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Country-specific life cycle inventories for human excretion of food products

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- Conclusions

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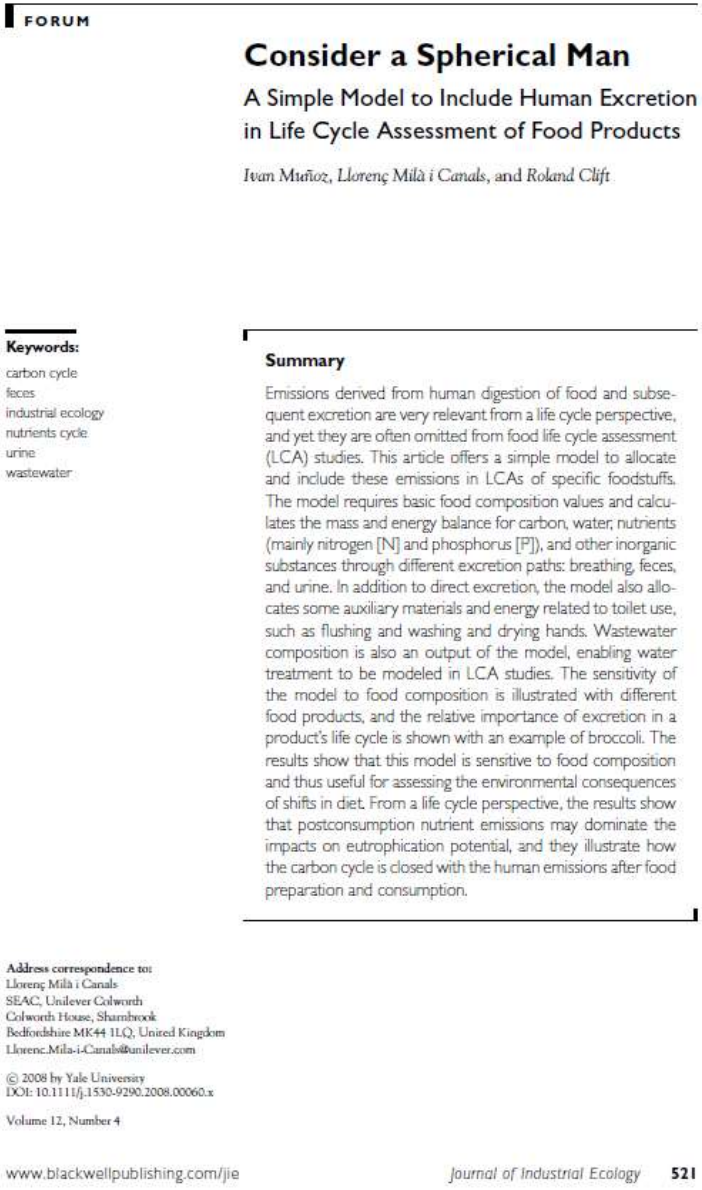
The human excretion model

- Ingestion of food leads to emissions from derived human excretion products, but no methods were available for LCA practitioners

- The ‘spherical man’ is an inventory model to account for the end-of-life stage of food products, addressing:
  - Human metabolism
  - Human waste management



FORUM

Consider a Spherical Man

A Simple Model to Include Human Excretion in Life Cycle Assessment of Food Products

Ivan Muñoz, Llorenç Milà i Canals, and Roland Clift

Keywords:
carbon cycle
feces
industrial ecology
nutrients cycle
urine
wastewater

Summary

Emissions derived from human digestion of food and subsequent excretion are very relevant from a life cycle perspective, and yet they are often omitted from food life cycle assessment (LCA) studies. This article offers a simple model to allocate and include these emissions in LCAs of specific foodstuffs. The model requires basic food composition values and calculates the mass and energy balance for carbon, water, nutrients (mainly nitrogen [N] and phosphorus [P]), and other inorganic substances through different excretion paths: breathing, feces, and urine. In addition to direct excretion, the model also allocates some auxiliary materials and energy related to toilet use, such as flushing and washing and drying hands. Wastewater composition is also an output of the model, enabling water treatment to be modeled in LCA studies. The sensitivity of the model to food composition is illustrated with different food products, and the relative importance of excretion in a product's life cycle is shown with an example of broccoli. The results show that this model is sensitive to food composition and thus useful for assessing the environmental consequences of shifts in diet. From a life cycle perspective, the results show that postconsumption nutrient emissions may dominate the impacts on eutrophication potential, and they illustrate how the carbon cycle is closed with the human emissions after food preparation and consumption.

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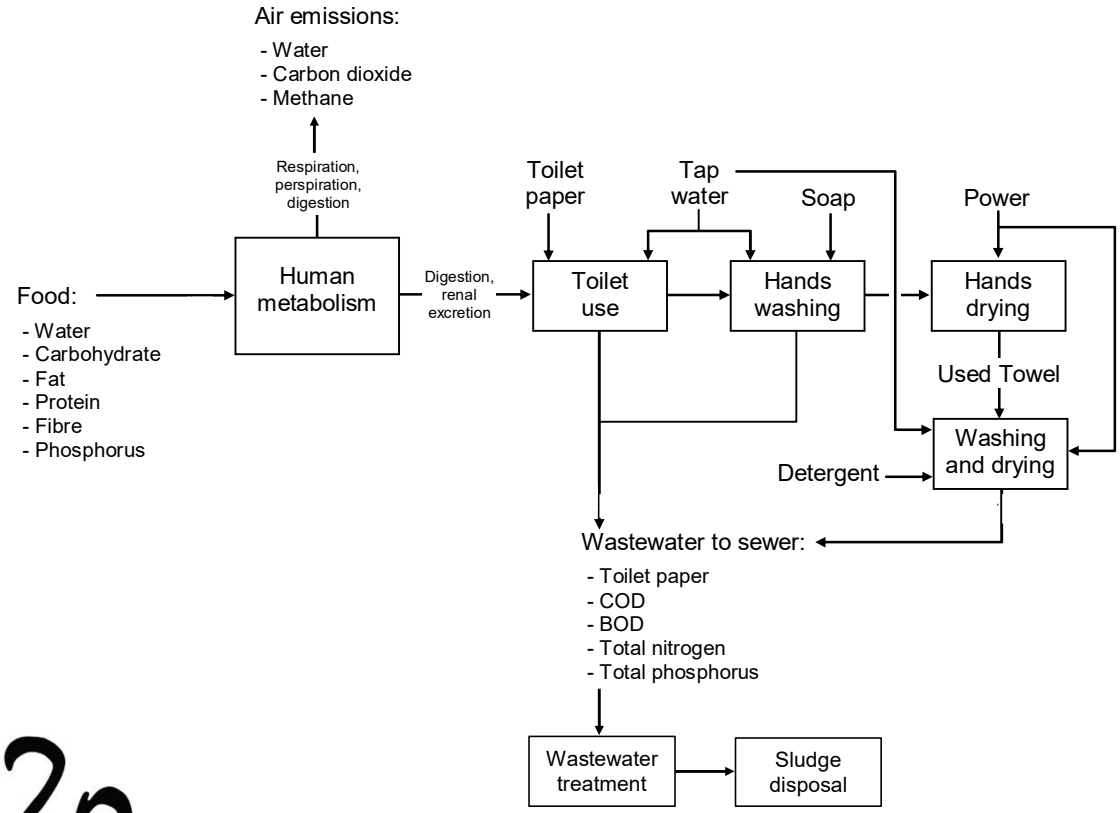
The human excretion model: scope 2008



- Outcome is an LCI (in Excel) for excretion of 1 kg ingested food item
- Wastewater treatment modelled with ecoinvent model for Switzerland (Doka 2007)
- Main limitation: focused on a typical Western scenario

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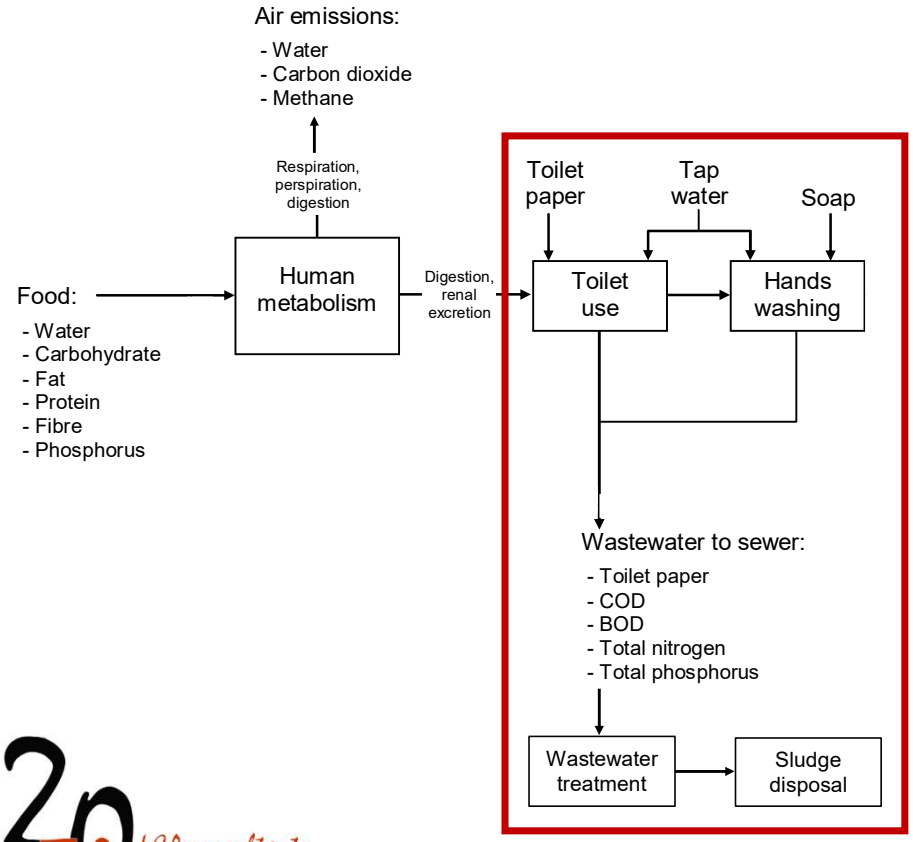
Doka (2007) Life cycle inventories of waste treatment services. ecoinvent report No. 13, v2.0. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland.

The human excretion model: update 2020



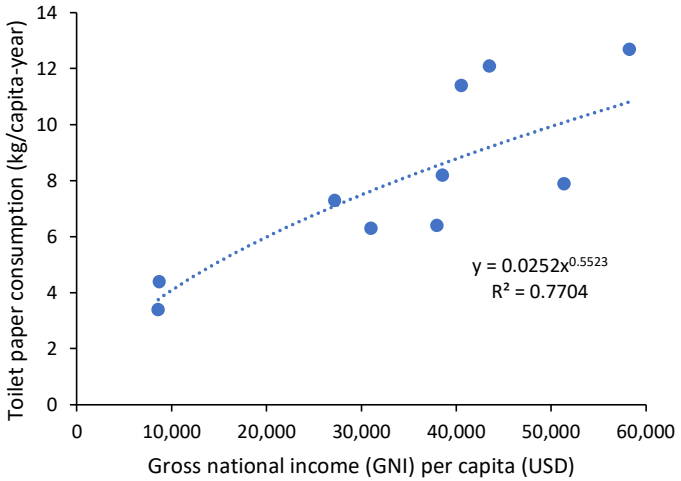
- Human metabolism model unchanged
- Hands drying and towel washing neglected
- Country-specific consumption of:
  - Toilet paper
  - Soap
  - Tap water
- Country-specific inventories for human excreta management

The human excretion model: update 2020

Regionalized consumption in toilets

- **Toilet paper**: Statista, European Tissue Symposium, correlation with GNI

- **Tap water and soap**: dependent on access to hygiene according to WHO-UNICEF statistics



Toilet item	Population with access to toilets	Population with access to basic hygiene	Population with no access to basic hygiene
Water, flushing (L/kg food)	20	0	0
Water, handwashing (L/kg food)	2.7	2.7	0
Soap, handwashing (g/kg food)	6	6	0

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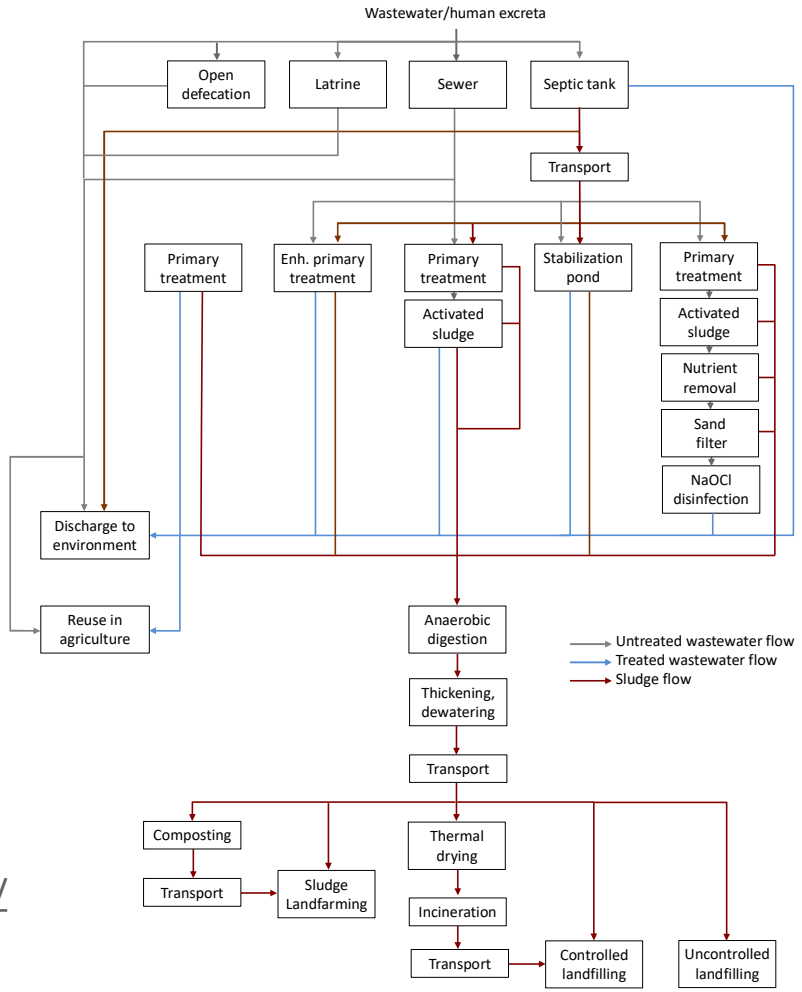
The human excretion model: update 2020

Regionalized human excreta: WW LCI

- Doka model replaced by WW LCI
- Inventory model for wastewater discharges developed by 2.-0 LCA consultants
- Statistics on 86 countries
- Adapted to include further sanitation options: latrines, open defecation
- Linked to ecoinvent, compatible with SimaPro



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https://lca-net.com/projects/show/wastewater-lci-initiative/

The human excretion model: update 2020

Coupling of human excretion and WW LCI

- Human excretion mass balance provides volume and composition of human excreta + flush water per kg ingested food
- This information is fed into WW LCI, as a wastewater flow containing:

Wastewater component	Chemical formula	Form in wastewater	Degradability in WWTP	Degradability in environment
Water	H_2O	n.a.	n.a.	n.a.
Urea	CH_4ON_2	Dissolved	Yes	Yes
Faeces	C_2H_4O (as in excretion model)	Suspended	Yes, but part in sludge	Yes
Fibre	$C_6H_{10}O_5$ (as cellulose)	Suspended	Yes, but part in sludge	Yes
Phosphate	PO_4	Dissolved	n.a.	n.a.
Sulfate	SO_4	Dissolved	n.a.	n.a.
Toilet paper	$C_6H_{10}O_5$ (as cellulose)	Suspended	Yes, but part in sludge	Yes
Soap	$C_{18}H_{35}NaO_2$ (as sodium stearate)	Emulsion (as suspended)	Yes, but part in sludge	Yes

The human excretion model: update 2020

Workflow

	A	B
1	**Food name:**	**Banana**
2	**Country of consumption:**	**NE**
3	Water (g)	75.3
4	Main organic constituents:	
5	Protein (g)	1.1
6	Fat (g)	0.2
7	Carbohydrate (g)	21
8	Fibre (g)	1.6
9	Other organic constituents:	
10	Alcohol (g)	
11	Organic acids (g)	
12	Inorganic constituents:	
13	P (g)	0.0256

	A	B	C	D	E	BD	BE
1	**Country:**			Product	**Banana, human excretion {NE}**		
2	**NE**			Unit	kg		
3					1		
4							
5				Category	_Human excretion		
6				Comment	LCI of human excretion for Banana in Niger. Includes direct emissions from the human body and [1], a country-specific estimate of toilet paper consumption, and country-specific treatment or di LCI v3 [2]. References: [1] Muñoz I, Milà i Canals LI, Clift R. Consider a spherical man – A simple Life Cycle Assessment of food products. Journal of Industrial Ecology, 12 (4), 2008, pp. 520-538. cycle inventory initiative. WW LCI version 3.0: changes and improvements to WW LCI v2. 2.-0 LC		
7	Compartmen	Product/Substance	Sub-compartment	Type	Material		
8		Tissue paper {GLO}| market for | Conseq, U		kg	0.000636792	Human excretion flow: Toilet paper	
9		Tap water {RoW}| market for | Conseq, U		kg	2.816641598	Human excretion flow: Tap water for toilet flushing, hand washing	
10		Soap {GLO}| market for | Conseq, U		kg	0.00249812	Human excretion flow: Soap for hand washing	
27		Polyvinylchloride, bulk polymerised {GLO}| market for | Conseq, U		kg	3.09062E-06	WW LCI flow: Wastewater treatment	
28		Polyethylene, high density, granulate {RER}| production | Conseq, U		kg	8.54849E-07	WW LCI flow: Wastewater treatment	
29		Extrusion, plastic pipes {GLO}| market for | Conseq, U		kg	3.94547E-06	WW LCI flow: Wastewater treatment	
30		Excavation, hydraulic digger {GLO}| market for | Conseq, U		m3	4.14556E-07	WW LCI flow: Wastewater treatment	
31		Glass fibre {GLO}| market for | Conseq, U		kg	9.5542E-06	WW LCI flow: Wastewater treatment	
32		Gravel, crushed {RoW}| market for gravel, crushed | Conseq, U		kg	0.000267065	WW LCI flow: Wastewater treatment	
35		Transport, freight, lorry, unspecified {GLO}| market for | Conseq, U		kgkm	0.931972432	WW LCI flow: Sludge transport	
99	Raw	Oxygen		kg	0.236997478	Human excretion flow: Oxygen for human metabolism	
101	Air	Carbon dioxide, biogenic		kg	0.324889202	Human excretion flow: Produced by human metabolism	
102	Air	Methane, biogenic		kg	0.000105648	Human excretion flow: Produced by human metabolism	
103	Air	Water		kg	0.31472481	Human excretion flow: Produced by human metabolism	
104	Air	Heat, waste		MJ	3.633855975	Human excretion flow: Produced by human metabolism	
110	Air	Carbon dioxide, biogenic	high. pop.	kg	0.000582414	WW LCI flow: Wastewater treatment & sludge composting	
111	Air	Methane, biogenic	high. pop.	kg	0.000282701	WW LCI flow: Wastewater treatment & sludge composting	
123	Air	Methane, biogenic	high. pop.	kg	0.000727747	WW LCI flow: Degradation in the environment	
124	Air	Carbon dioxide, biogenic	high. pop.	kg	0.050592407	WW LCI flow: Degradation in the environment	
125	Air	CO2 stored, biogenic	high. pop.	kg	0.001242182	WW LCI flow: Degradation in the environment, CO2 stored, long-term	
126	Air	Dinitrogen monoxide	high. pop.	kg	2.36395E-05	WW LCI flow: Degradation in the environment	
193	Water	COD, Chemical Oxygen Demand	river	kg	0.00114409	WW LCI flow: Degradation in the environment	

SimaPro

(optional)

Examples with some food products

- Impact of human excretion vs. production (cradle to farm or factory gate, ecoinvent)
- Three example products: bread, cheese, banana
- Human excretion in 10 example countries:

Bangla Desh (BD)	Denmark (DK)	Spain (ES)	Niger (NE)	Thailand (TH)
China (CN)	Egypt (EG)	Iceland (IS)	Peru (PE)	United States (US)

- Impact assessment on only 2 categories:
  - GHG emissions (GWP-100, with biogenic CO_2 = neutral)
  - Eutrophication (CML 2001)

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Examples with some food products

Food data

Food data	Banana	Cheese	Breadcrumbs
Nutritional composition			
Water (g/100 g)	75.3	49.7	10
Protein (g/100 g)	1.1	28.9	11.6
Fat (g/100 g)	0.2	17.7	1.5
Carbohydrates (g/100 g)	21	1	69.8
Fibre (g/100 g)	1.6	0	6.9
Phosphorus (g/100 g)	0.026	0.44	0.1
Life cycle impacts, cradle to gate			
GHG (kg CO_2-eq/kg)	0.032-0.18	5.5	0.68
Eutrophication (kg PO_4-eq/kg)	0.0012-0.0032	0.034	0.0075

Sanitation scenarios

Country	Sewer discharge	Sewer to WWTP	Septic tank	Latrine	Open defecation
BD		3%	3%	95%	
CN	13%	33%	6%	46%	2%
DK		91%	9%		
EG	35%	45%	11%	8%	
ES	3%	95%	2%	1%	
IS	25%	66%	7%	2%	
NE			9%	20%	71%
PE	46%	22%	11%	14%	7%
TH		27%	8%	65%	
US	6%	76%	19%		

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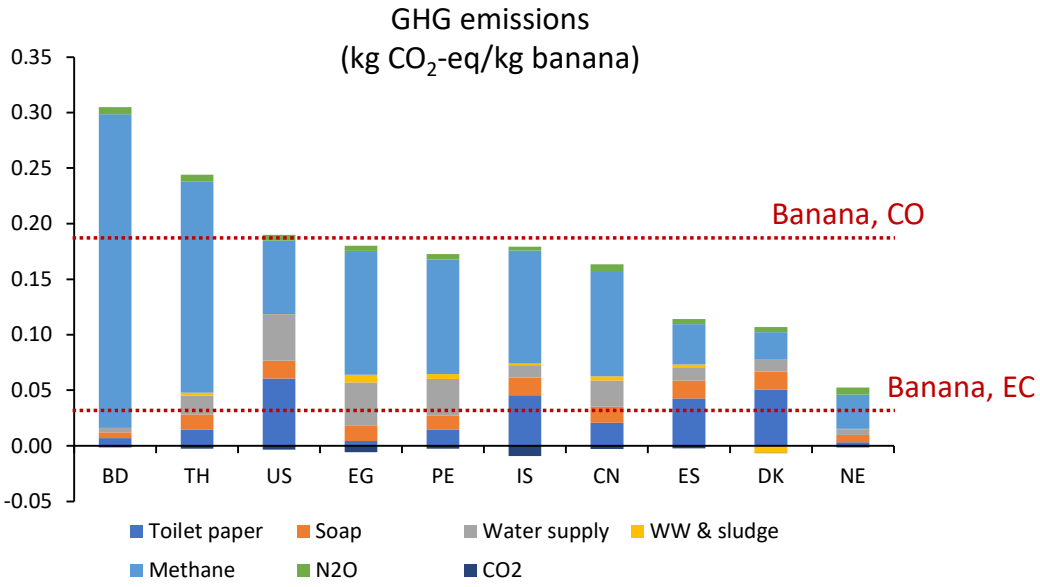
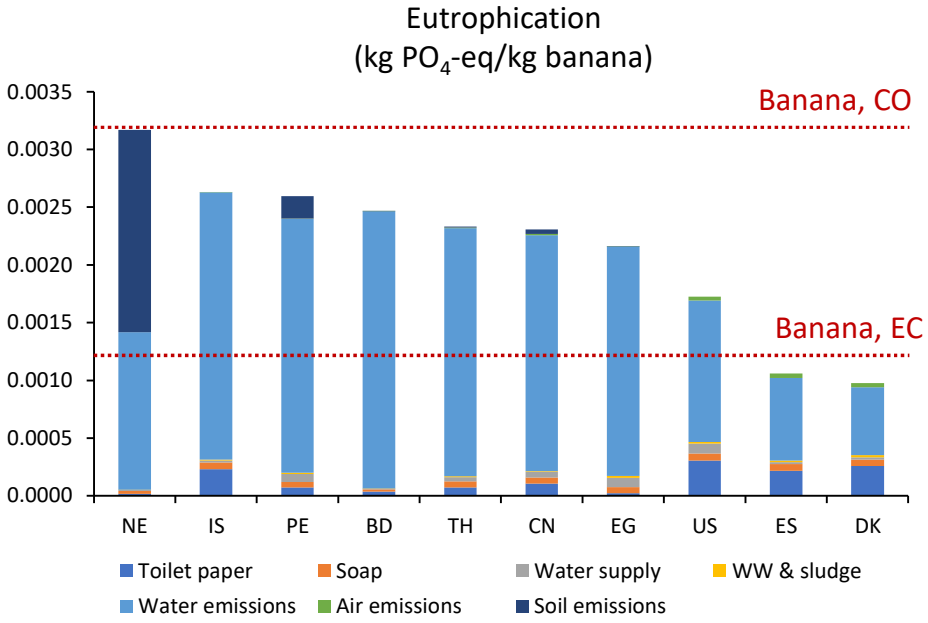
Examples with some food products

Banana





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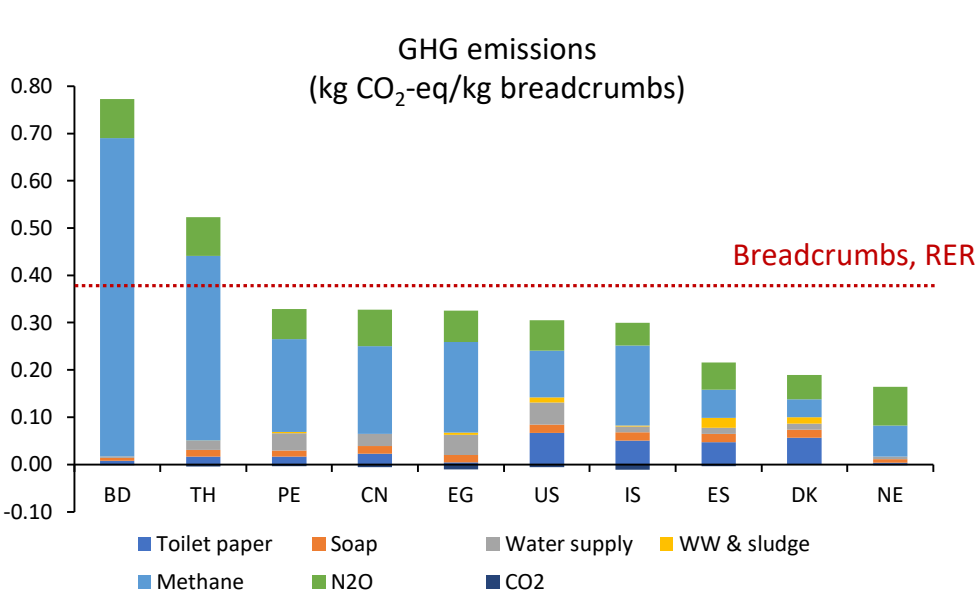
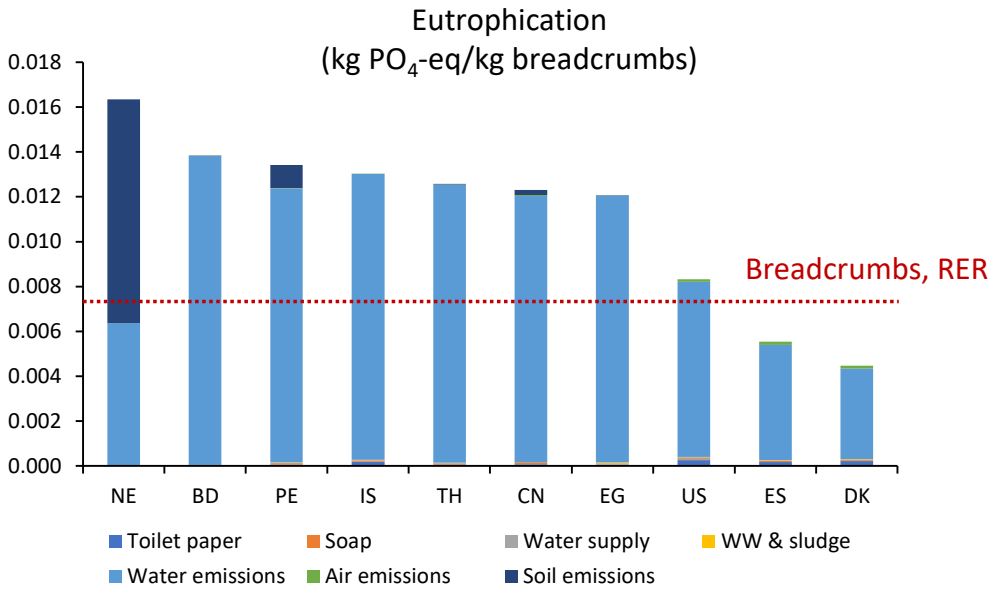
Examples with some food products
Breadcrumbs





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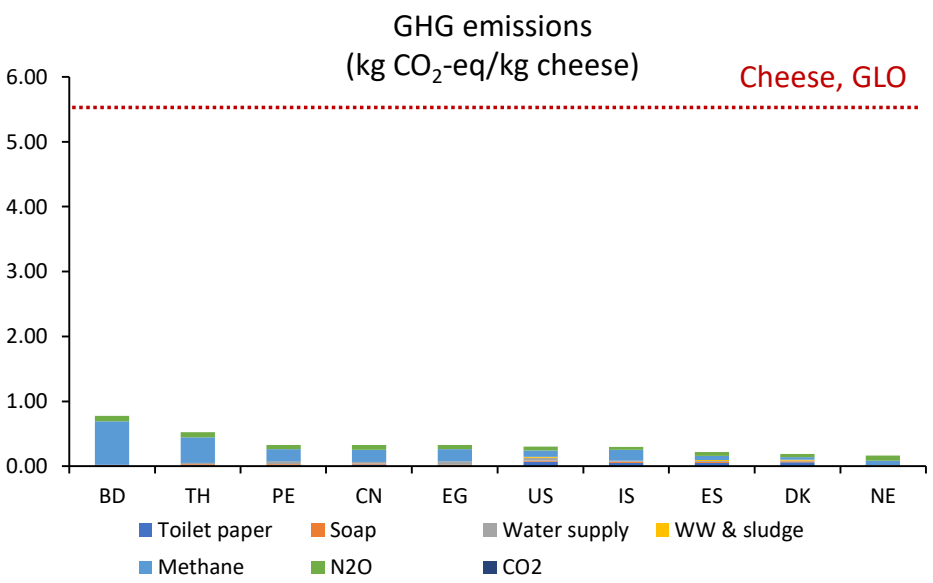
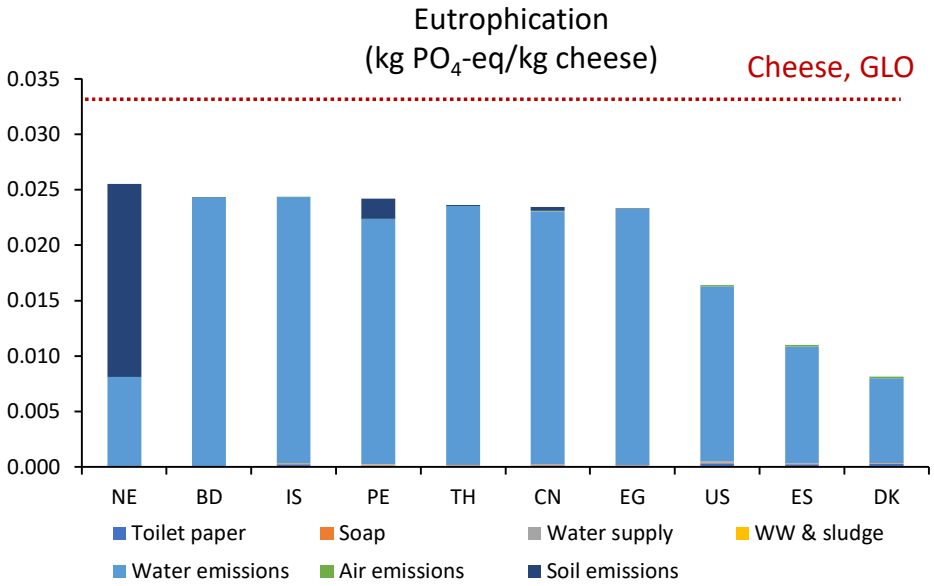
Examples with some food products
Cheese





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Conclusions

- Inclusion of human excretion in food LCA strongly recommended
  - Cradle to grave studies, hotspot identification
  - Comparisons, e.g. diet shifting
- Updated model shows (for GHG emissions and eutrophication)
  - Wide geographical variability
  - Sanitation linked to food consumption is more relevant than previously thougt
  - Relative relevance likely to decrease with high-impact foods, e.g. beef

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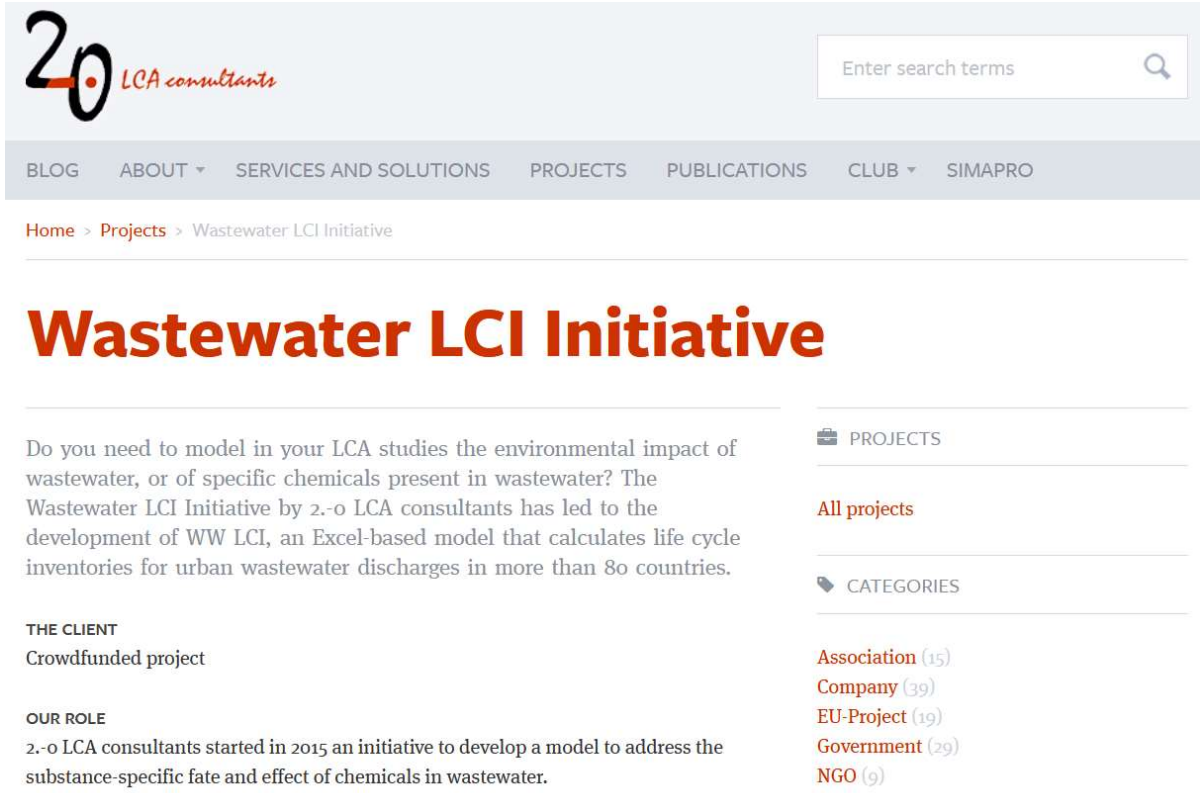

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