Ecological comparison of selected alternative sanitation concepts with Life Cycle Assessment

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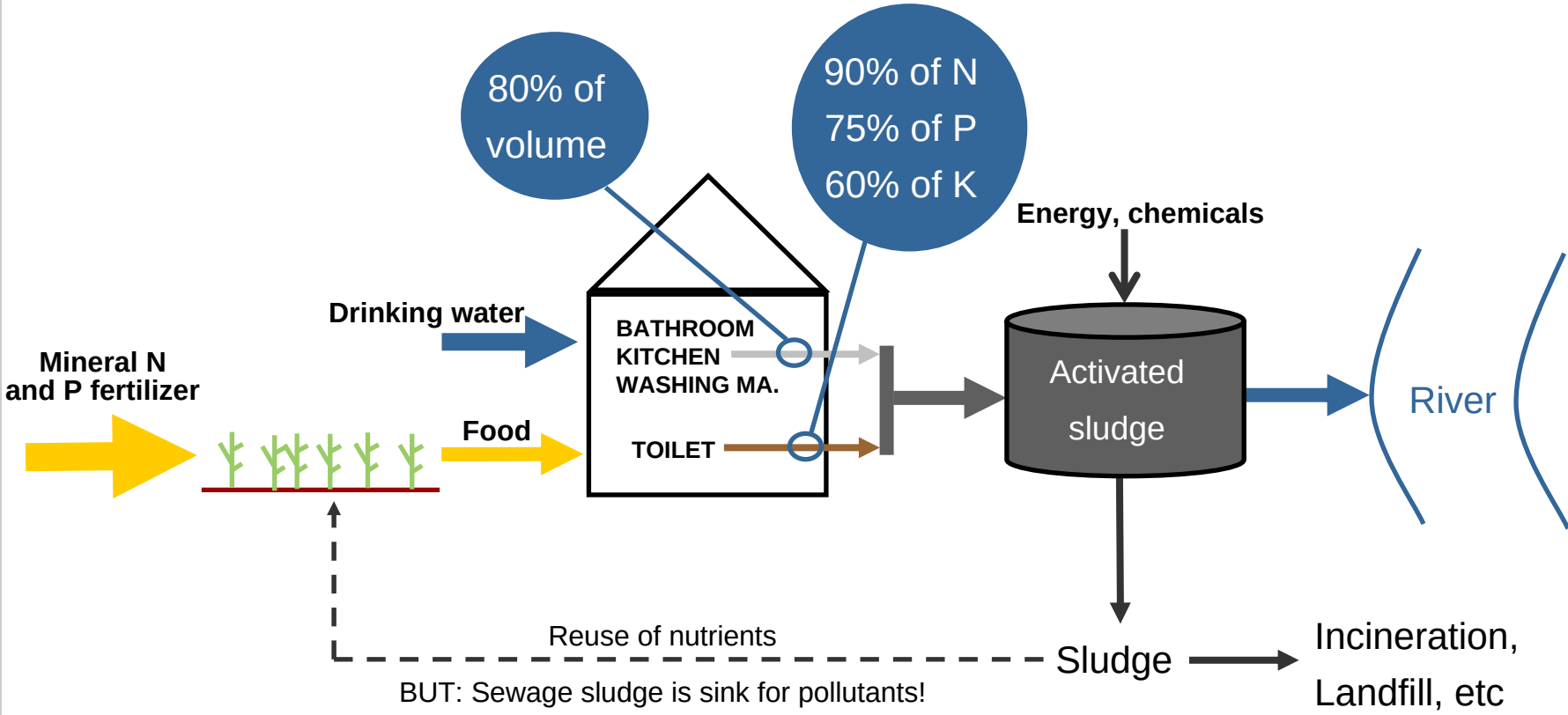
Ecological comparison of selected alternative sanitation concepts

Background

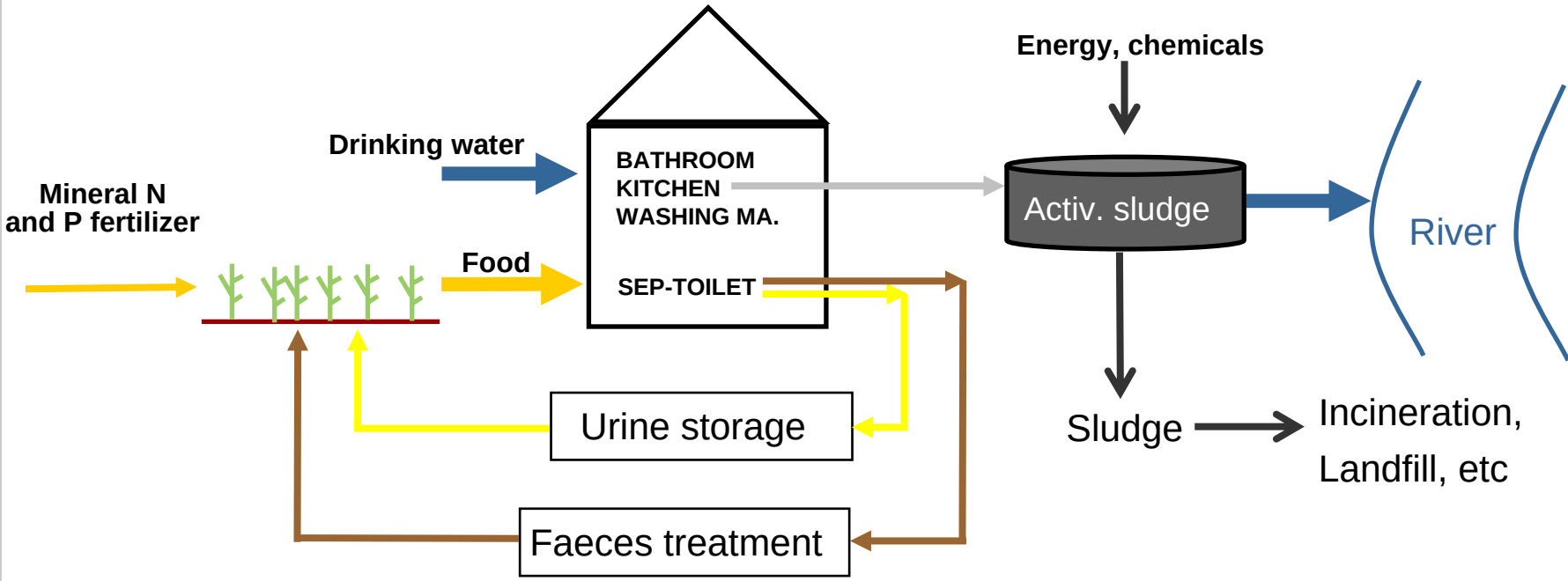
Conventional sanitation system



- Mixing of wastewater streams with different quality and quantity
- Centralized treatment in activated sludge plant

- Enhanced treatment required for removal of oxygen demand and nutrients
- Limited possibility of nutrient reuse (contaminated sludge)

Alternative sanitation system



- Separate collection and treatment of wastewater streams
- Nutrient recycling to agriculture

- Reduction of organic and nutrient load to wastewater treatment process
- Substitution of mineral fertilizer
- Recycling of limited P resources

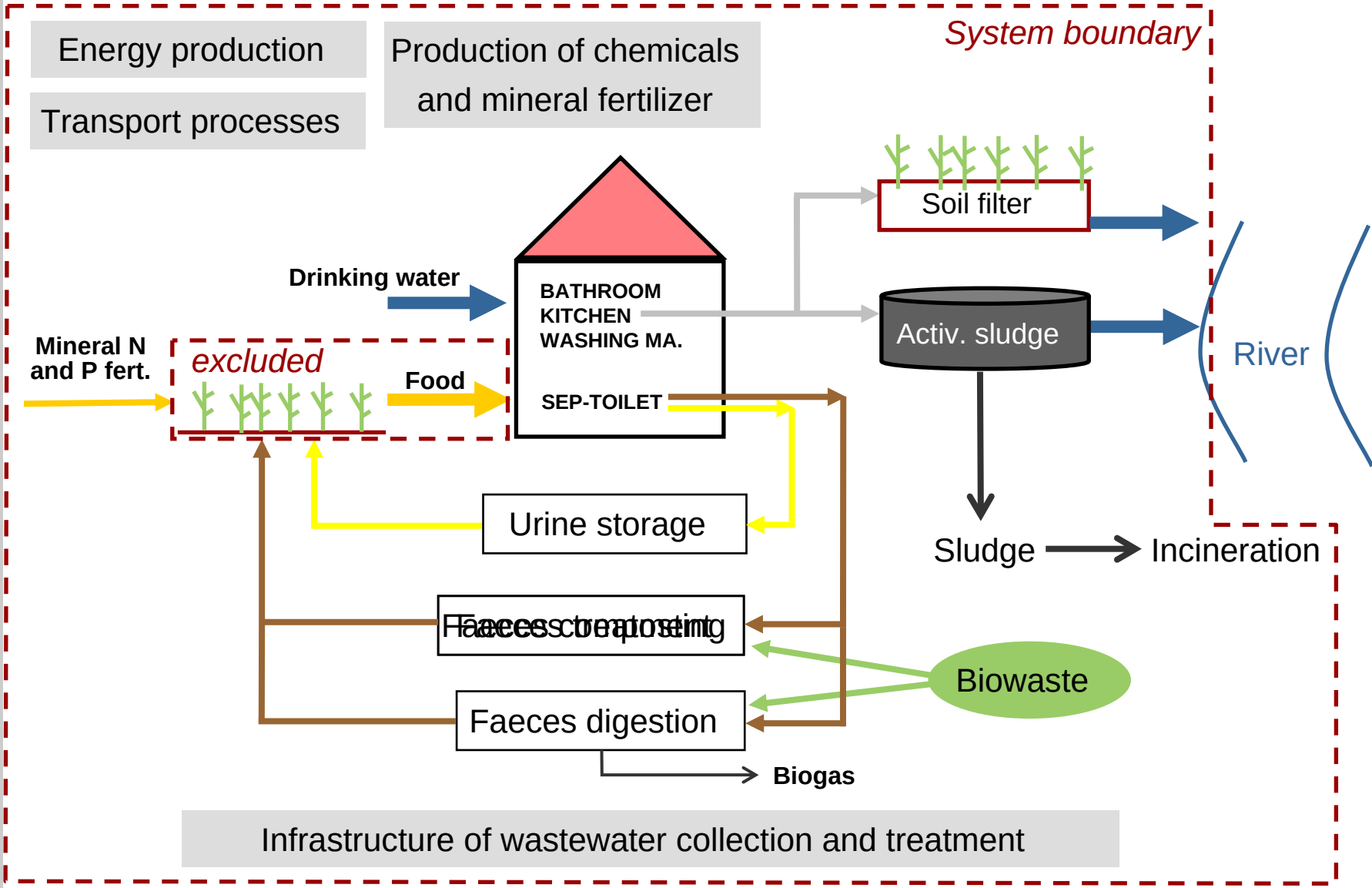
Goals of this study

- Comparing conventional and several alternative sanitation concepts in terms of ecological impacts
- Finding ecological „hot spots“ of alternative systems
- Identifying relevant key parameters for simplified assessment

→ **Methodology: Life Cycle Assessment (LCA) following ISO 14040 ff**

1. Definition of goals and LCA framework
2. Life Cycle Inventory (modeling of relevant processes)
3. Life Cycle Impact Assessment
4. Normalisation and interpretation

Definition of LCA framework



Definition of sanitation scenarios

Scenario	Urine	Faeces	Greywater	Biowaste	System expansion
0	Conventional activated sludge plant			Composting	Mineral fertilizer + energy
1	Storage → Fertilizer	Composting → Fertilizer	Soil filter	Composting	Energy
2			Activated sludge		
3		Digestion → Fertilizer + Biogas	Soil filter	Digestion	
4			Activated sludge		

→ Study area: hypothetical settlement with 5000 inhabitants in Germany 2006

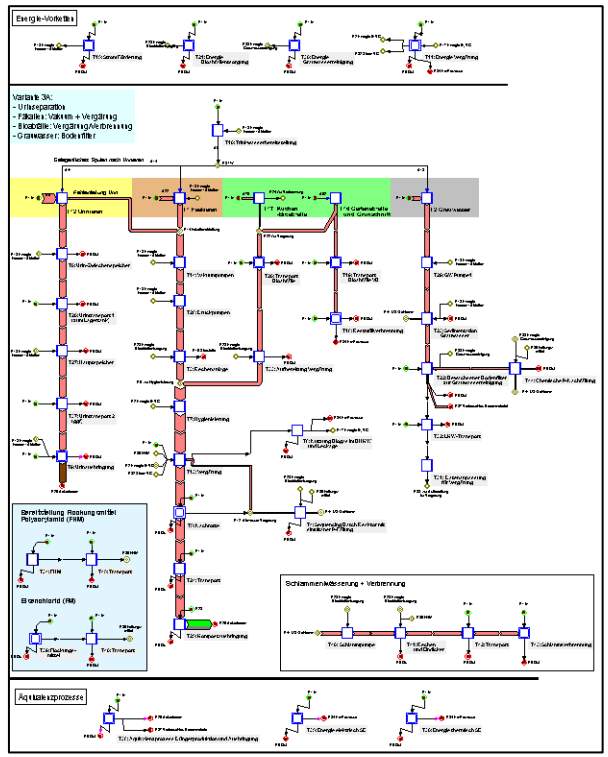
Substance flow model and data origin

- Software: UMBERTO® 5.0
- Linear input-output model
  - Modular structure
  - > 300 parameters
  - Elementary flows:
    - Water
    - Organics (C, O, H)
    - Nutrients (N, P, K)
    - Salts
    - Heavy metals

  Excluded: organic micropollutants
- Data origin (prospective LCA):
  - Pilot projects
  - Literature
  - Qualified assumptions

  } Wastewater treatment + infrastructure
  - UMBERTO® database — Background system

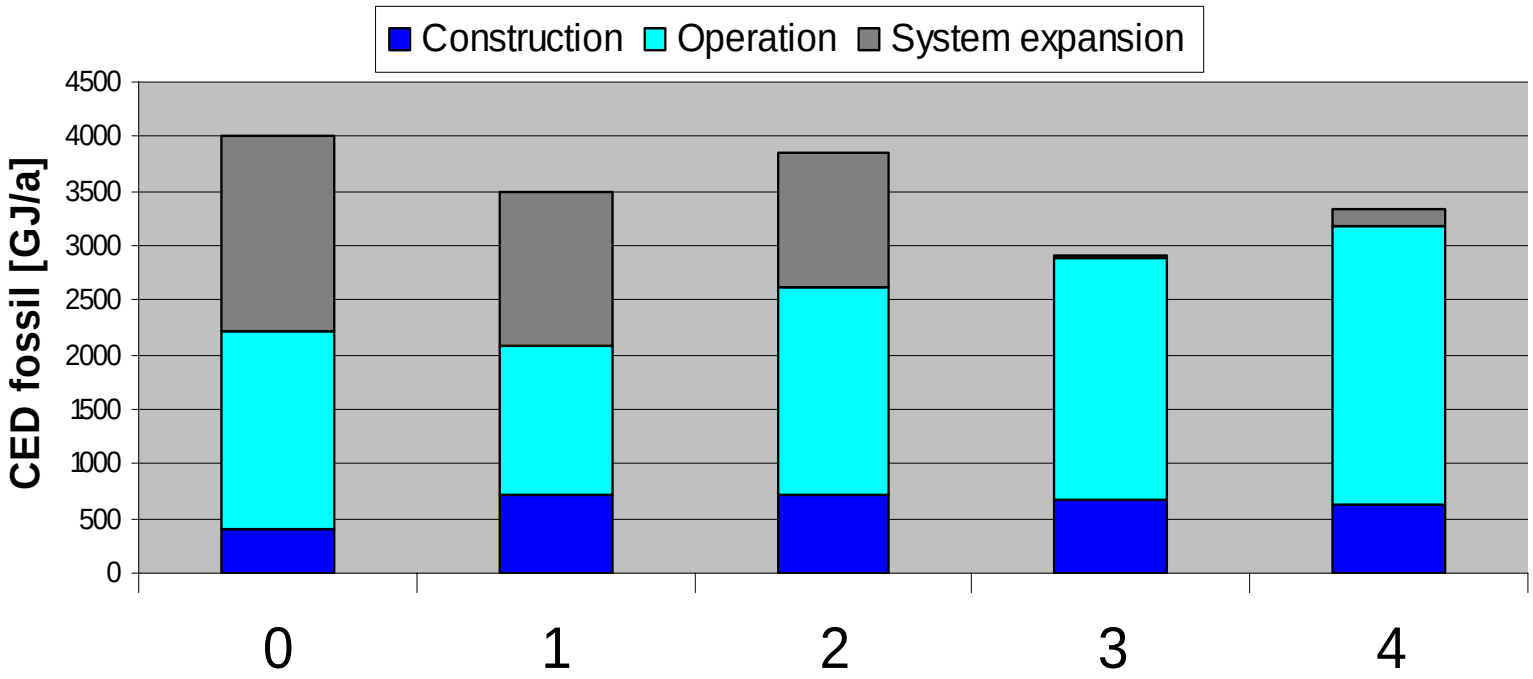
UMBERTO® screenshot



Indicators for Impact Assessment

Impact categories		Source
★ Cumulated energy demand fossil	CED_{fossil}	VDI 1997
Cumulated energy demand nuclear	$CED_{nuklear}$	VDI 1997
Depletion of abiotic resources	ADP	CML 2001
Global warming	GWP	CML 2001 (100a)
★ Acidification	AP	CML 2001 + regional and fate factors
★ Eutrophication	EP	IMPACT 2002+ (P-limited watershed)
Human toxicity	HTP	CML 2001 (inf)
Terrestrial ecotoxicity	TETP	CML 2001
Aquatic ecotoxicity	FAETP	CML 2001

Cumulated energy demand fossil

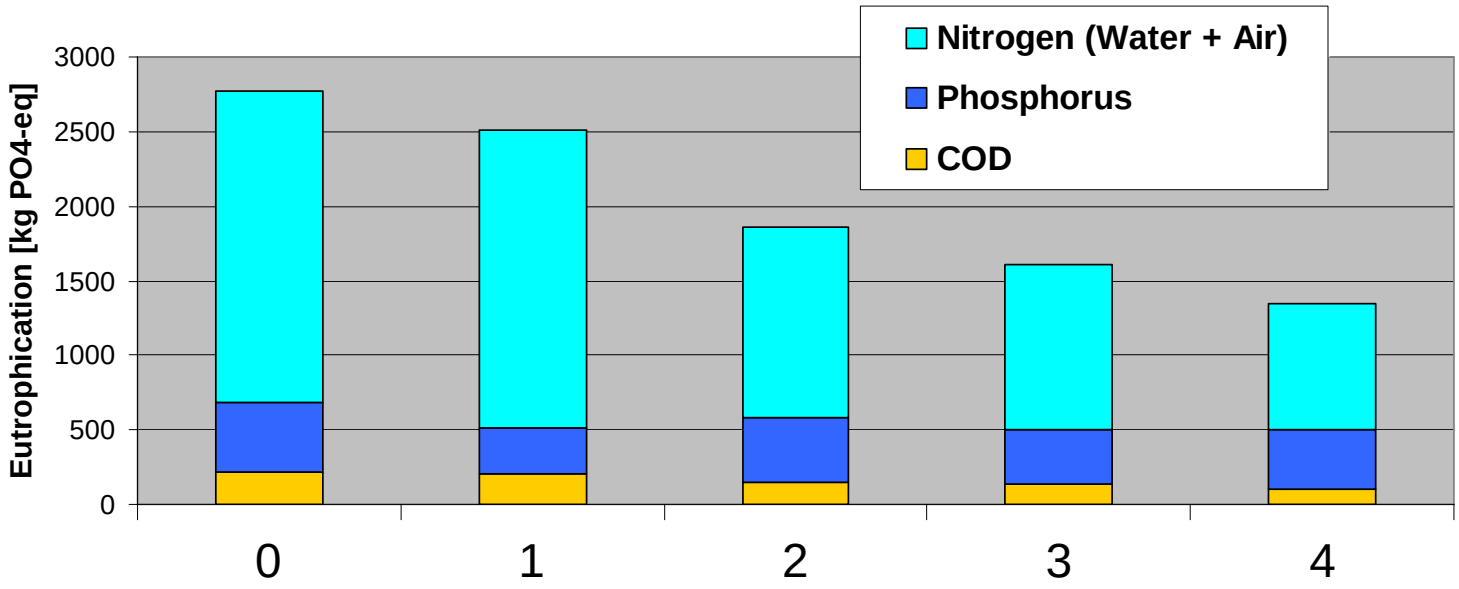


- Construction of alternative systems has higher energy demand
- System expansion (fertilizer + energy) results in overall energetic benefits
- Correlation of GWP with CED fossil (not shown)

Ecological comparison of selected alternative sanitation concepts

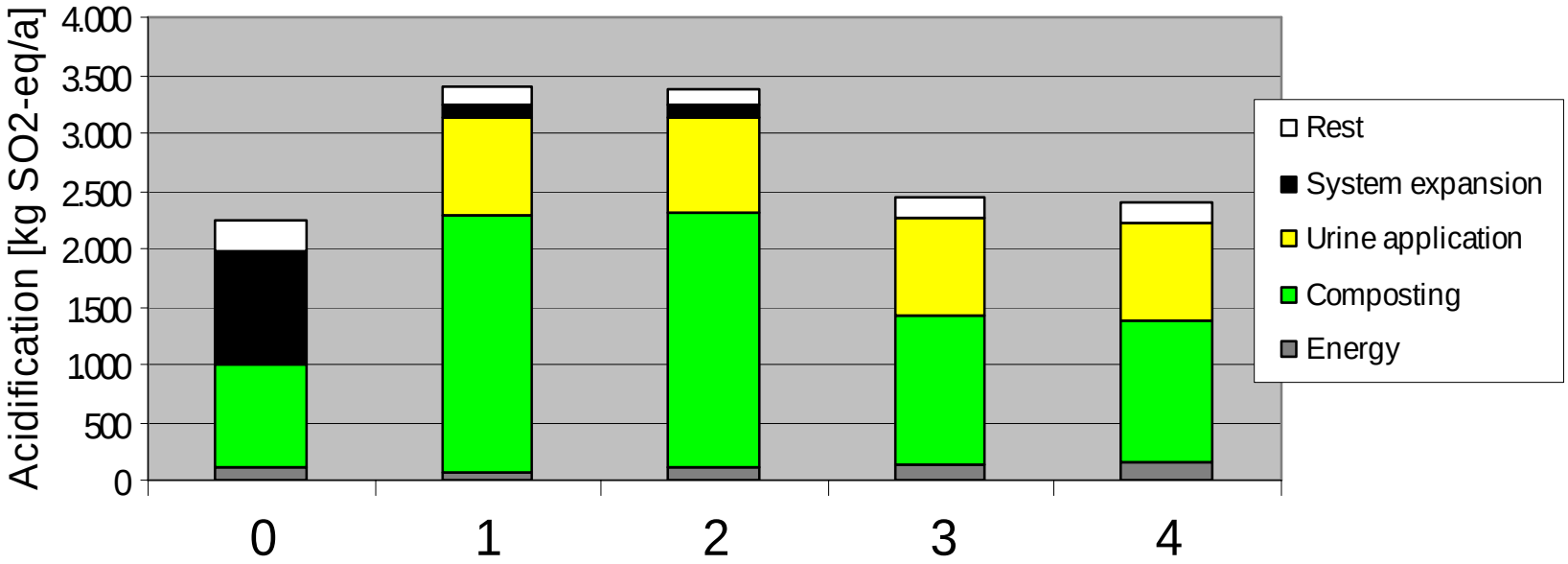
Impact assessment

Eutrophication potential



- Less nutrient emissions in alternative wastewater treatment process
- Composting scenario (1+2): high nutrient emissions due to filtrate from faeces dewatering

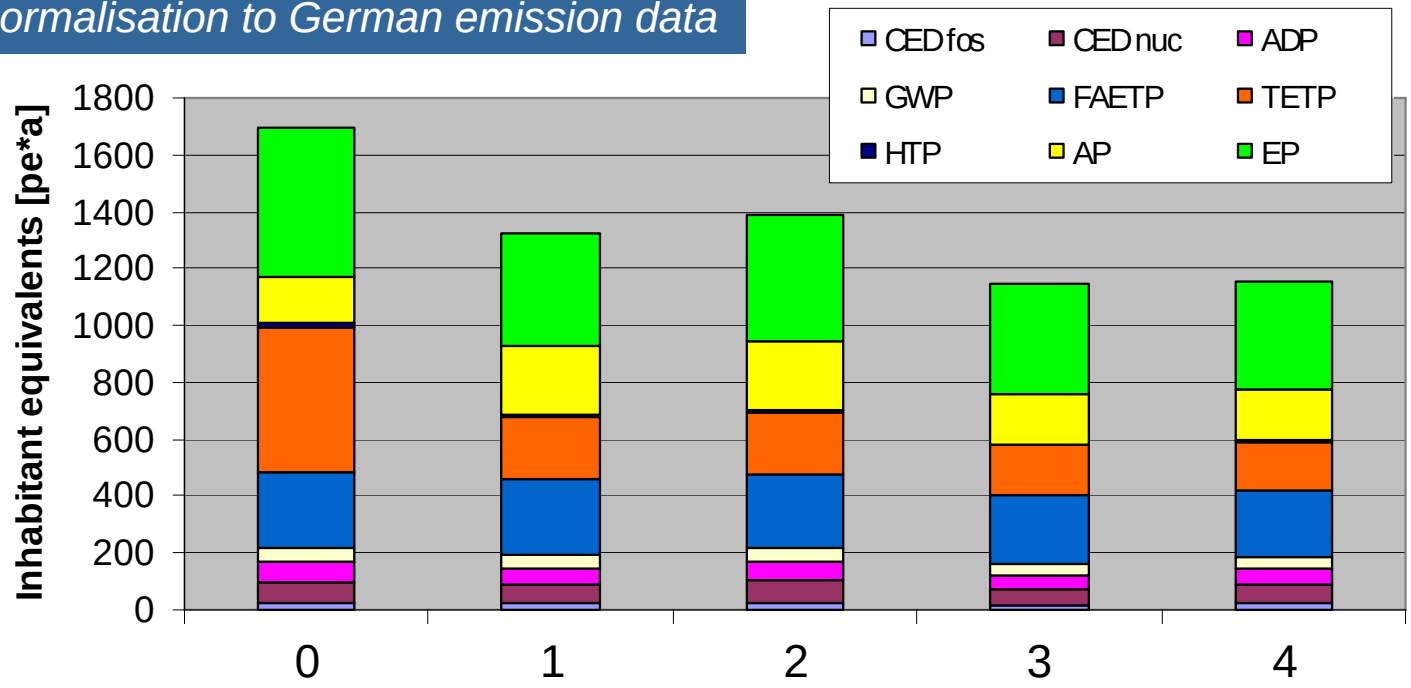
Acidification potential



- HOT SPOT: High ammonia emissions during
  - Composting of faeces
  - Urine application
- Minimization of NH_3 emissions:
  1) Encapsulated composting with air filter
  2) Urine application with injection or instant ploughing

Comparison of normalised eco-profiles

Normalisation to German emission data



- Decisive indicators:
  - Eutrophication
  - Acidification
  - Soil toxicity
- Energy-related indicators have minor significance (CED, GWP, ADP)
- Infrastructure (not shown): alternative systems cause higher impacts due to multiple pipe networks (small influence: < 5% of total eco-profile)

Key parameters for simplified Life Cycle Inventory

	Urine separation	Faeces digestion	Faeces composting	Greywater treatment
Process	Separation efficiency	Biogas yield	Dewatering	Quality of faeces filtrate
Energy	-	Vacuum system, processing	-	Activated sludge plant
Emissions	NH_3, N_2O	(NH_3)	NH_3, N_2O	PO_4
Transports	To storage + farmland	-	To composting	-

→ *Qualitative assessment, detailed sensitivity analysis will follow*

Conclusions

- Alternative systems show less environmental impacts in many impact categories:
  - Energy demand
  - Global warming (not shown)
  - Eutrophication
  - Soil toxicity (not shown)
- Hot spots (acidification) have been identified and can be addressed with technical improvements
- Decisive for the overall comparison in this LCA are eutrophication, acidification and soil toxicity
- Construction phase has minor influence on LCA results
- Key parameters for simplified LCI have been identified

Outlook

- Implementation of
  - Urine treatment (solid fertilizer, micropollutants?)
  - Water reuse via membrane bioreactor

- Sensitivity and uncertainty analysis → PhD thesis in 2008

Thank you for our attention!
Questions?

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Life

VEOLIA EAU

Full report will soon be available at www.kompetenz-wasser.de

Data sources for Life Cycle Inventory

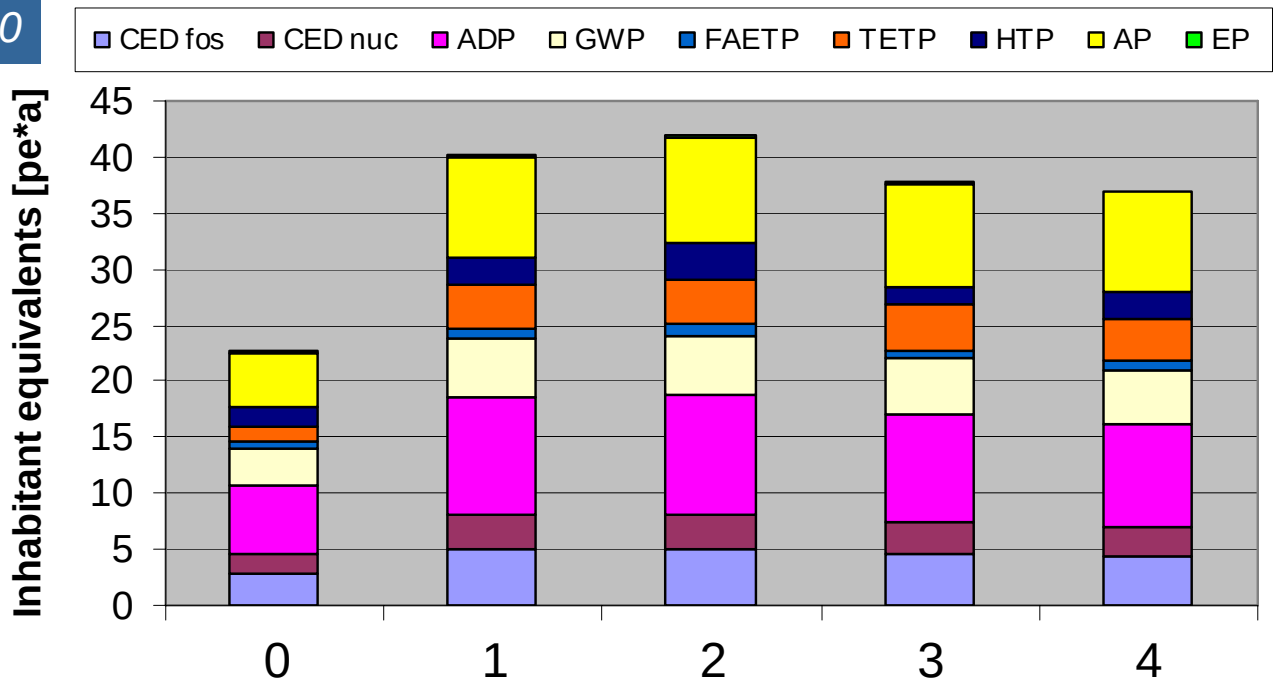
Qual	Processes	Sources	Remarks
☺	Composition of wastewater flows	Literature	Average values
😐	Global system parameters	Pilot plants + literature	Qualified assumptions
☺	Activated sludge plant	TU Berlin	LCA model
☺	Digestion, soil filter	Pilot plants + literature	
☹	Composting	Literature	LCA of biowaste composting
☺	Fertilizer application	Pilot trials + literature	
😐	Mineral fertilizer production	Literature	Market shares of 1998
☺	Energy production	UMBERTO database	Updated energy mix 2003
😐	Transport		Distances are estimated
☺	Construction materials		Layout by consultant

→ Prospective LCA for comprehensive system analysis

→ Pilot plants: Berlin-Stahnsdorf (~ 30 inhab.), Lübeck-Flintenbreite (~ 100 inh.)

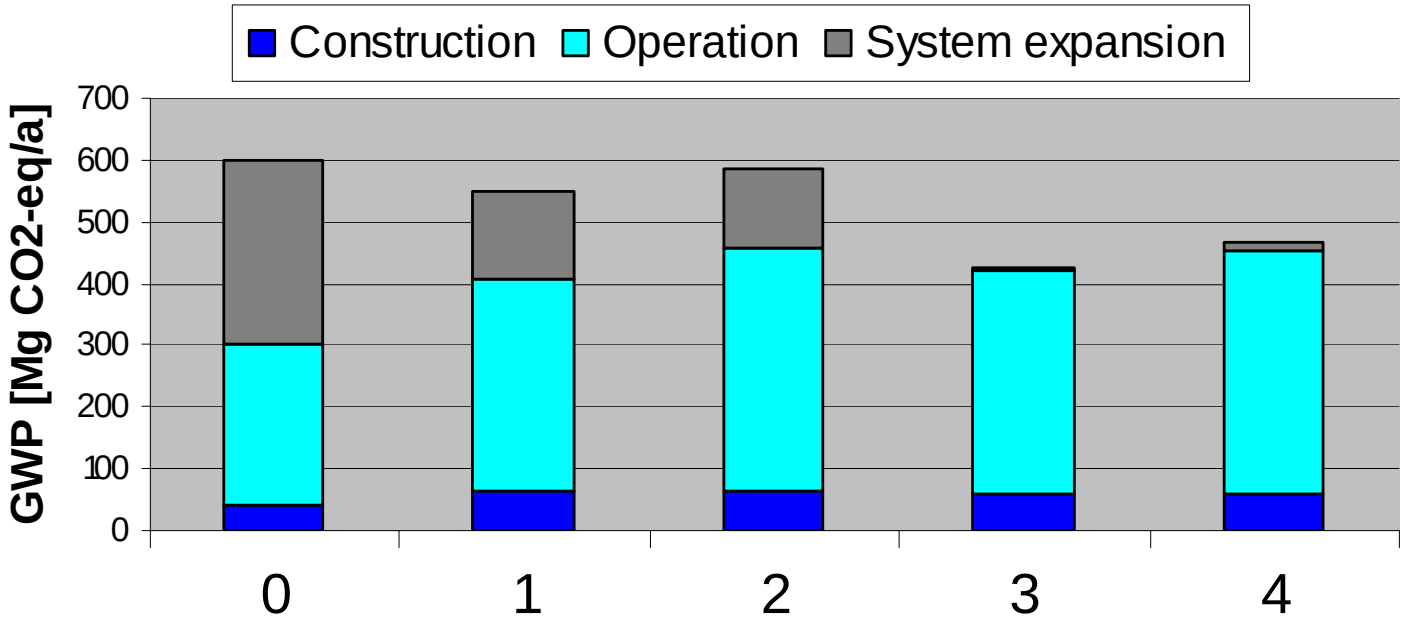
Service life (a)
Buildings = 40
Tanks = 40
Pipes = 40 – 50

Eco-profiles of construction



- Construction of alternative systems: higher impacts due to multiple pipe networks
- BUT: construction phase has negligible influence on the overall comparison (< 5% of total eco-profile)

Global warming potential



- Global warming potential correlates with energy demand
- Fossil CO_2 determines GWP
- Emissions of CH_4 + N_2O from composting and fertilizer application are small