment (LCA) model for different modes of transport. It is divided into three main phases: Production, Infrastructure, and Use phase. Each phase is further subdivided into Upstream Processes and Operational Processes.

- Production:** Shows images of an aircraft on the assembly line, a car on the assembly line, and a bus interior. A green checkmark is present.
- Infrastructure:** Shows images of a road, a highway, and an airport tarmac. A red arrow points from the Infrastructure section towards the Operational Processes diagram.
- Use phase:** Shows images of a road, an airplane in flight, and a train. A green checkmark is present.

Upstream Processes:

- Aircraft: EIO-LCA
- Intercity Bus: GREET_2
- Personal Vehicle: GREET_1
- Infrastructure: Chester (2008)
- Fuel Upstream: GREET_1

Operational Processes:

- Aircraft:** Cruise, LTO, GSE, AEDT, EDMS
- Intercity Bus & Automobile:** Highway Operation, City Street Operation, Drop-off, Terminal Trip
- Maintenance:** EIO-LCA, GREET_2 & Chester (2008)

Legend:

- Data Source/Modeling Tool
- Energy/Emission Process

Models used in the life-cycle assessment (LCA) analyses.

Model	Model full name	Life-cycle stage
MOVEs	MOtor Vehicle Emission Simulator	Motor vehicle operations
GREET_1	The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model 1: Fuel Cycle Model	Fuel upstream
GREET_2	The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model 2: Vehicle Cycle Model	Manufacturing
AEDT	Aviation Environmental Design Tool	Aircraft operations
EDMS	Emission and Dispersion Modeling System	Airport-related operations Landing and takeoff Ground support equipment Infrastructure, manufacturing, and maintenance
EIO-LCA	Economic Input-Output Life Cycle Assessment	

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Final summary and comparison

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