Wastewater Treatment Technologies: Applicability and limitations in LCA for constructed wetlands systems: using vertical reed bed filters

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Wastewater treatment technologies

Applicability & Limitations in LCA for constructed wetland systems: Using vertical reed bed filters

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ELSA-LCA Environmental Lifecycle and Sustainability Assessment

ELSA research group

http://www.elsa-lca.org

- **Regional platform**
  - Area of Montpellier, France
  - 5 French research institutes and universities
  - 26 members (professors & associate researchers, PhD students).

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Cemagref — Science, water & land management

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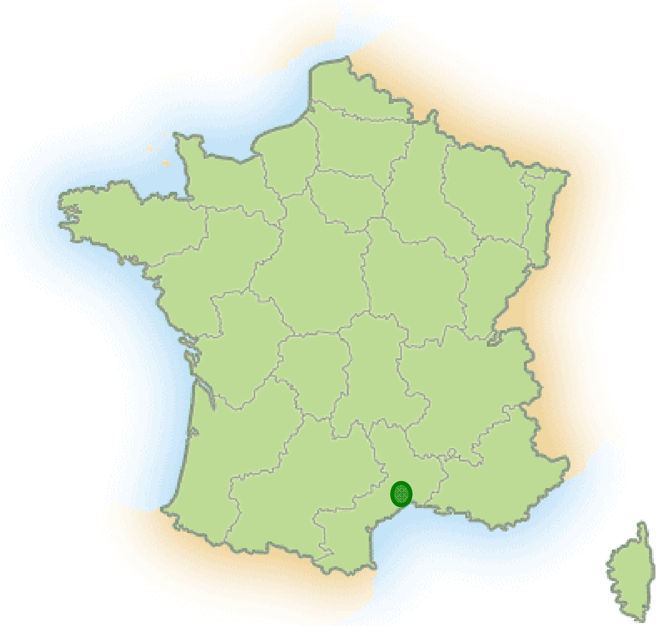


- **Fields of competence**
  - Environmental & Social LCA
  - Industrial Ecology
  - Agro-bioprocesses : bioenergy, solid & liquid waste treatment, crop production, tropical production.

Introduction

Challenges of LCA for WWTPs

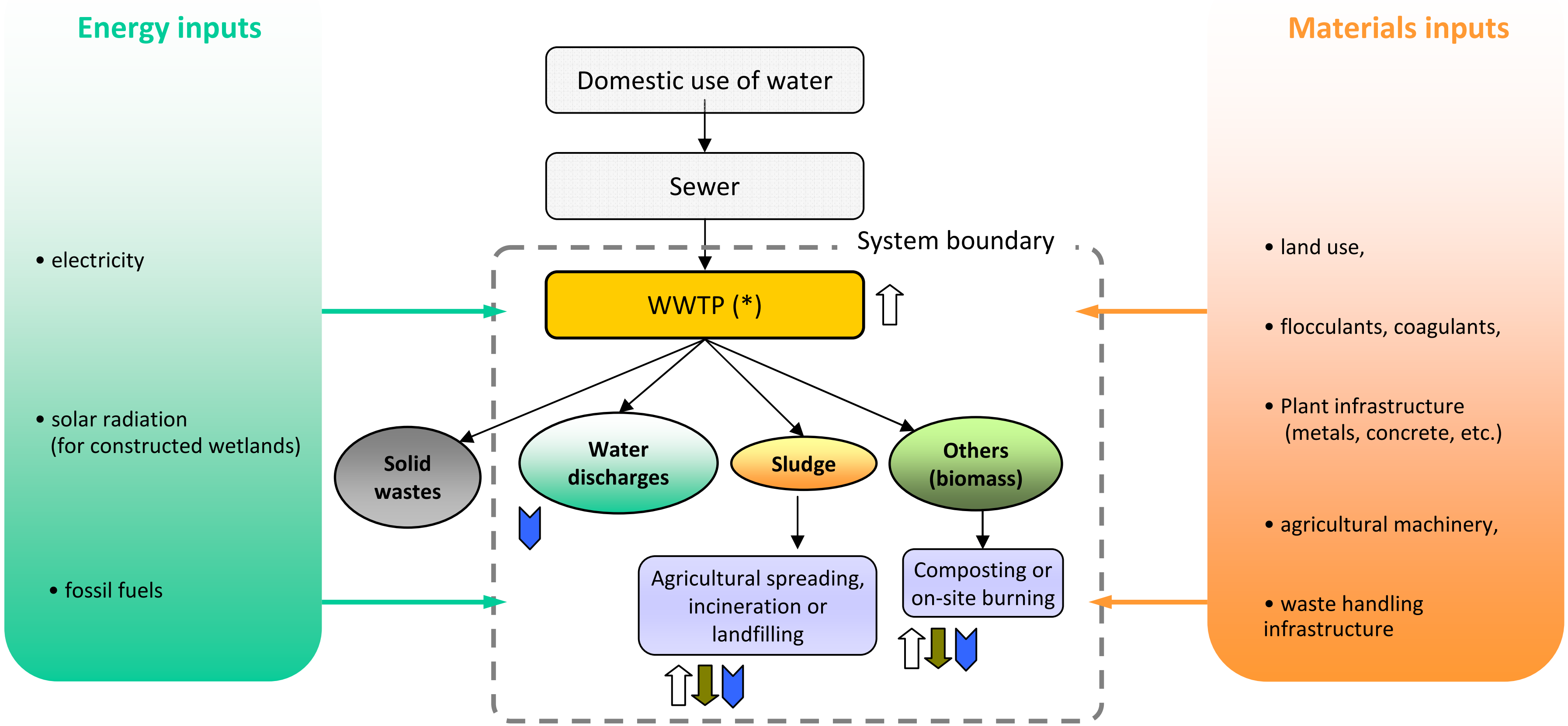
- Calculate the systems' environmental impacts
  - ⇨ **LCI** of all air, water & soil emissions
  - ⇨ Balance inputs and outputs of treatment plants

- Which system has the 'lowest' impacts?
  - ⇨ Applying a comparative LCA

Constructed Wetlands (vRBF) **VS** Activated Sludge

Goal & scope

(*) wastewater treatment plant



Functional Unit

Treatment of

« a kilogram of daily organic load (kgBOD5) of domestic origin »

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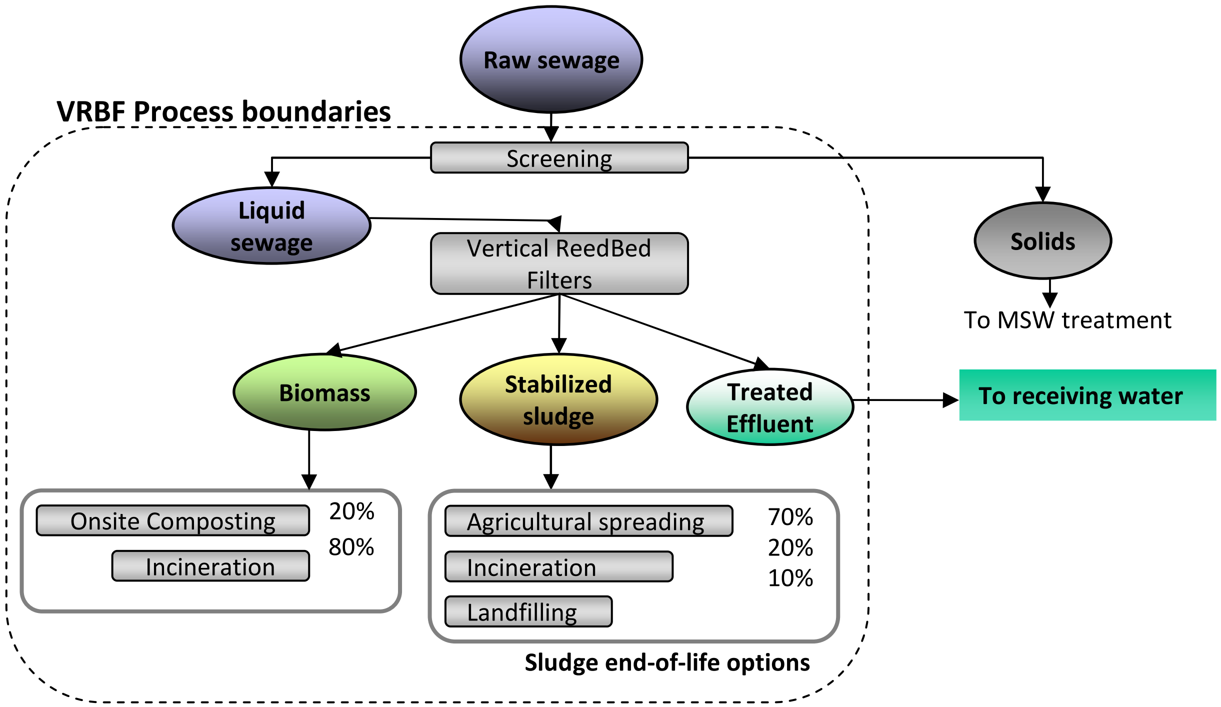
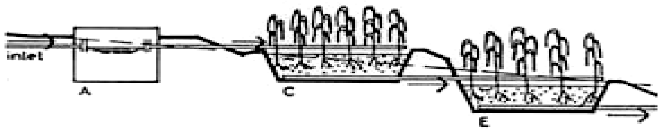
System 1. Constructed Wetland

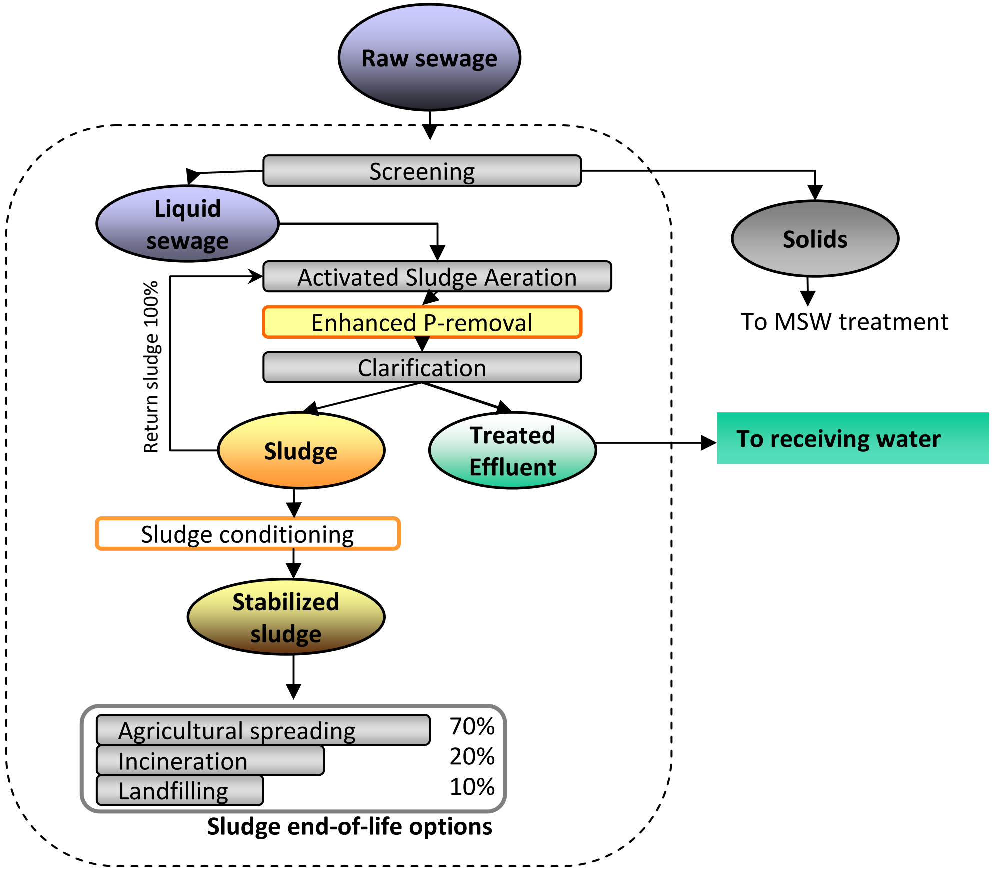


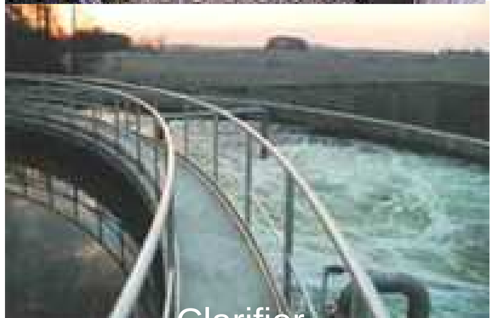


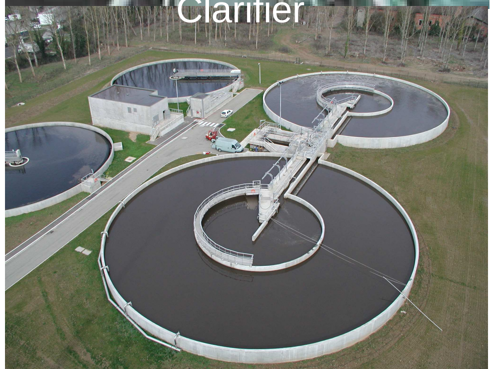
First stage (3 filters)

Second stage (2 filters)

System 2. Activated Sludge







LCI. Elemental mass balance for a CW system (vRBF)

INPUT

Input wastewater content		**vRBF outputs ($g.d^{-1}.hab^{-1}$)** - discharges and other outputs (<< stands for negligible quantities)						
		Emissions and direct discharges			**By-products**			**Total output**
Substances	**$g.d^{-1}.hab^{-1}$**	**Air**	**Soil**	**Water**	**Sludge**	**Reeds**	**Filter matrix**	
P P-org	0,40			0	0	0,05	<<	
P-PO4	1,60			1,50	0	<<	0	
P-P2O5	0			0	0,44	<<	0,01	
Total P, in	***2,00***	**-**	**-**	***1,50***	***0,44***	***0,05***	***0,01***	***2,00***

Complete P mineralization

Estimation of plant uptake for P

Sludge phosphorus levels, as phosphates

total P balance

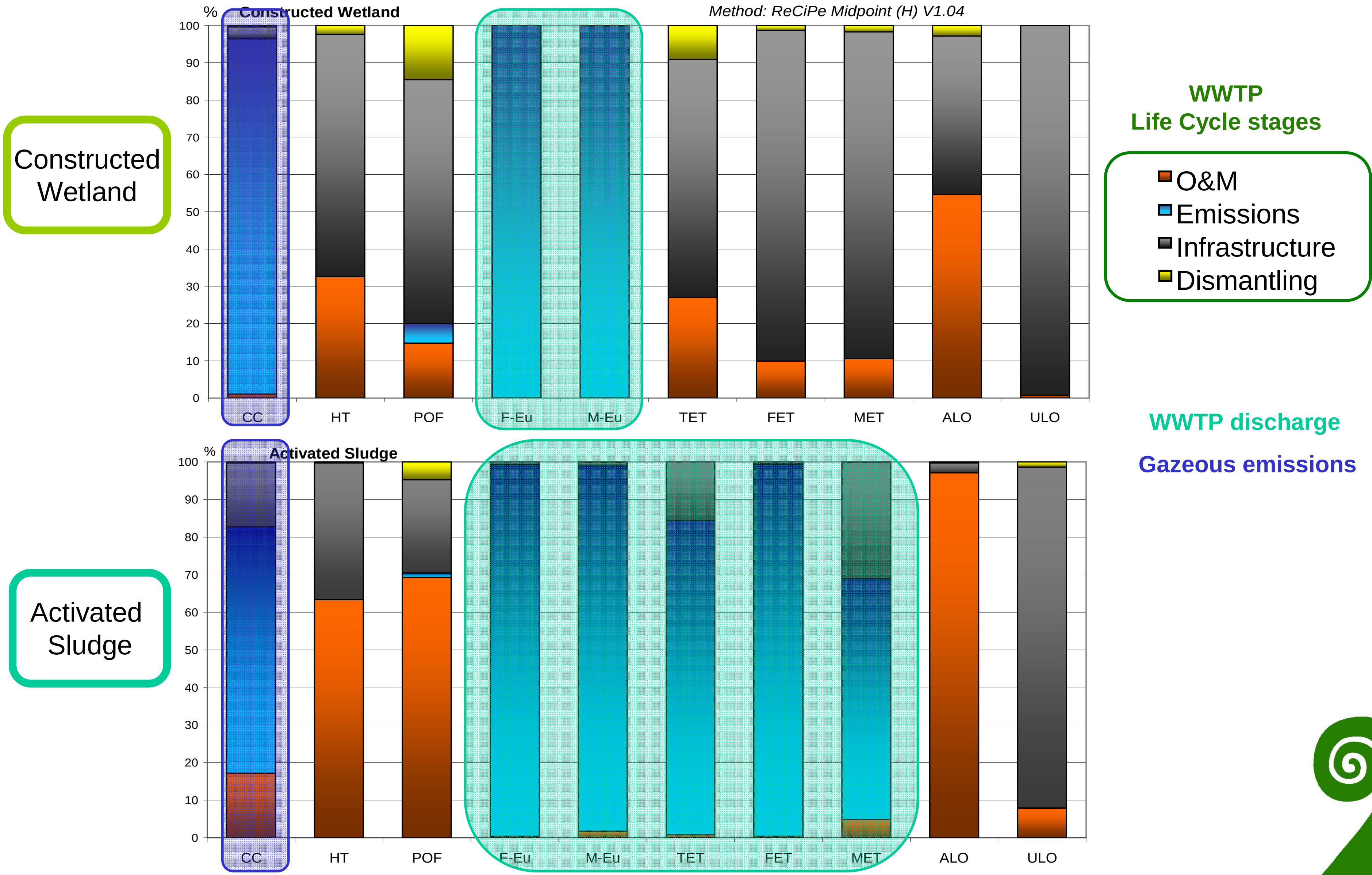
Data availability

GOOD, measured

OK, estimated

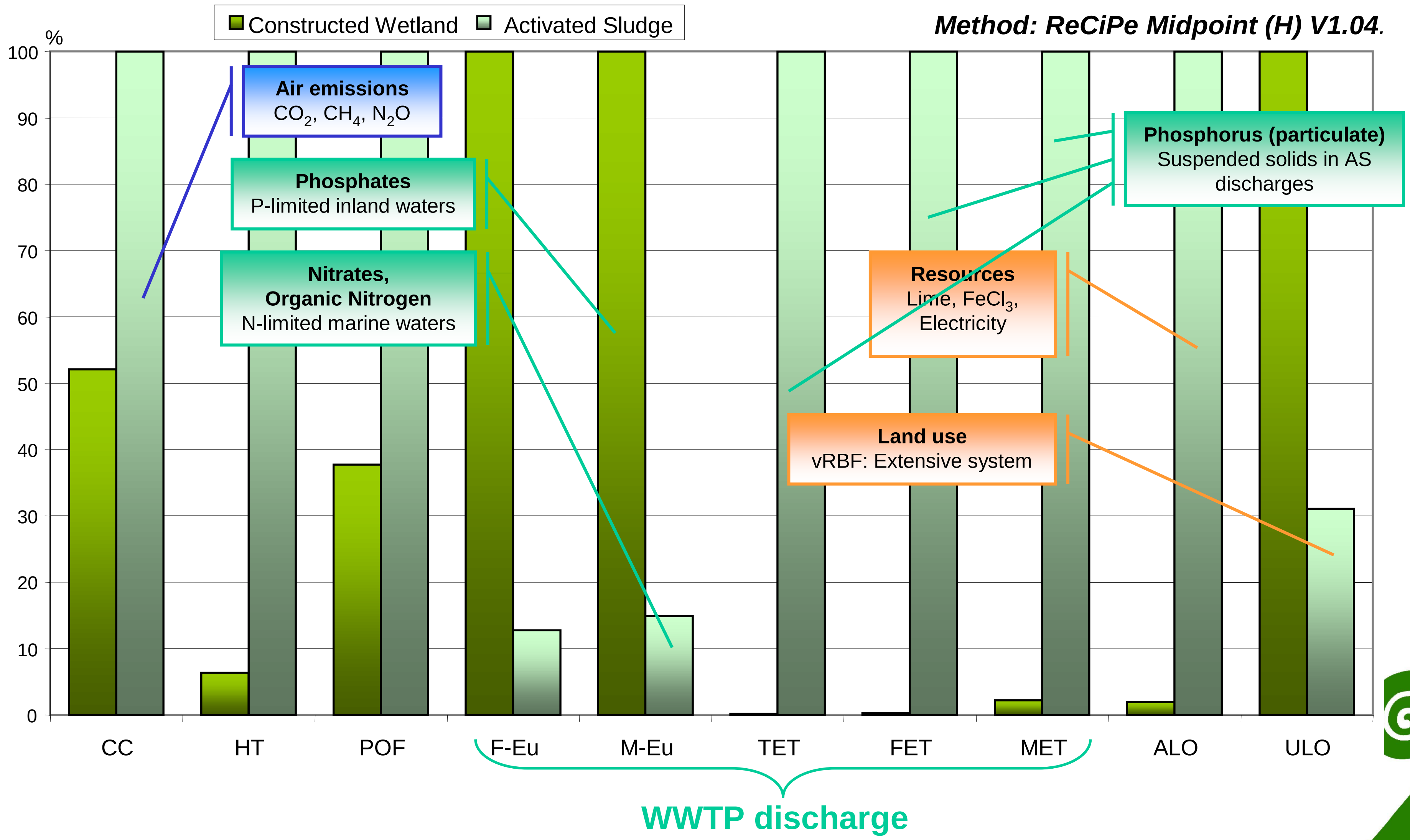
POOR, deducted

LCIA. Contribution Analysis



LCIA. Systems Comparison

Functional Unit : 1 kg BOD_5/day



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Conclusions

- **LCIA results**
  - ⇨ Constructed wetlands technology outperforms Activated Sludge on global impacts
  - ⇨ Design optimization options for CW
    - Phosphates precipitation
    - Increased denitrification

- **Trade-offs between process performance and operation in environmental costs**

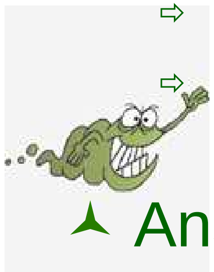
Perspectives

Applicability challenges

- Data availability for inventory of air emissions
  - Uncertainty, process variability, few monitored processes
- Hydraulic flows per capita
  - Huge variability across regions
  - Scaling of WWTP infrastructure

Limitations

- Normalization not consistent for ‘end-of-pipe’ processes
- Need to track emerging pollutants & pathogens (micropollutant level)



Answers brought by LCA in wastewater treatment:

- Ecodesign / Process design optimization : Midpoint approach
- Wastewater technology options : Endpoint approach

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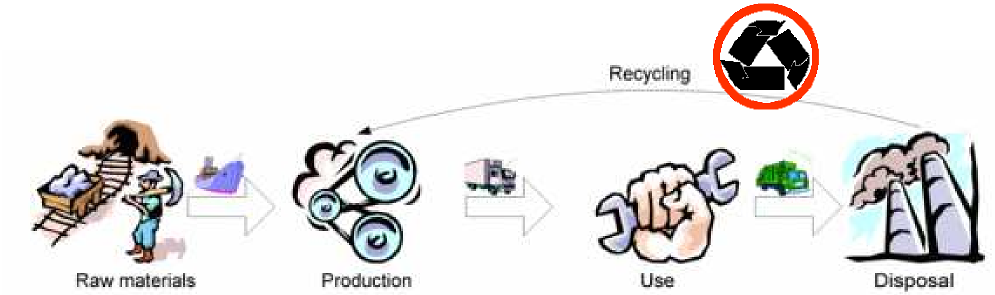
Thanks for your attention



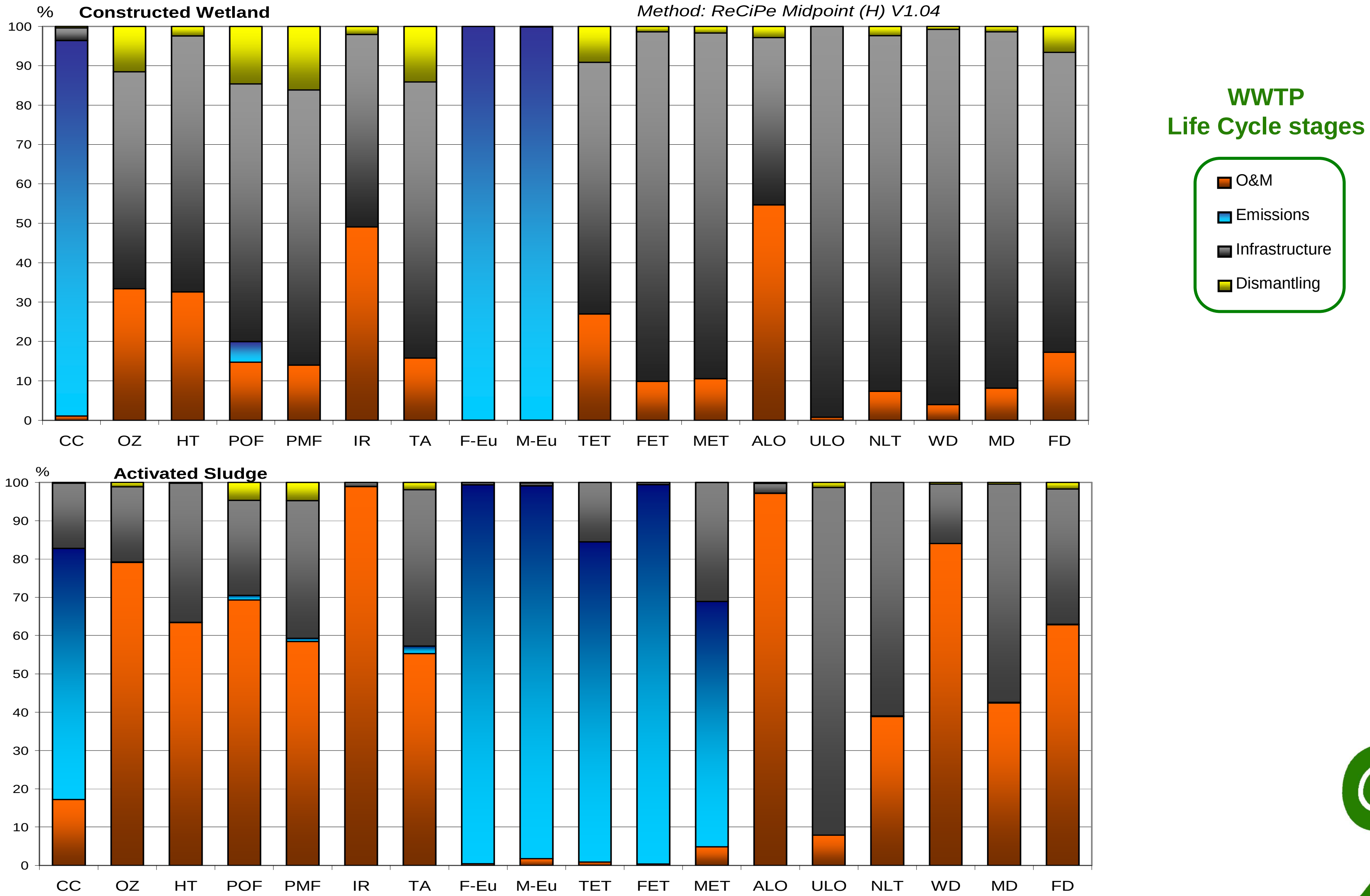
Think globally (Life Cycle) … Act locally !

Extra's

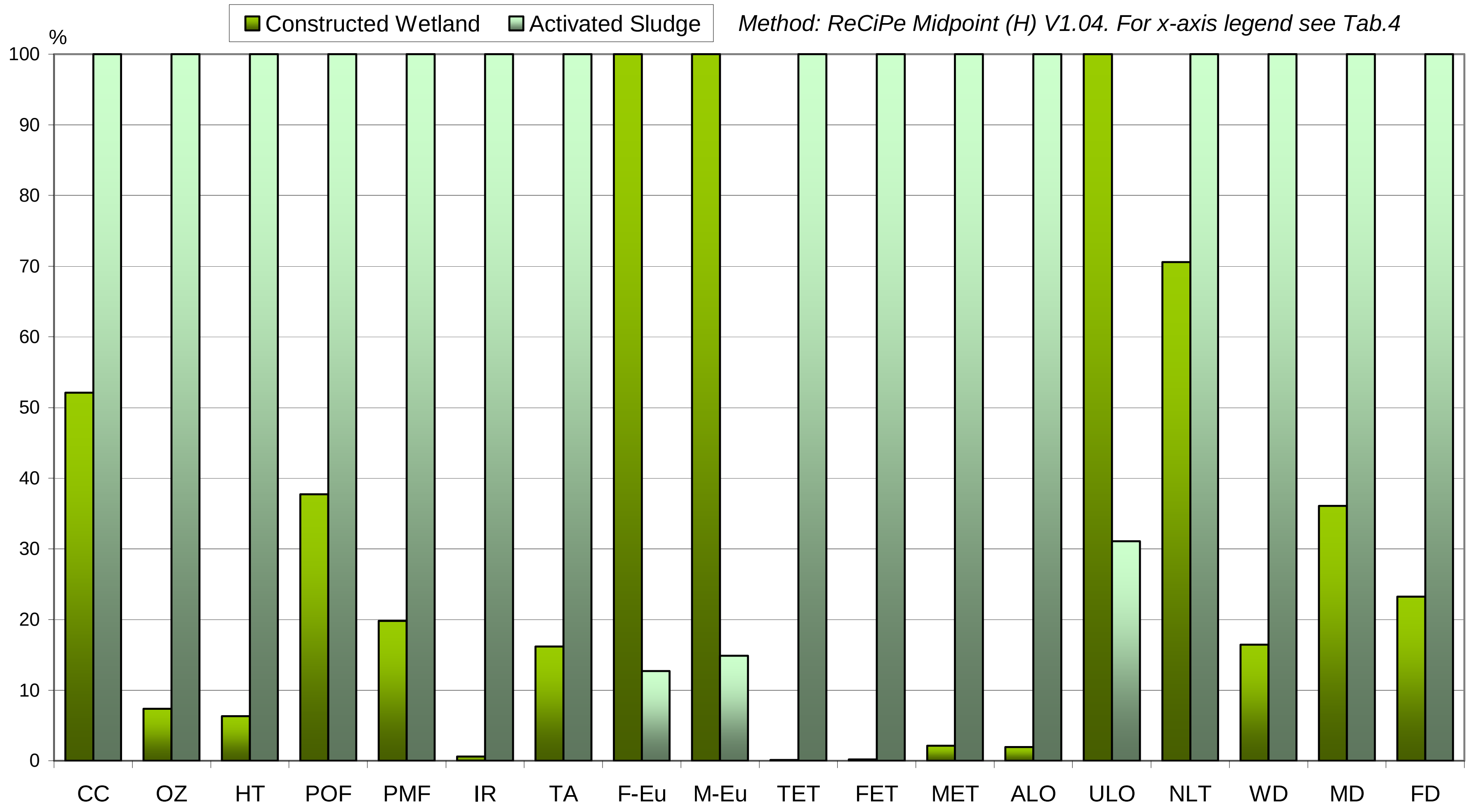
LCIA method: ReCiPe Midpoint (H), v.1.04

Abbr.	Impact category
CC	Climate change
OZ	Ozone depletion
HT	Human toxicity
POF	Photochemical oxidant formation
PMF	Particulate matter formation
IR	Ionising radiation
TA	Terrestrial acidification
F-Eu	Freshwater eutrophication
M-Eu	Marine eutrophication
TET	Terrestrial ecotoxicity
FET	Freshwater ecotoxicity
MET	Marine ecotoxicity
ALO	Agricultural land occupation
ULO	Urban land occupation
NLT	Natural land transformation
WD	Water depletion
MD	Metal depletion
FD	Fossil depletion

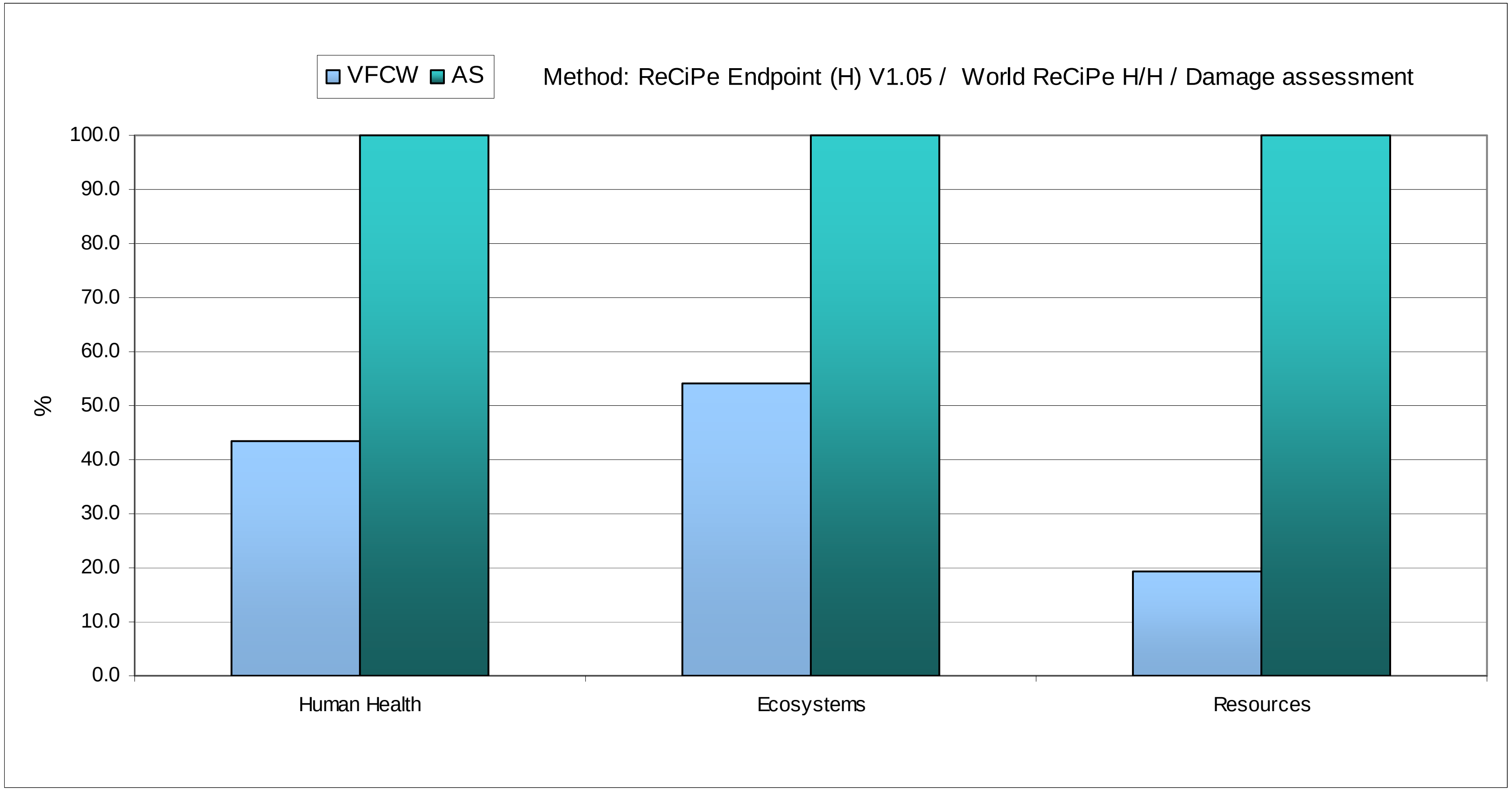
LCIA. Full Contribution Analysis



LCIA. Full Comparative Analysis



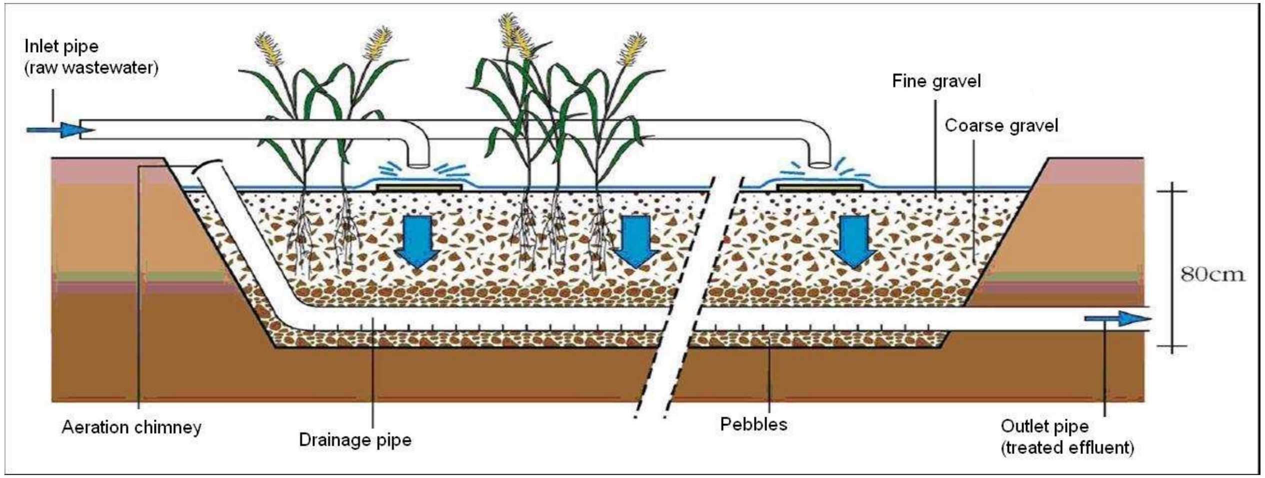
Endpoint approach



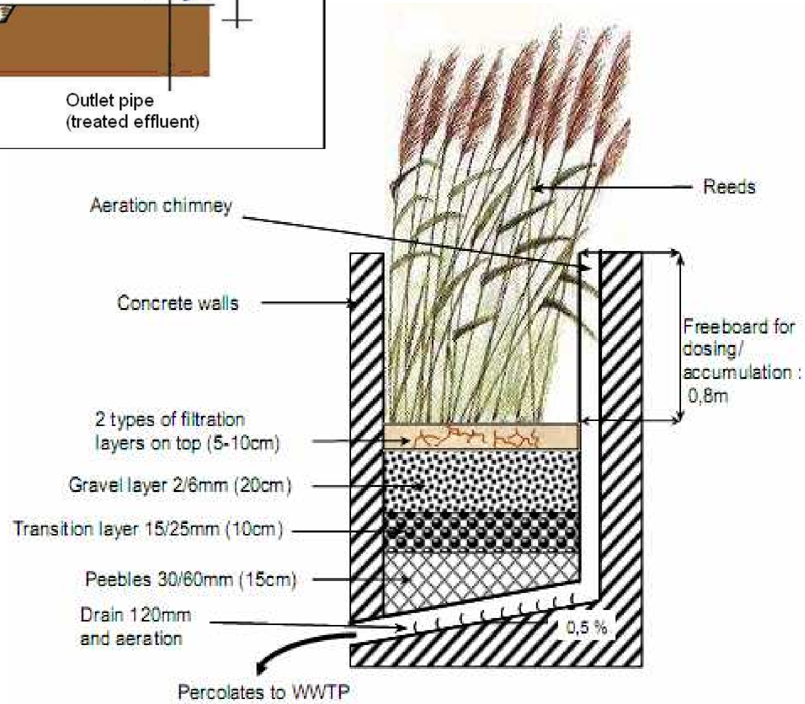
Vertical Flow Constructed Wetland

- Process design

Schematic view



Cross section of a VFCW



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Input sewage composition

System input		ecoinvent Class 5 AS (CH)	vRBF (FR)	AS (FR)
Nominal Organic load ($kgBOD_5.d^{-1}$)		48,36		312
Nominal hydraulic load ($m^3.day^{-1}$)		446	145	936
Treatment capacity		806 PE	967 Hab.	6240 Hab.
Concentration ($mg.L^{-1}$)	BOD_5	103.6	333	
	COD	155.4	800	
Flows ($g.day^{-1}$)		**per P.E.** [(a)]	**per Hab.** [(b)]	
BOD_5		60,0	50,0	
COD		90,0	120,0	
$N\text{-}NH_4$		8,27	7,5	
N-org[(c)]		6,46	2,5	
$N\text{-}NO_2$		0,22	0,0	
$N\text{-}NO_3$		0,58	0,0	
Total N		***15,53***	***10,0***	
P-Part		0,34	0,4	
$P\text{-}PO_4$		1,36	1,6	
Total P		***1,70***	***2,0***	

Mass balance on C, N, P

	Input wastewater content		vRBF outputs ($g.d^{-1}.hab^{-1}$) - effluents and other outputs (<< stands for negligible quantities)						
			Emissions and direct discharges			**By-products**			**Total output**
	Substances	$g.d^{-1}.hab^{-1}$	**Air**	**Soil**	**Water**	**Sludge**	**Reeds**	**Filter matrix**	
N	N-NH4	7,50			0,25	<<		0,10	
	N-org	2,50			1,80	0,75	0,76		
	N-NO2+3	0			6,23			<<	
	N-NH3		<<						
	N-NO		<<						
	N-N_2O		0,11						
	N-N_2		<<						
	Total N, in	***10,0***	***0,11***	**-**	***8,28***	***0,75***	***0,76***	***0,10***	***10,0***
P	P-org	0,40			0	0	0,05	<<	
	P-PO4	1,60			1,50	0	<<	0	
	P-P2O5	0			0	0,44	<<	0,01	
	Total P, in	***2,00***	**-**	**-**	***1,50***	***0,44***	***0,05***	***0,01***	***2,00***
C	C_{org}	45,0			1,87	13,1	<<	<<	
	C-CO2		29,8						
	C-CH4		0,16						
	$C_{mineral}$	5,00			2,00	3,00			
	Total C, in	***50,0***	***30,0***	**-**	***3,87***	***16,1***	**-**	**-**	***50,0***