Technical University of Denmark

Towards a Standard Method for Life Cycle Assessments of Wastewater Treatment

Corominas, Ll; Foley, J; Guest JS, JS; Hospido A, A; Larsen, Henrik Fred; Shaw, A

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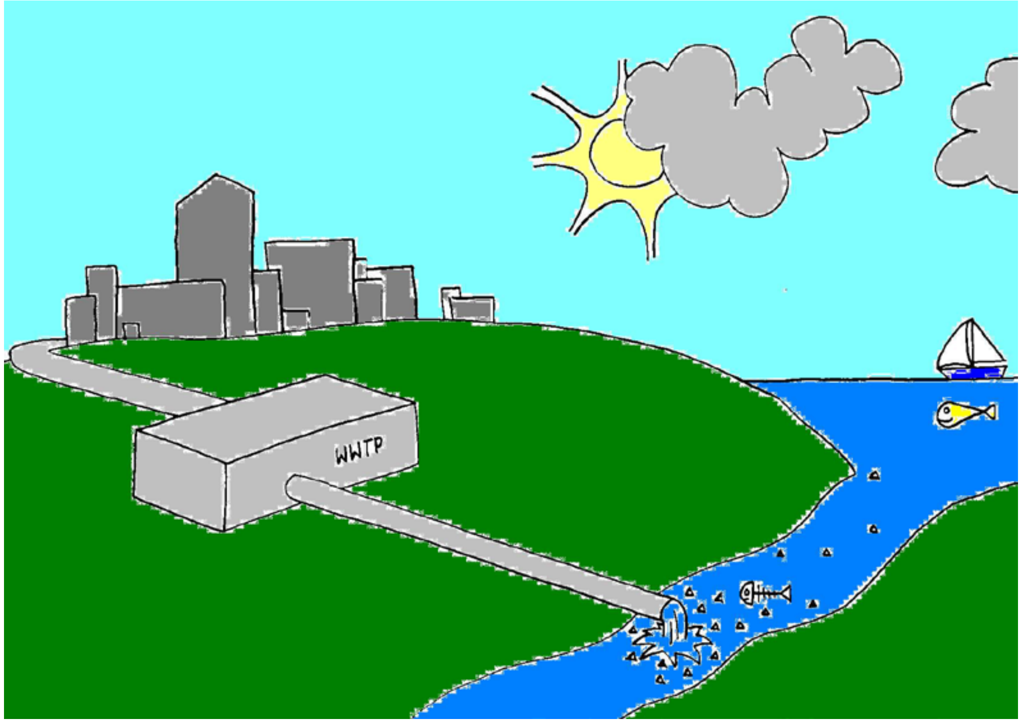
Ll. Corominas, J. Foley, J.S. Guest, A. Hospido, H.F. Larsen, A. Shaw

Watermatex 2011, 20th June San Sebastian (Spain)

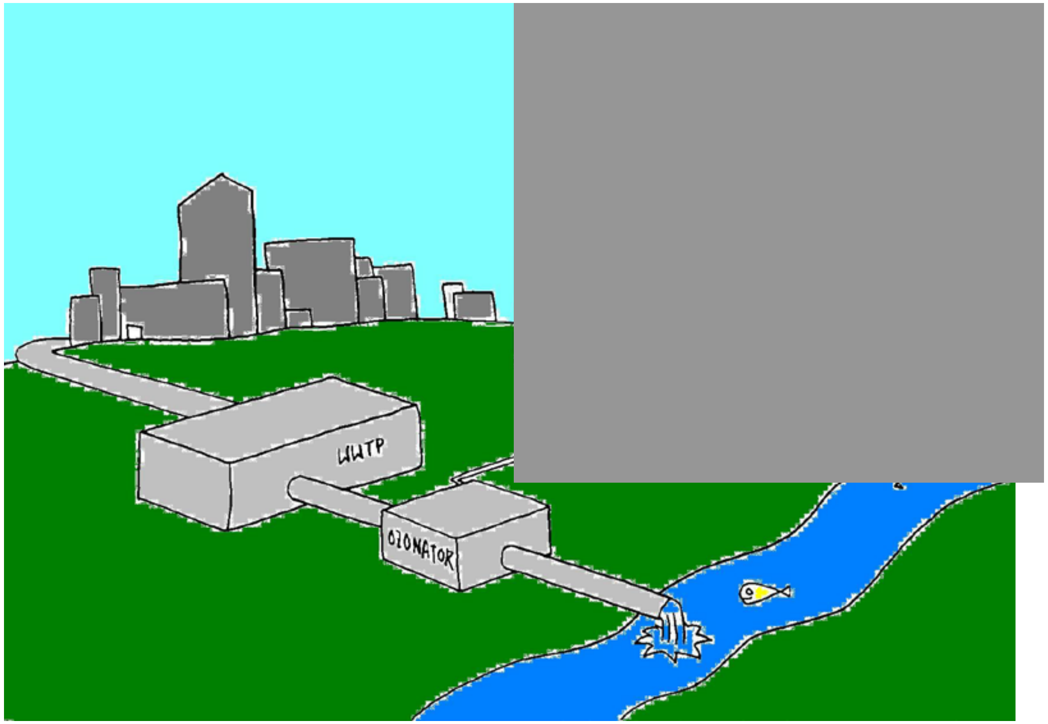
ICRA Institut Català de Recerca de l'Aigua

Life Cycle Assessment



Taken from H.F. Larsen

Life Cycle Assessment



Taken from H.F. Larsen

Problem statement

- 1960s: Beggining of this technique
- 1990s: Pressure to standardize → ISO 14040 and 14044
- 2010s: Increase of popularity

↓

Increase of information: databases

Software tools, models, etc

Problem statement

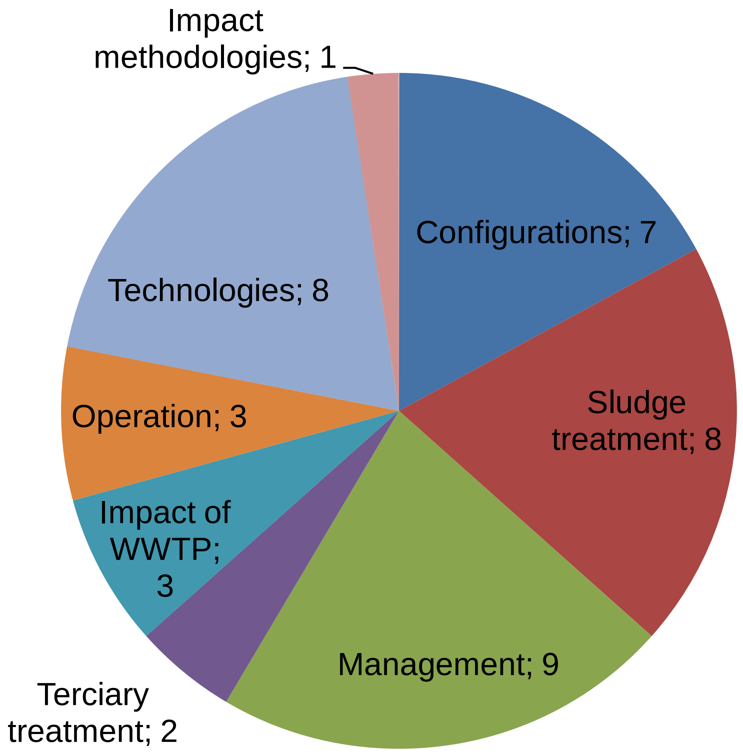
In WASTEWATER field

- 1990s: Flückiger and Gubler (1994); Emmerson et al. (1995); Fahner et al. (1995); Zimmermann et al. (1996); Roeleveld et al. (1997)
- Until now, about 41 published papers in peer-reviewed journals (+ conference papers)

It is now time to make a review
What have we learned
Were should we go?

What have we learned?

- Applications



What have we learned?

- Boundaries

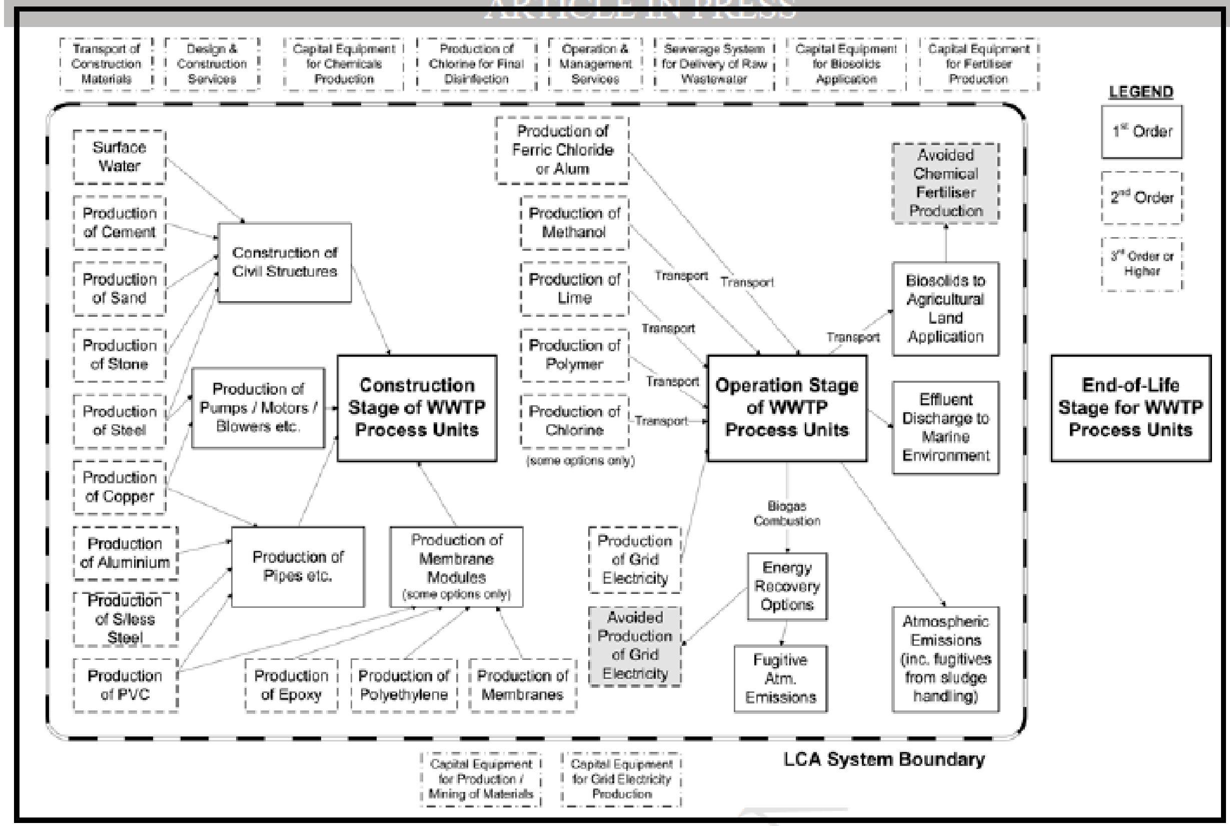


Figure 2. System boundary for life cycle inventory of WWTP scenarios

What have we learned?

- Main Outcomes

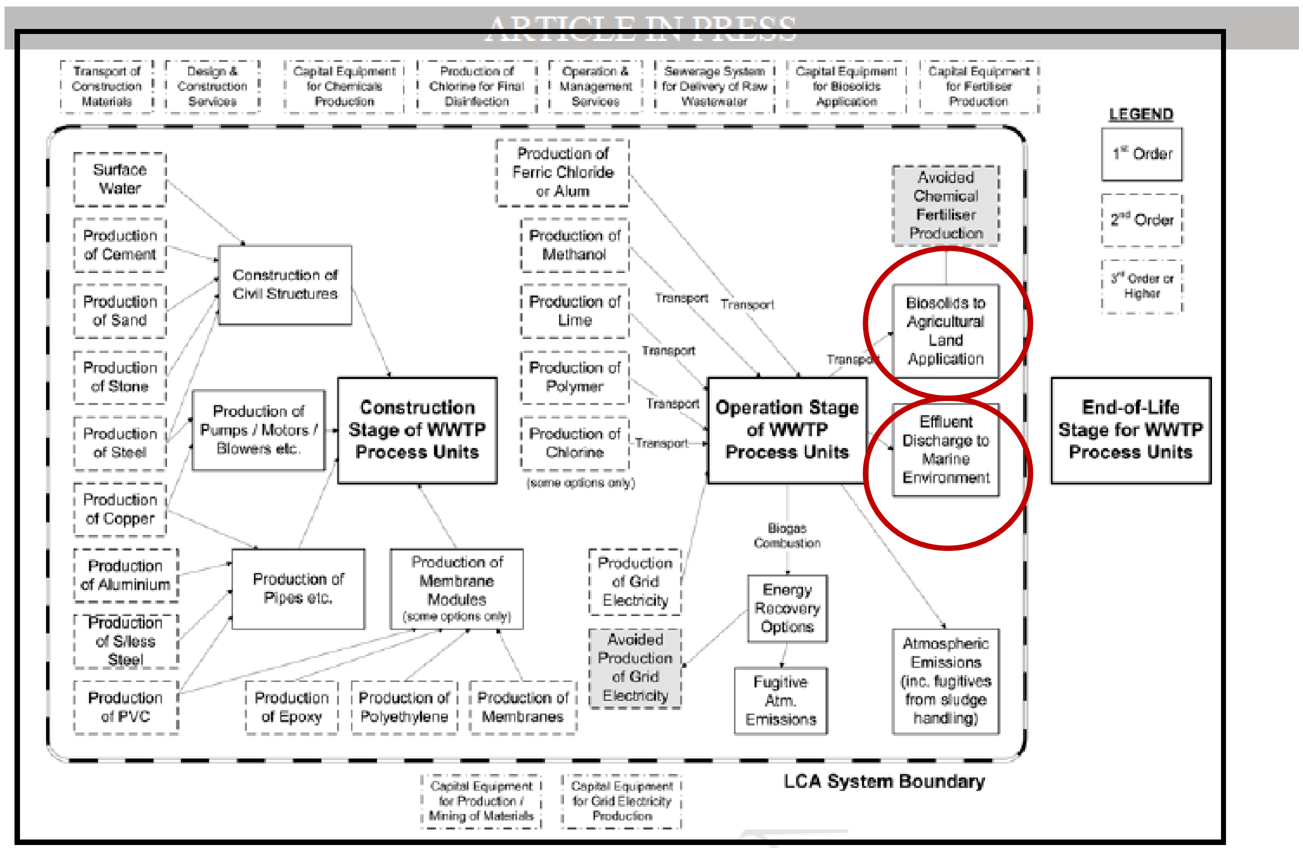


Figure 2. System boundary for life cycle inventory of WWTP scenarios

What have we learned?

- Outcomes
  - Impact of WWTP → water discharge and sludge application
  - Technologies → Avoided vs induced impact (constructed wetlands and sand filtration appropiate)
  - Configurations → Better N removal but Resources depletion, global warming, acidification, human toxicity
  - Operation → Better N and P removal and increase energy efficiency

What have we learned?

- Outcomes
  - Separation systems (urine) have environmental advantages (avoided fertilizers)
  - Sludge treatment → Anaerobic digestion combined with electricity production. Incineration and land application are acceptable (but minimization of heavy metals from sludge)
  - Impact methodologies → For GHG emissions, acidification, eutrophication, resource depletion not a critical issue

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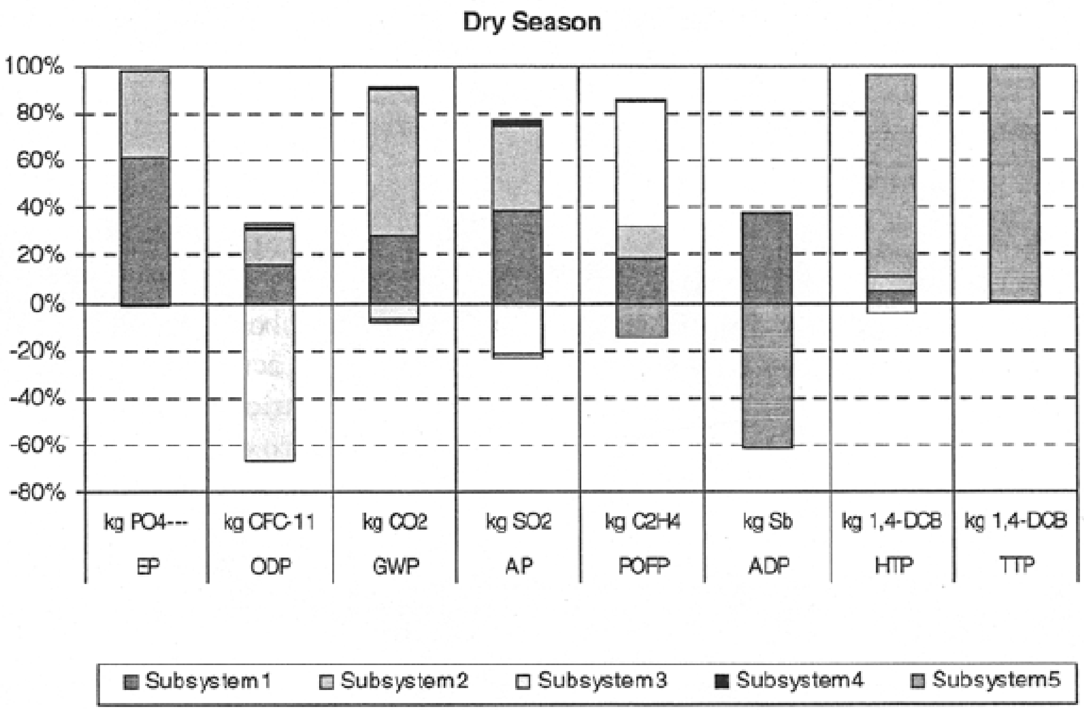
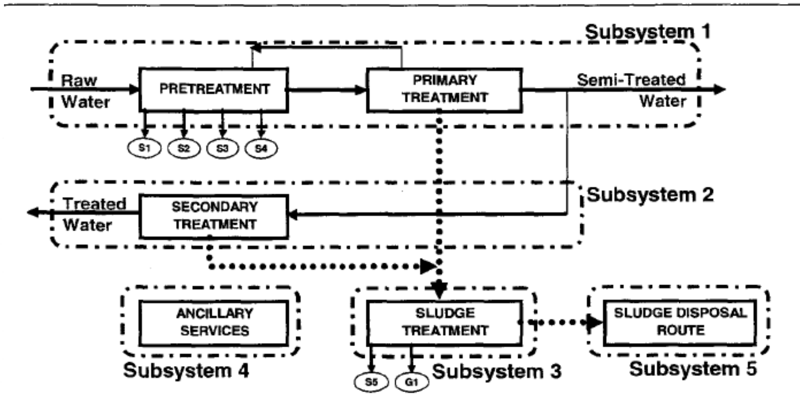
What have we learned?

WWTP impact



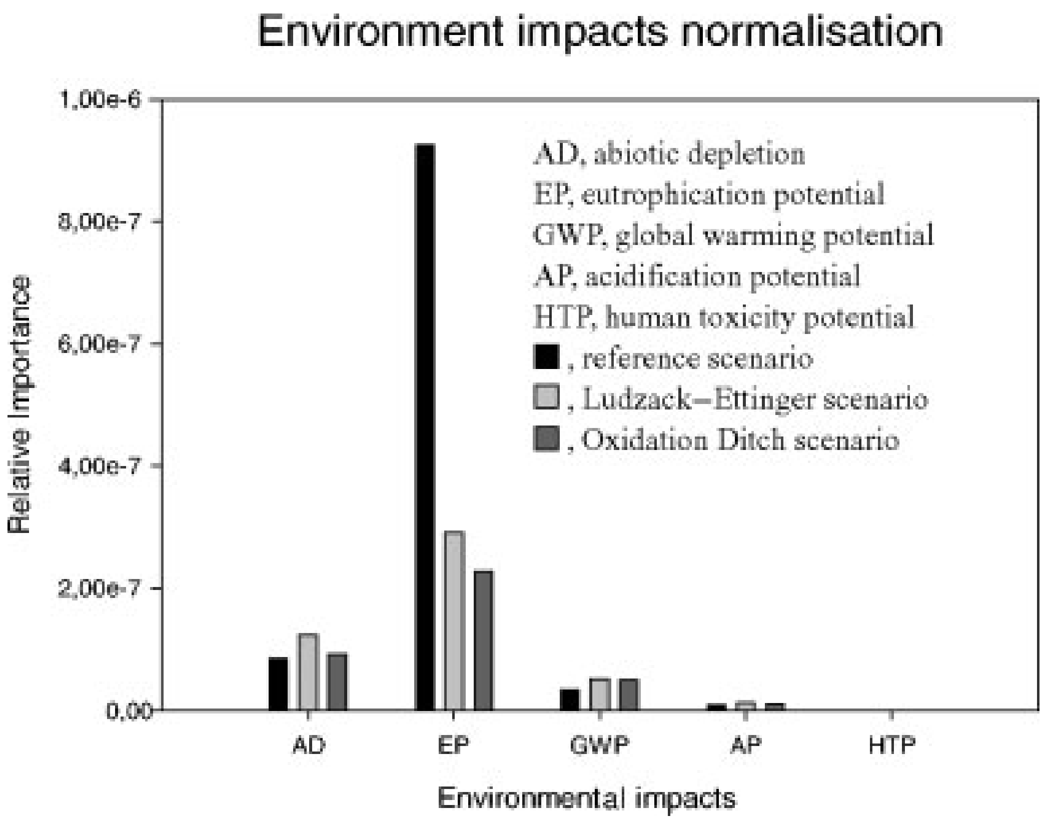


Hospido et al., 2004

Fig. 2: Characterisation profiles for both Functional Units. Subsystem 1 is represented in dark grey, subsystem 2 in light grey, subsystem 3 with dots, subsystem 4 in black and subsystem 5 with oblique lines

What have we learned?

Configurations



Vidal et al., 2002

What have we learned?

Technologies

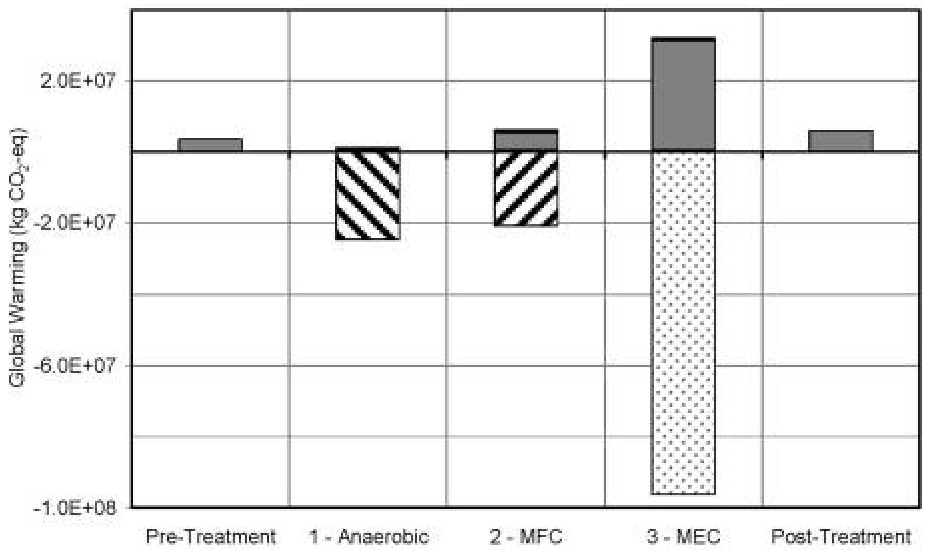


FIGURE 4. Selected midpoint life cycle impact assessment results, disaggregated into the following: "Con.", construction phase; "Op.", operational phase (i.e., power, chemicals, transportation); "Av. Gas", avoided natural gas from operational phase of anaerobic reactor (Option 1 only); "Av. Elec", avoided electricity from operational phase of MFC (Option 2 only); "Av. H2O2", avoided AO hydrogen peroxide from operational phase of MEC (Option 3 only); and "Sludge", sludge dewatering and disposal from operational
phase. The results are expressed in terms of a reference unit for each environmental impact category (e.g., kg CO2-eq for global warming, kg C2H3Cl-eq for carcinogens). Positive values indicate an adverse environmental impact (i.e., the higher the value, the worse is the impact), and negative values indicate an environmental benefit.

Foley et al., 2009

Con.	Op.	Av. Gas
Av. Elec.	Av. H2O2	Sludge

What have we learned?

Sludge treatment

Discrepancies

- Inclusion/ exclusion of infrastructure

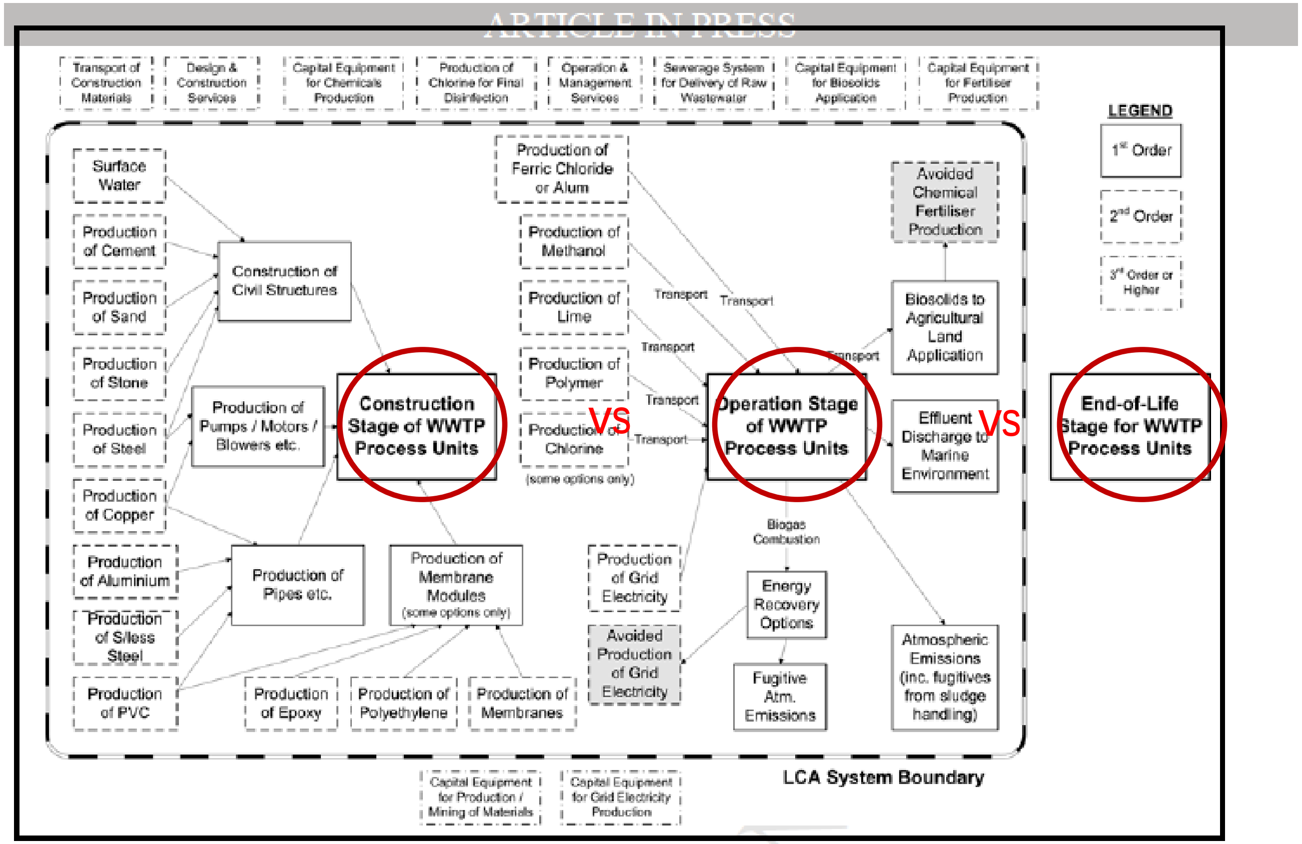
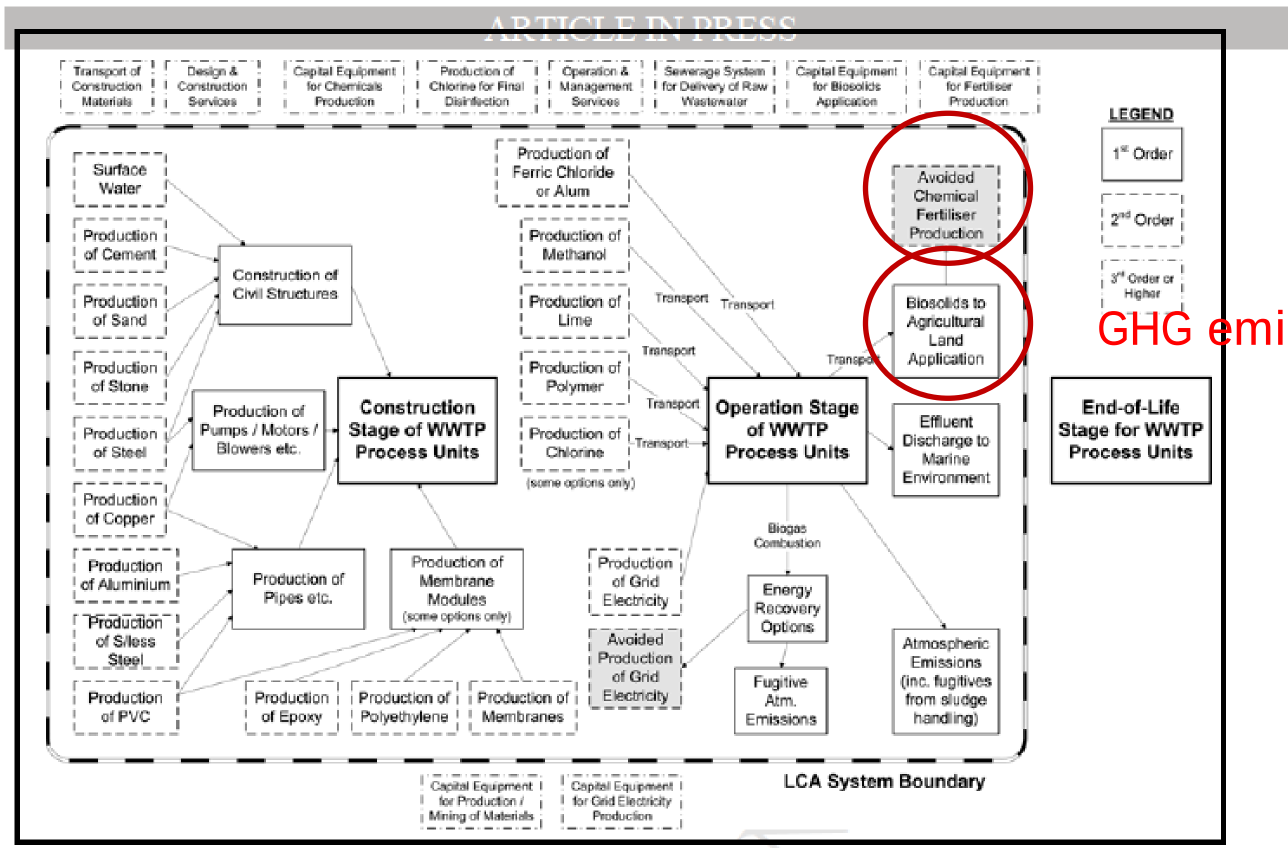


Figure 2. System boundary for life cycle inventory of WWTP scenarios

Discrepancies

- The importance of including disposal of waste

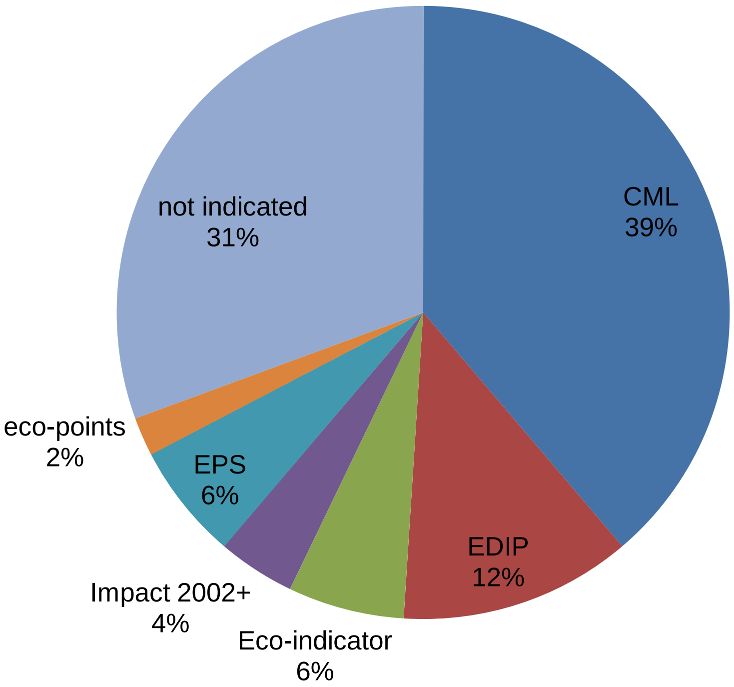


GHG emissions?

Figure 2. System boundary for life cycle inventory of WWTP scenarios

Discrepancies

- Selection of impact methodology



Discrepancies

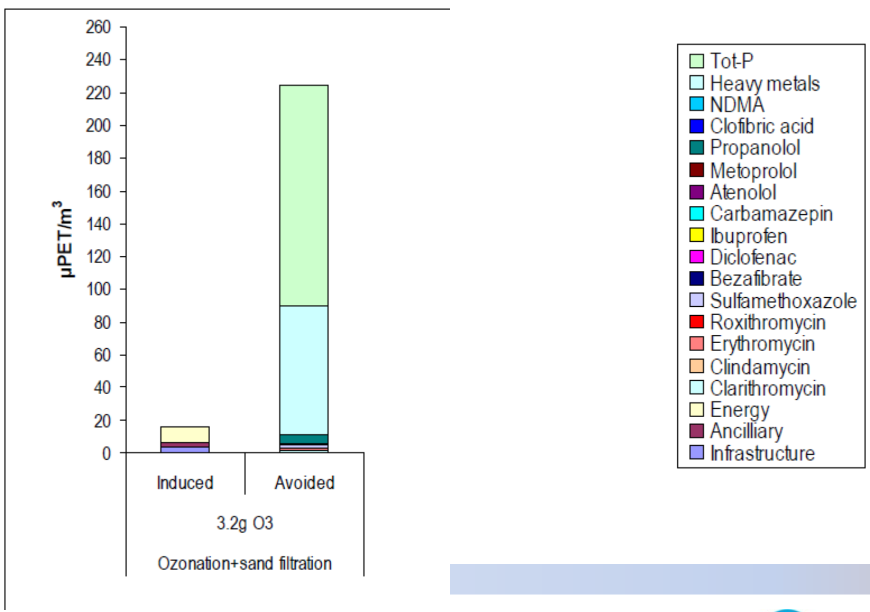
- Selection of categories

	Nº papers including category	Nº CML papers including category	Nº CML papers indicating relevant category
Global warming potential	43	16	7
Acidification potential	27	15	6
Freshwater eutrophication potential	25	15	8
Marine eutrophication potential	3	2	1
Human Toxicity	19	11	4
Terrestrial eco-toxicity	18	10	6
Photochemical oxidation	19	12	3
Fresh water eco-toxicity	14	6	5
Marine eco-toxocity	6	4	3
Fossil energy depletion	17	12	3
Material depletion	7	2	1
Ozone layer depletion	14	9	2
Land Occupation	2	1	0
Others	8	2	0

Where should we go?

- Developments in toxicity-related categories

Environmental sustainability profiles; ozonation + sand filtration
(including both metal and phosphorus removal)
(31 micropollutants + P (only significant ones shown); weighting factor = 1 for all impact categories)



Larsen et al., 2010

Where should we go?

- Provide local factors, e.g. eutrophication

Table 4 Characterization factors for N and P contained in wastewaters

Substance (*j*)	Water area (*i*)	γ_i	ε	$\mu_{j,i}$	Equ_j[a]	$C_{j,\text{wastewater},i}$[a] (Eq.4)
N	Maritime waters[b]	0.80	0.7	1	0.42	0.24
	Freshwaters	0.80	0.7	0[c]	0.42	0.00
P	Ocean	0.87	1	0[c]	3.06	0.00
	Freshwaters + rias	0.87	1	1	3.06	2.66

[a] Expressed as kilogram PO_4^{3-} equivalent per kilogram substance *j* emitted

[b] Maritime waters = ocean + rias

[c] The ocean is considered N limited and the freshwaters P limited

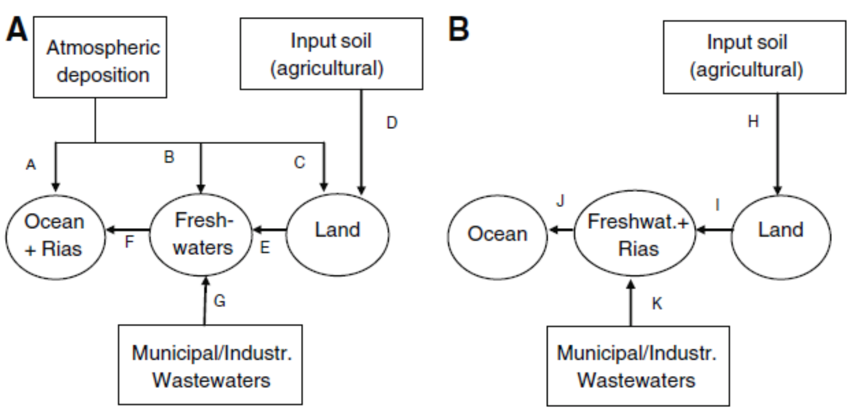


Fig. 2 Principal pathways considered for N (a) and P (b) transport in Galicia

Gallego et al., 2010

Where should we go?

- Better data quality (evaluation of uncertainty)

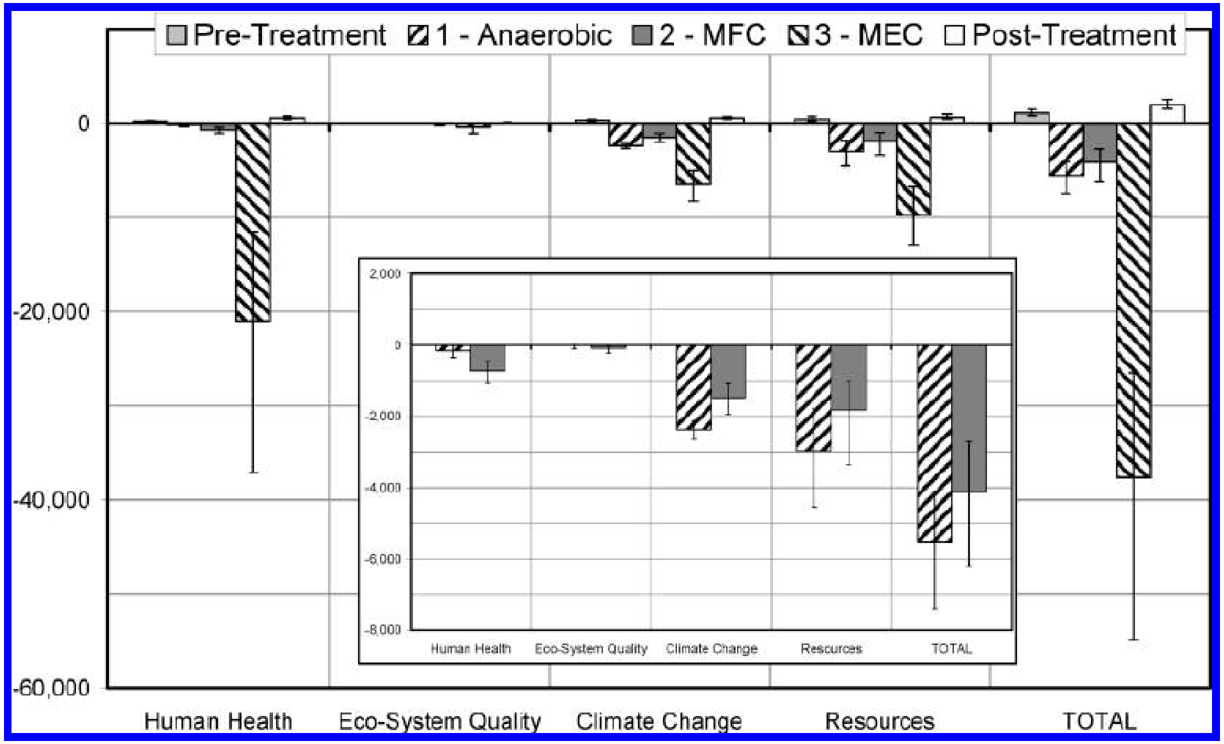


FIGURE 6. Comparison of IMPACT 2002+ normalized end-point scores, including Monte Carlo analysis uncertainty ranges. Inset shows a magnification of the comparison between Option 1 (anaerobic) and Option 2 (MFC). Error bars (95% confidence interval) indicate the uncertainty inherent in the background inventory data for the three options. This uncertainty range is generated using a Monte Carlo analysis (1000 runs) on each option in SimaPro.

Where should we go?

- Decission-making (link with economic and social criteria)

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