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Simulation and Visualization of Material Flows in Sanitation Systems for Streamlined Sustainability Assessment

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Sanitation systems: New (pre-)planning challenges

- New and alternative sanitation systems (NASS), which often are decentralized, provide new system configuration options
- Increasing importance of sustainability assessment, *e.g.* EIA, LCA
- Increasing interest in nutrient recovery

-> Discussion and selection of locally appropriate solution becomes more challenging

- Some earlier and related approaches to support this process:
  - Campos *et al.* (2012), Ormandzhieva *et al.* (2014) (visualization)
  - Spuhler *et al.* (2018) (systematic selection process)
  - … and many more …

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Sanitation systems: New (pre-)planning challenges: (1) Criteria

- How to assess potential options? → Criteria definition
- Requirement: feasible for practical application
- Analysis of other approaches: ESAT (2012), TWIST++ (2017), DWA-A272 (2018), …

-> Sampsons Criteria Set:

	Criterion	Description	Indicator
Ecology	Eutrophication Potential (EP)	Essentials: N, P, COD, NH_3	kg PO_4-eq
	Energy Input	final energy, primary energy use.	MJ
	Greenhouse Gas Emissions	CO_2, CH_4, N_2O	kg CO_2-eq
	pharmaceuticals	ecotoxicological substances (Proxy here: Diclofenac).	%
	Physical Footprint	Surface area required	m^2
Economy	Life-Cycle Cost	Costs and revenues (CAPEX, OPEX)	NPV (€)
Social Issues	Social Acceptance	Qualitative indicator	Rating scale
Flexibility	Flexibility	Regarding changing general conditions	Rating scale

Sanitation systems: New (pre-)planning challenges: (2) Visualisation

- Numerous discussions (often enthusiastic)
- Earlier attempts: e.g. Excel-based approach
- Easy-to-use, fun-to-use approach missing

- Building and visualising sanitation systems in a model
- Objective here:
  - NOT detailed process simulation (such as in ASM, ADM1 etc.)
  - BUT "quick-and-easy" visualisation of resource fluxes and assessment
- Solution idea here:
  - Setup of building blocks using flexible simulator framework (Simba#) (availability/demand, process models, GUI, LCA – simba.ifak.eu)
  - Provision of Sampsons tool to the enduser

Resource fluxes and constituents of interest

- Resource fluxes (adapted from Tilley et al., 2008, 2014)

Input/Output	Colour	Input/Output	Colour
Urine	→	Blackwater	→
Faeces	→	Sludge	→
Drinking water	→	Digested sludge	→
Wastewater	→	Biogas	→
Pre-treated wastewater	→	Biowaste	→
Treated wastewater	→	Digestate	→
Grey water	→	Fertilizer	→
Pre-treated greywater	→	Ash	→
Treated greywater	→	Rain water	→

- Constituents of interest:

  N, P, K, S, Diclo, COD, TSS

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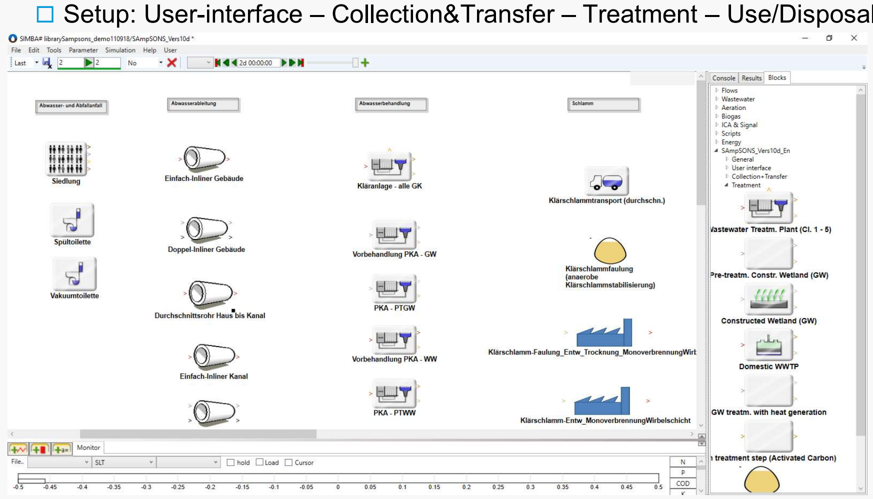
Sanitation systems: Simulation and Visualisation

- Block (module) library: Building your system in a model
  - Setup: User-interface – Collection&Transfer – Treatment – Use/Disposal



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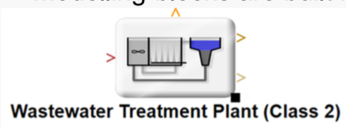
Sanitation systems: Simulation and Visualisation

- An example block: Act. Sludge Plant (Class 2: 1000 – 5000 PE)

  Modelling blocks are built by project team members

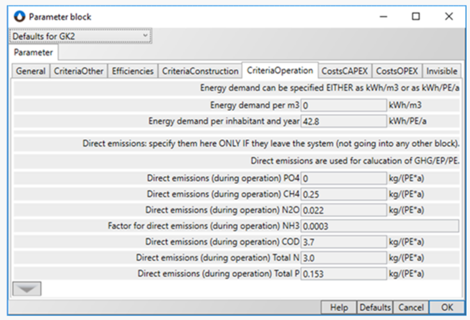


This block:
Input: - Wastewater
Outputs: - Treated Wastewater
- Sludge

User parameter dialogue

Parameter categories:
- Normal
- Advanced
- Non-editable

Process description:
Input-Output models, but also states and dynamic modelling possible



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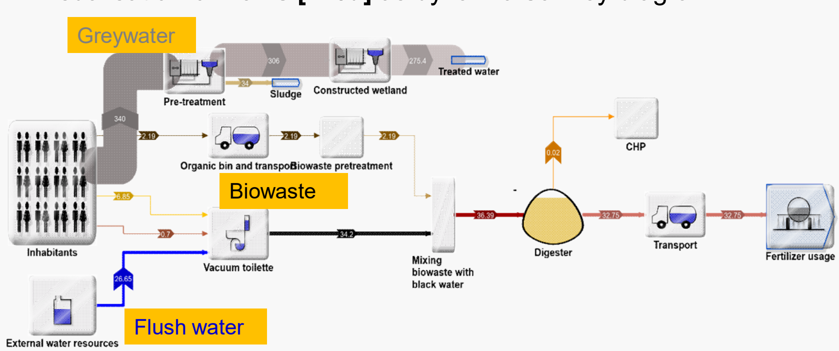
Sanitation systems: Simulation and Visualisation

- Example model: Co-digestion of biowaste and blackwater

  Visualisation of **flows [m³/d]** as dynamic Sankey diagram



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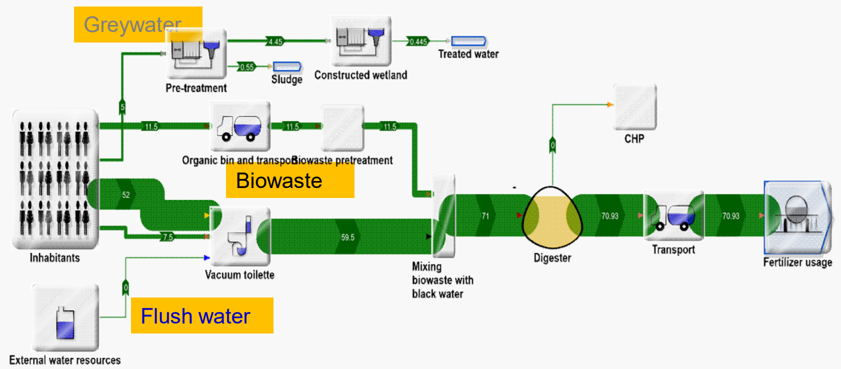
Sanitation systems: Simulation and Visualisation

- Example model: Co-digestion of biowaste and blackwater

  Visualisation of **Nitrogen fluxes [kg/d]** as dynamic Sankey diagram



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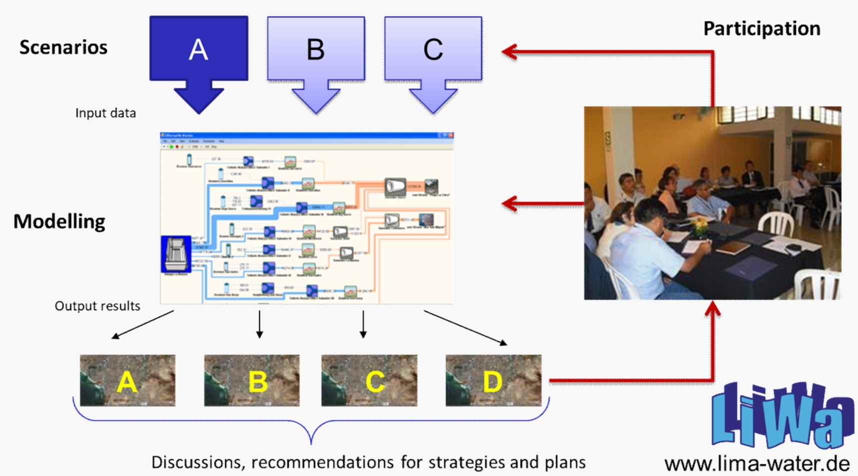
Sanitation systems: Simulation and Visualisation

- Modelling as a tool to aid stakeholder participation



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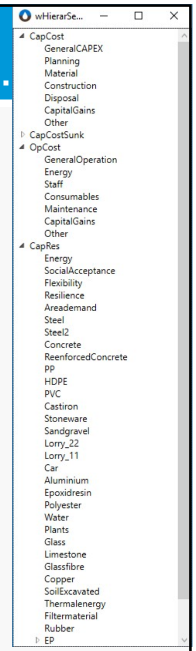
New (pre-)planning challenges (3): LCA Integration of modelling with LCA/assessm.



Requirement: not only simulation and visualisation, but also sustainability assessment

Categorisation of Sampsons criteria

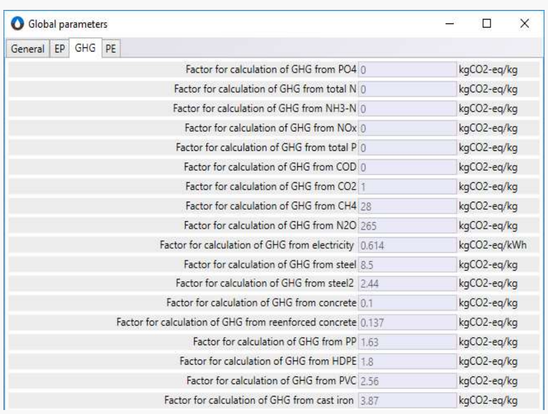
- Capital costs (overall; planning, construction, ...)
- Operational costs (Overall; maintenance, energy, ...)
- Capital resources (material demands for construction)
- Operational resources (consumption during operation, energy, emissions, ...)

-> Calculation of evaluation criteria for system's life cycle (LCA)

Integration of modelling with LCA and sustainability assessment

Coupling of process modelling and LCA calculations

- Each block has evaluation functions using global LCA parameters
- Evaluation (aggregation); Output at end of the simulation


Global parameters

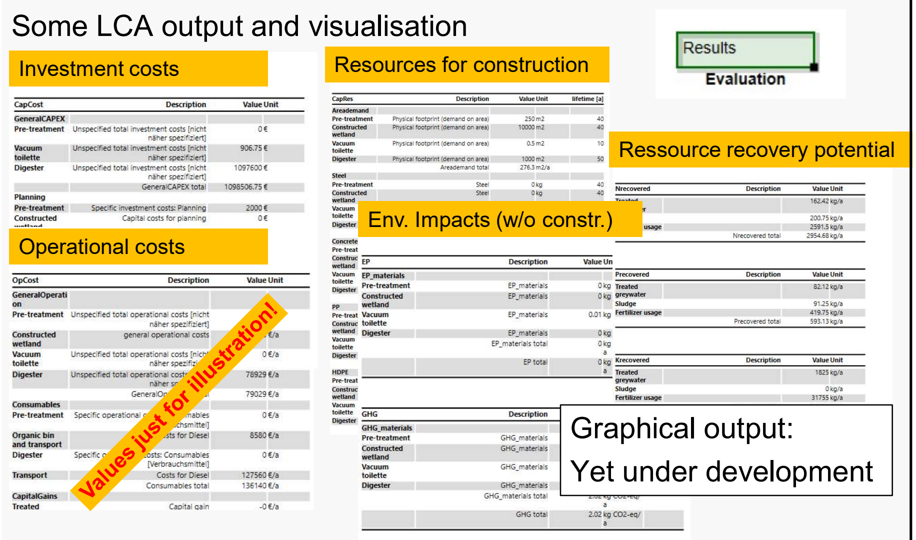
General | EP | GHG | PE

Factor for calculation of GHG from PO4	0	kgCO2-eq/kg
Factor for calculation of GHG from total N	0	kgCO2-eq/kg
Factor for calculation of GHG from NH3-N	0	kgCO2-eq/kg
Factor for calculation of GHG from NOx	0	kgCO2-eq/kg
Factor for calculation of GHG from total P	0	kgCO2-eq/kg
Factor for calculation of GHG from COD	0	kgCO2-eq/kg
Factor for calculation of GHG from CO2	1	kgCO2-eq/kg
Factor for calculation of GHG from CH4	28	kgCO2-eq/kg
Factor for calculation of GHG from N2O	265	kgCO2-eq/kg
Factor for calculation of GHG from electricity	0.614	kgCO2-eq/kWh
Factor for calculation of GHG from steel	8.5	kgCO2-eq/kg
Factor for calculation of GHG from steel2	2.44	kgCO2-eq/kg
Factor for calculation of GHG from concrete	0.1	kgCO2-eq/kg
Factor for calculation of GHG from reenforced concrete	0.137	kgCO2-eq/kg
Factor for calculation of GHG from PP	1.63	kgCO2-eq/kg
Factor for calculation of GHG from HDPE	1.8	kgCO2-eq/kg
Factor for calculation of GHG from PVC	2.56	kgCO2-eq/kg
Factor for calculation of GHG from cast iron	3.87	kgCO2-eq/kg

Source of LCA parameters: GaBi and ecoinvent databases

Integration of modelling with LCA and sustainability assessment

Some LCA output and visualisation



Example models

Example models, serving for validation

- SCST Berlin-Stahnsdorf
- Sanitation system of Wohlsborn/Thuringia
- “Wastewater-free university campus” of Birkenfeld/Nahe
- …

Technology fact sheets

Fact sheet example: “Flush toilet”

Factsheet System Component Flush Toilet
Status:
complete

Topic	Information	Description	Value	Unit	Reference / Knowledge Source	Comment
Component Name		convential flush toilet				
Short Name		flush toilet				
Component Description		n.a.				
Capacity		n.a.				
Lifespan			10	year	http://www.sustainableminds.com/showroom/toto/pdf/TOTO-CommercialWall-HungToilet.pdf	
Spacerequirement			0,5	m2		estimated
Input - Material Flows						
	Material Flow 1	tap water	40	L/PE*d	http://www.verivox.de/themen/wasserverbrauch/	also https://de.wikipedia.org/wiki/Wasserverbrauch
	Material Flow 2	faeces	1,5	L/PE*d	https://cgi.tu-harburg.de/~awwweb/susan/downloads/desar_de.pdf	500 litres of urine and 50 litres of faeces per person per year (1st sentence in reference.)
	Energy Flow 1	n.a.				
Output - Material Flows	**Material Flow 1**	wastewater	41,5	L/PE*d		calculated
Performance (e.g., Cleaning efficiency)		n.a.				For characterisation of waste water see TWIST data
Raw and Auxiliary Material Usage						Suggestion: since every system will have some kind of toilet and the environmental impact of the production of the toilets will be comparable, we should consider these effects as equal and therefore omit this information.
	Material 1	GWP	20,2	kg/unit		
	Material 2	EP	0,008	kg/unit		exact material composition not known, therefore indication of the environmental impacts of the production (based on a total weight of 27.1 kg)
	Material 3	Primary Energy Demand	741,5	MJ/unit	IBU EPD Sanitärkeramik Duravit	
Energy Usage						
	Energy 1	n.a.				
Direct Emissions		n.a.				
Costs/revenues - LCC						
	Investment Costs		213,60	€	see 'Übersicht € WC"	estimated via google shopping
	Installation Costs		70	€		estimated one hour installation time by a specialist
	Operational Costs		0	€/a		
	Revenues		0	€		
	Depreciation Period		10	a		according to lifespan
Comments and Assumptions						

<u>Information required:</u>
- Efficiencies of process
- Costs (CAPEX, OPEX)
- Material demand
- Consumables demand
- Energy demand
- Direct emissions
- …

Based on this information, additional technology blocks can be created

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Example models

Remaining work

- ☐ Visualisation of LCA results
- ☐ Completion of example models
- ☐ Implementation of additional sanitation technologies

And you?

If you are interested in

- ☐ **Supplying fact sheet** of additional sanitation technologies or
- ☐ **Using the Sampsons tool** once it is finished,

please, contact us!

Email: manfred.schuetze@ifak.eu

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Thank you!

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