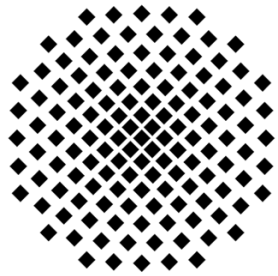

Environmental performance analysis of the operation phase for an aircraft



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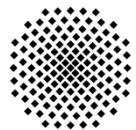
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Life Cycle Engineering

Agenda

- ▶ Motivation
- ▶ Goal and scope
- ▶ LCA modelling of the use phase
- ▶ Results
- ▶ Summary and outlook



Motivation

▶ EU Emission Trading System

- Applied for aeronautic sector from 2012
- At first only CO₂-emissions, from 2013 on also methane, fluorocarbons and nitrous oxides
- Currently about 12 € per t CO₂

▶ Growing ecological awareness of costumers

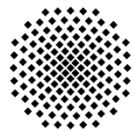
- Voluntary dues (emission calculators)

▶ Scarce resources

- Continuous rising oil price
- Biofuels as an alternative

→ **Environmental impacts are gaining importance as a cost factor and for communication.**

Seite 3



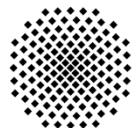
Goal and scope

Goal:

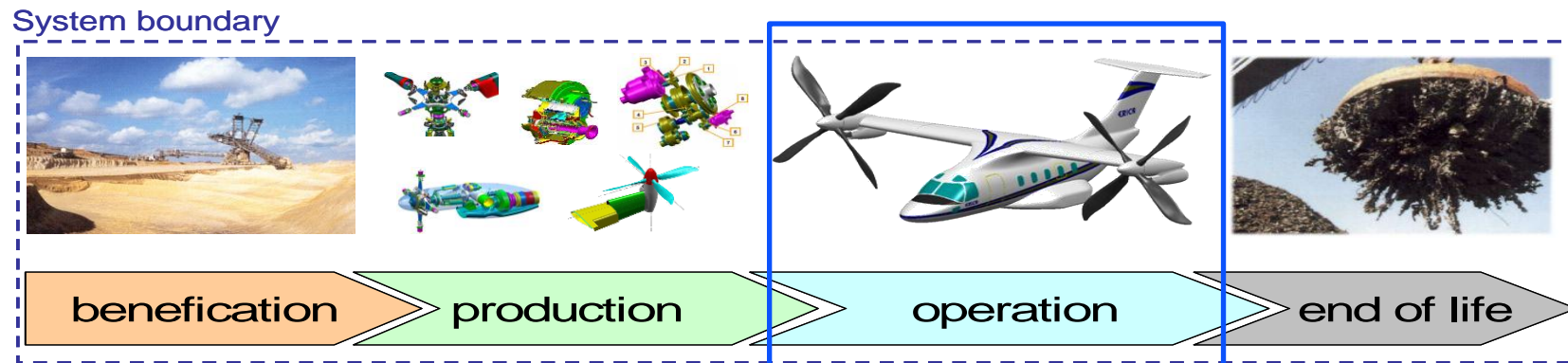
Assessing environmental impacts of the use phase on an aircraft system by using the LCA method.

Scope:

Conducting an LCA for the case study of the NICETRIP tilt rotor flight, taking into account operation, maintenance and infrastructure use.



System boundaries

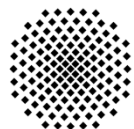


NICETRIP – Tilt Rotor Aircraft

- Range 1200 km
- Capacity 19 (VTOL) / 22 (STOL) passengers
- Cruise speed up to 610 km/h

→ Combining the advantages of rotorcraft and aircraft

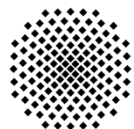
Seite 5



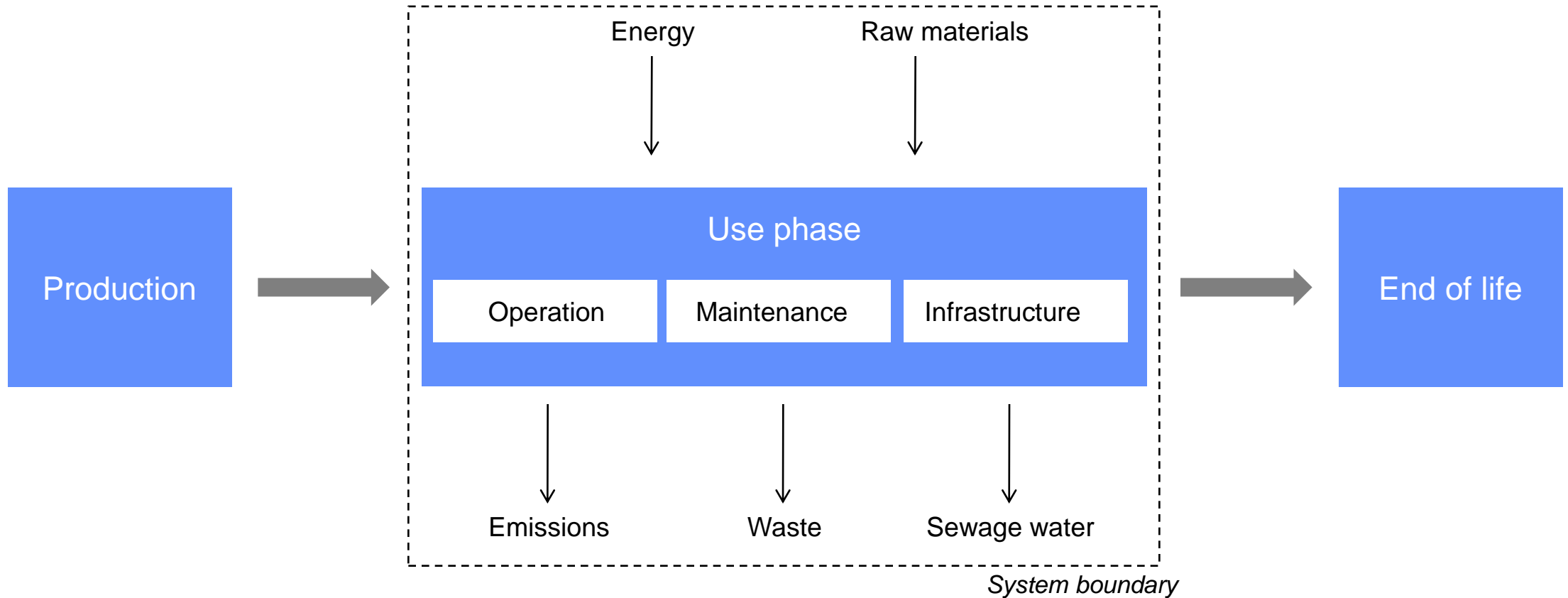
Environmental indicators and impact categories

Selected impact categories

- ▶ PED: Primary energy demand [MJ]
- ▶ GWP: Global warming potential [kg CO₂-eq.]
- ▶ POCP: Photochemical ozone creation potential [kg C₂H₄-eq.]
- ▶ AP: Acidification potential [kg SO₂-eq.]
- ▶ EP: Eutrophication potential [kg PO₄³⁻-eq.]

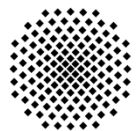


System boundaries



Functional unit: Transportation of one passenger over the entire flight distance

Seite 7



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Ganzheitliche Bilanzierung



System boundaries

▶ Aircraft operation

- Tilt Rotor Aircraft
- Flight distance 735 km
- Seat load factor 68,1 %



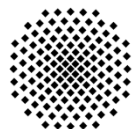
▶ Maintenance

- Service and overhaul



▶ Infrastructure operation

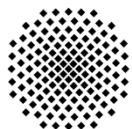
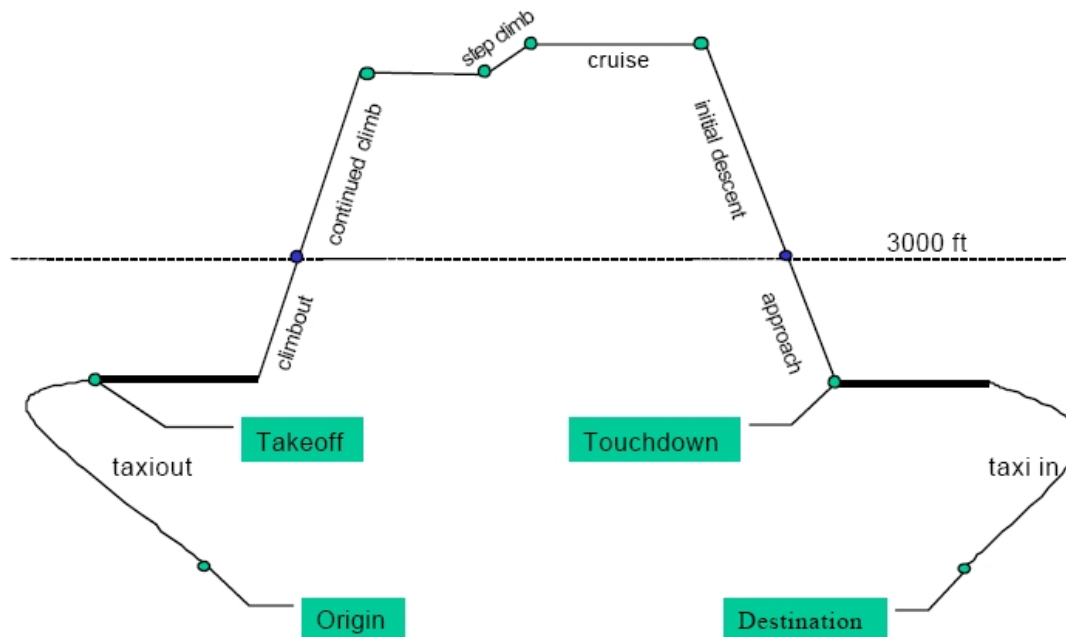
- Representative airport
- 12,7 million passengers per year
- 2 airport utilisations per passenger (takeoff and landing)



System boundaries – Aircraft operation

► Flight pattern and distances

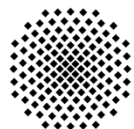
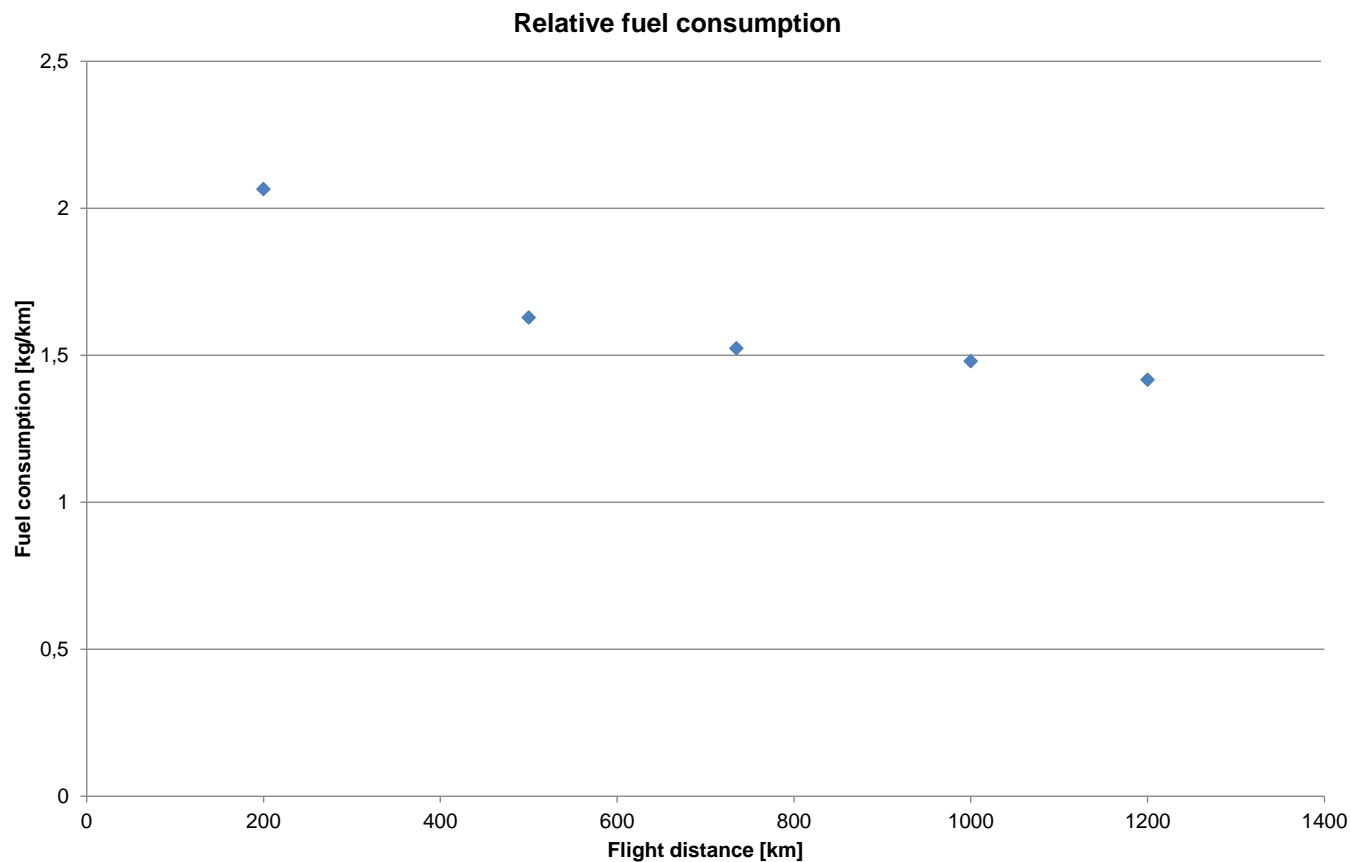
- Seat load factor 68,1 %
- Different flight phases use different engine load, resulting in different combustion of fuel



System boundaries – Aircraft operation

▶ Relative fuel consumption

- Based on information from Project consortium
- Assumption: fuel is 100 % Kerosene



System boundaries – Maintenance

▶ Service

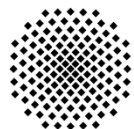
- Short notice, aircraft stays on flight schedule

▶ Overhaul

- Scheduled
- Time requirements & frequency
 - A-check: several hours / after 250-650 hrs airborne
 - B-check: 150 working hours / after 1000 hrs airborne
 - C-check: 5000 working hours, on ground for 1-2 weeks / after 15-18 months
 - D-check: 30.000-80.000 working hours, on ground for 4-6 weeks / after 6-10 years

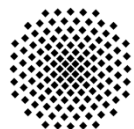
▶ No information on NICETRIP maintenance processes available yet

→ Estimation: 5% of production efforts (correlating with maintenance costs)



System boundaries – Infrastructure

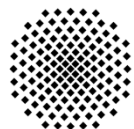
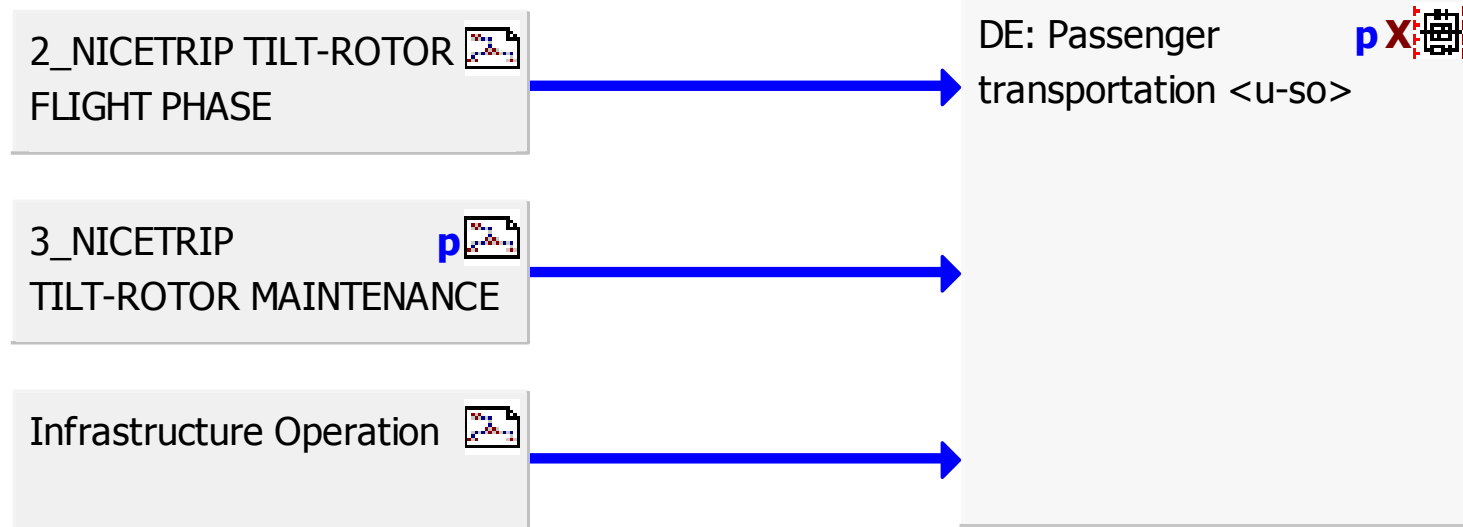
- ▶ Energy consumption (Electricity, heating, cooling)
- ▶ Fuel consumption of airport vehicles
- ▶ Maintenance of buildings, runways and rollways
- ▶ Waste



LCA modelling of the use phase

NICETRIP full operation phase

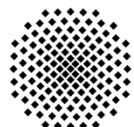
GaBi 4 process plan: Reference quantities
The names of the basic processes are shown.



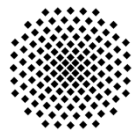
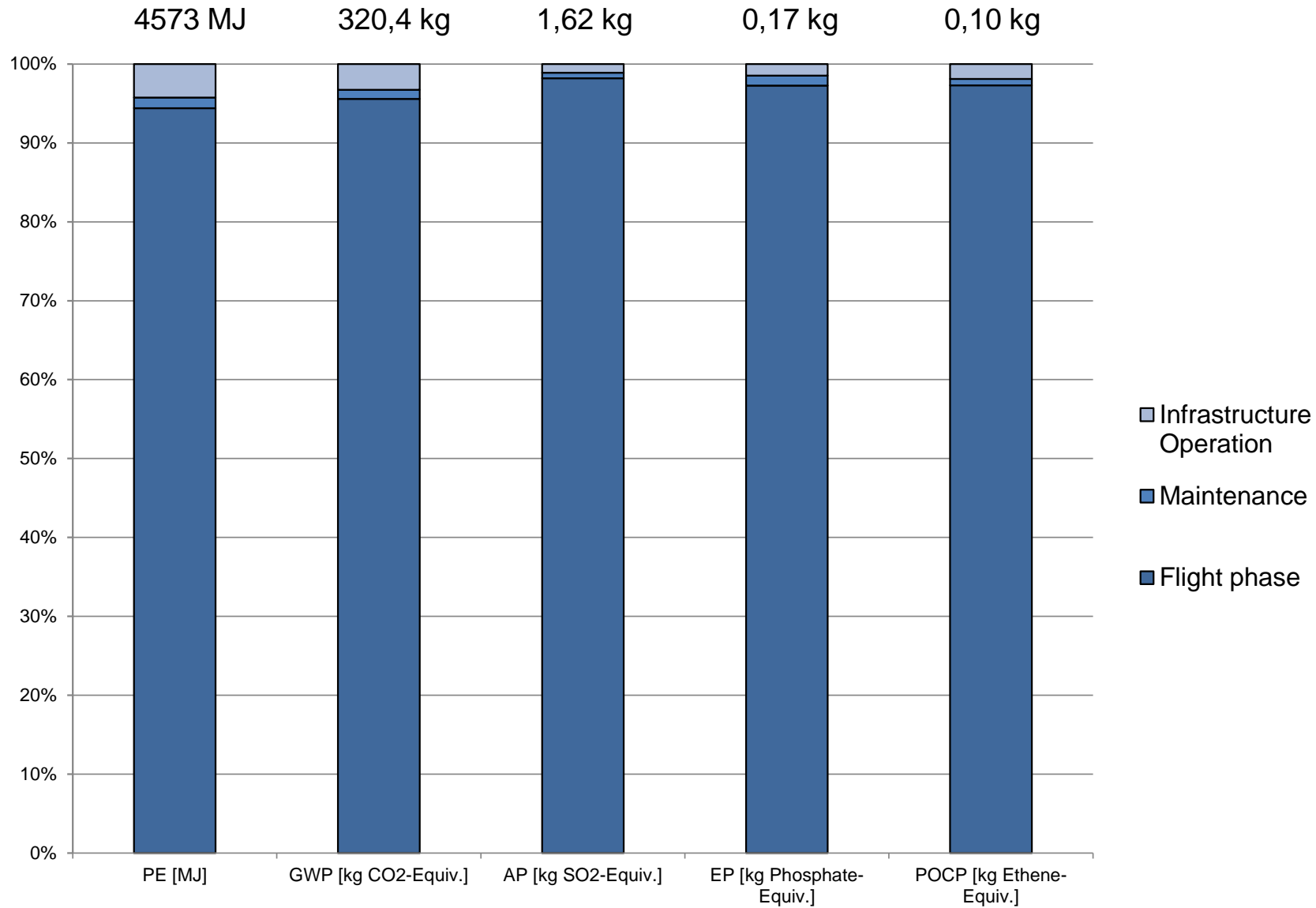
LCA modelling of the use phase

Parameter						
Parameter	Formula	Value	Minimum	Maximum	Standard	Comment, units, defaults
cap	[x] fl.cap	19				[001] maximum no. of passengers [max 19]
cap_use	[x] fl.cap_use	0,681				[002] seat load factor. Europe=68,1%, transatlantic=82,3%. Source: LH
dist	[x] fl.distance	735				[003] [km] distance travelled [max 1850 km]
ppm_sulfur		400			0 %	[004] [ppm] sulfur content of kerosine.
cons_total_in	cons_0+cons_1+cons_2+cons_3+cons_4	860				[005] [kg] total fuel consumption interpolated [cruise phase]
cons_ph1	50	50				[005a] [kg] consumption phase 1 (taxi)
cons_ph2	22	22				[005b] [kg] consumption phase 2 (take off)
cons_ph3	128	128				[005c] [kg] consumption phase 3 (climb)
cons_ph5	60	60				[005d] [kg] consumption phase 5 (landing)
total_consump	cons_ph1+cons_ph2+cons_ph3+cons_ph5+cons_total	1120				[005e] [kg] total consumption
cons_km	total_consumpti/dist	1,5238				[006] [kg/km] kerosine consumption per kilometer. Source: EIG
cons_pax	total_consumpti/(cap*cap_use)	86,56				[007] [kg/passenger] total kerosine consumption per passenger
cons_paxkm	cons_pax/dist*100	11,777				[008] [kg/Pkm] kerosine consumption per 100 passengerkilometer
ef_CO	1,5	1,5				[010] [g/kg] ef carbon monoxide. Source: EIG
ef_CO2	3150	3150				[011] [g/kg] ef carbon dioxide. Source: UBA
ef_H2O	1240	1240				[012] [g/kg] ef water vapour. Source: UBA
ef_N2O	0,15	0,15				[013] [g/kg] ef nitrous oxide. Source: UBA
ef_HC	0,85	0,85				[014] [g/kg] ef non-methane volatile organic compounds. Source:EIG
ef_NOx	13,05	13,05				[015] [g/kg] ef nitrogen oxide. Source: EIG
ef_pm	0,0076	0,0076				[015a] [g/kg] ef for particulate matter (PM2,5)
ef_sulfur	ppm_sulfur*2/100	8				[016] [g/kg] ef sulfur
em_H2O	ef_h2o*total_consumpti	1,3888E006				[017] [g] emissions of water vapour
em_N2O	ef_n2o*total_consumpti	168				[018] [g] emissions of nitrous oxide
em_HC	(ef_HC*cons_total_in)+6760	7491				[019] [g] emissions of NMVOC, assumption based on Shorts SC7 emission data
em_NOx	(ef_nox*cons_total_in)+3114	14337				[020] [g] emissions of nitrogen oxide
em_sulfur	ef_sulfur*total_consumpti	8960				[021] [g] emissions of sulfur dioxide
em_co	(ef_co*cons_total_in)+2362	3652				[023] [g] emissions of carbon monoxide
em_co2	ef_co2*total_consumpti	3,528E006				[024] [g] emissions of carbon dioxide
em_pm	(ef_pm*cons_total_in)+19,2	25,736				[025] [g] emissions of particulate matter (PM2.5)

- 1 – free parameters, adaptable by user
- 2 – calculation of fuel consumption
- 3 – emission factor for combustion of 1 kg of fuel
- 4 – total emissions for entire flight distance



Results

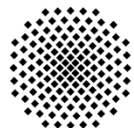
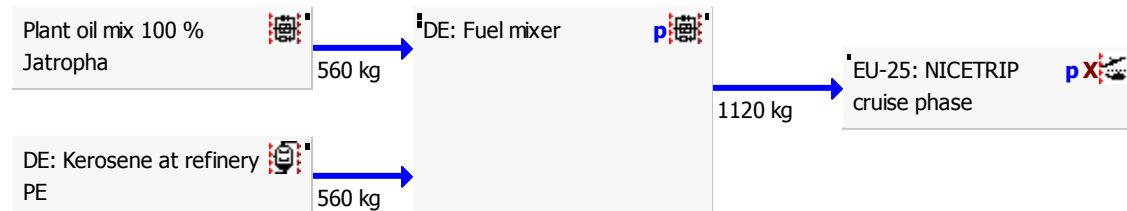


Scenario - Biofuel

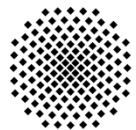
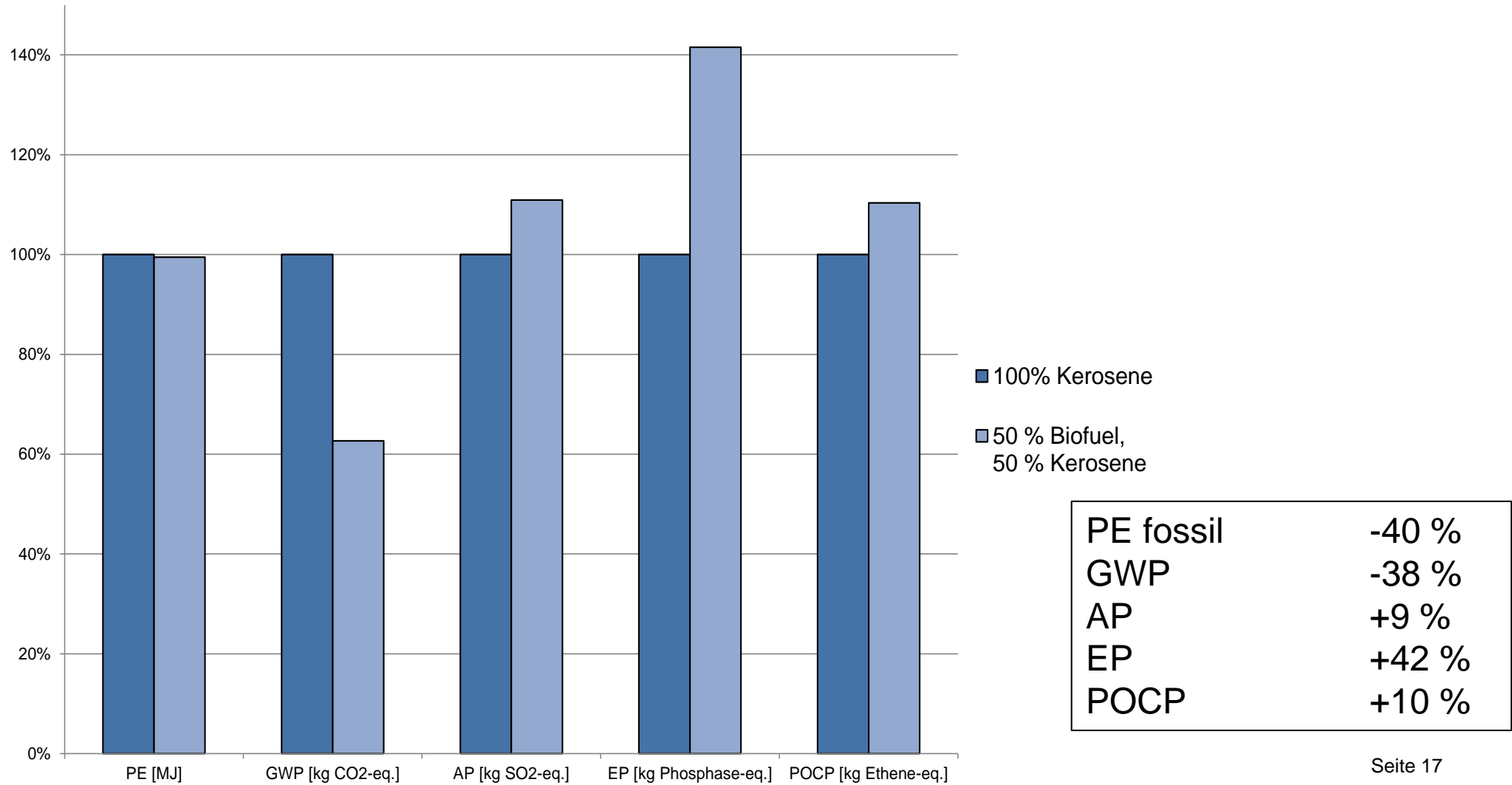
- Jatropha based Biofuel
- 50 % Biofuel, 50 % Kerosene
- Drop-in fuel
- Assumption: biofuel has same combustion properties as kerosene

2_NICETRIP TILT-ROTOR FLIGHT PHASE

GaBi 4 process plan:Reference quantities
The names of the basic processes are shown.



Results - Biofuel



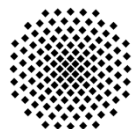
Summary and outlook

Summary and analysis

- ▶ Description of the use phase for passenger transportation
- ▶ Assessing infrastructure, maintenance and tilt-rotor operation
- ▶ Flexible model: seat load factor, distance, infrastructure, share of biofuel can be adapted
- ▶ Different types of fuel can be used in the model
- ▶ Quantification of environmental impacts in the aeronautic sector
- ▶ Flight has strongest impacts, Infrastructure & Maintenance have little impact

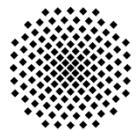
Outlook

- ▶ Combustion of alternative fuels can be modelled (Jatropha, Rapeseed oil, Palm Oil, LNG, Biomethan,...)
 - Data requirements for combustion processes
- ▶ Optimisation of technology (light weight construction, optimised engines) and traffic control (Single European Sky) can be evaluated and quantified



Acknowledgement

This paper is based on work conducted in the scope of the EU-Project “NICETRIP - Novel Innovative Competitive Effective Tilt Rotor Integrated Project”, co-financed by the European Commission under the contract number AIP5-CT-2006-030944. This contribution is highly appreciated.



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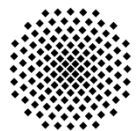
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