Source separation for wastewater management and resource recovery at the district scale

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DESIGN project

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MUSES Project

AGENCE DE L'EAU ADOUR-GARONNE
ÉTABLISSEMENT PUBLIC DU MINISTÈRE DU DÉVELOPPEMENT DURABLE

Toulouse Biotechnology Institute
Bio & Chemical Engineering

INSA Université Fédérale Toulouse Midi-Pyrénées cnrs INRAE

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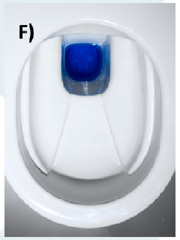
Source separation ? Why ?



Limits of big infrastructures

- Cost of WWTP operation & infrastructure
- Emissions from WWTP (N_2O…)

Water scarcity

- Do not flush toilet with potable water!
- Facilitate wastewater reuse

Circular economy

- N,P,K Fertiliser needs

Green cities

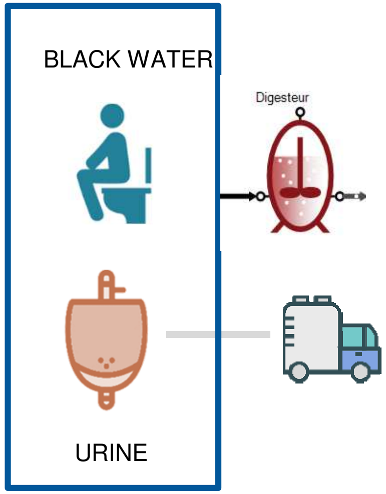
- Eco-district, urban farming, more vegetal, climate regulation, …

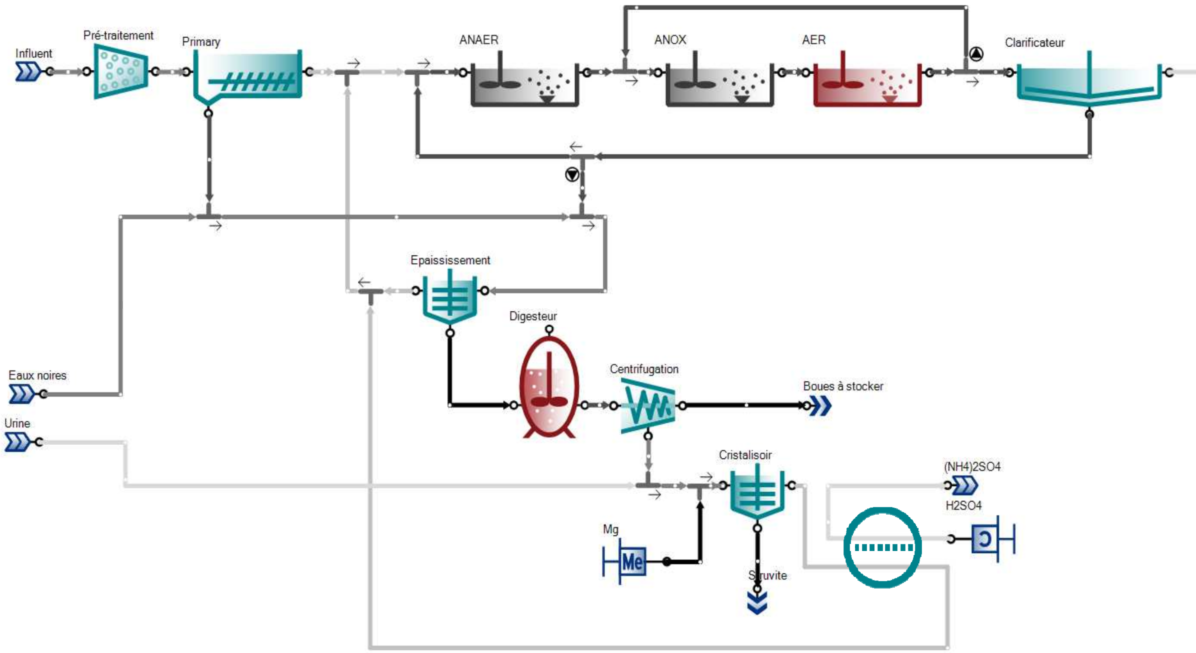
Merci P. Molle!

Separated vs mixed ? Centralised vs decentralised ?

GREY WATER

?





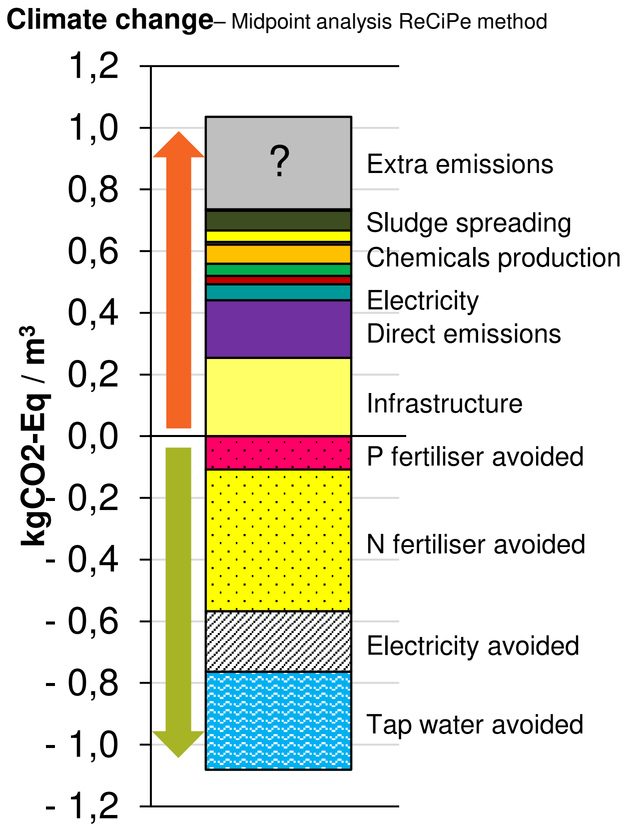
Coupling process modelling and LCA

1. Bisinella de Faria, A.B., Mathilde Besson; Aras Ahmadi; Kai M. Udert, and Mathieu Spérandio. 2020. Dynamic Influent Generator for Alternative Wastewater Management with Urine Source Separation. J. Sustainable Water Built Environ., 6(2)
2. Igos E, Besson M, Navarrete Gutiérrez T, Bisinella de Faria AB, Benetto E, Barna L, Ahmadi A, Spérandio M. 2017. Assessment of environmental impacts and operational costs of the implementation of an innovative source-separated urine treatment. Water Research 126: 50–59.
3. Bisinella de Faria, A.B., A. Ahmadi, L. Tiruta-Barna, M. Spérandio. 2016. *Feasibility of rigorous multi-objective optimization of wastewater management and treatment plants*. Chemical Engineering Research and Design 09, 2016; 115.
4. Bisinella de Faria, A.B., M Spérandio, A Ahmadi, L Tiruta-Barna. 2015 *Evaluation of new alternatives in wastewater treatment plants based on Dynamic Modelling and Life Cycle Assessment (DM-LCA)*. Water Research 07/2015; 84:99-111.

resources from wastewater

- Is carbon neutral wastewater management possible?
- Solution for maximizing resource recovery?
- Potential of source separation ?

Conventional WWTP	Optimised (WRRF)	Source separation ?	Ideal resource recovery
1.3-3 $kgCO_2eq/m^3$	**1.2** $kgCO_2eq/m^3$	**?** $kgCO_2eq/m^3$	**-0.15** $kgCO_2eq/m^3$

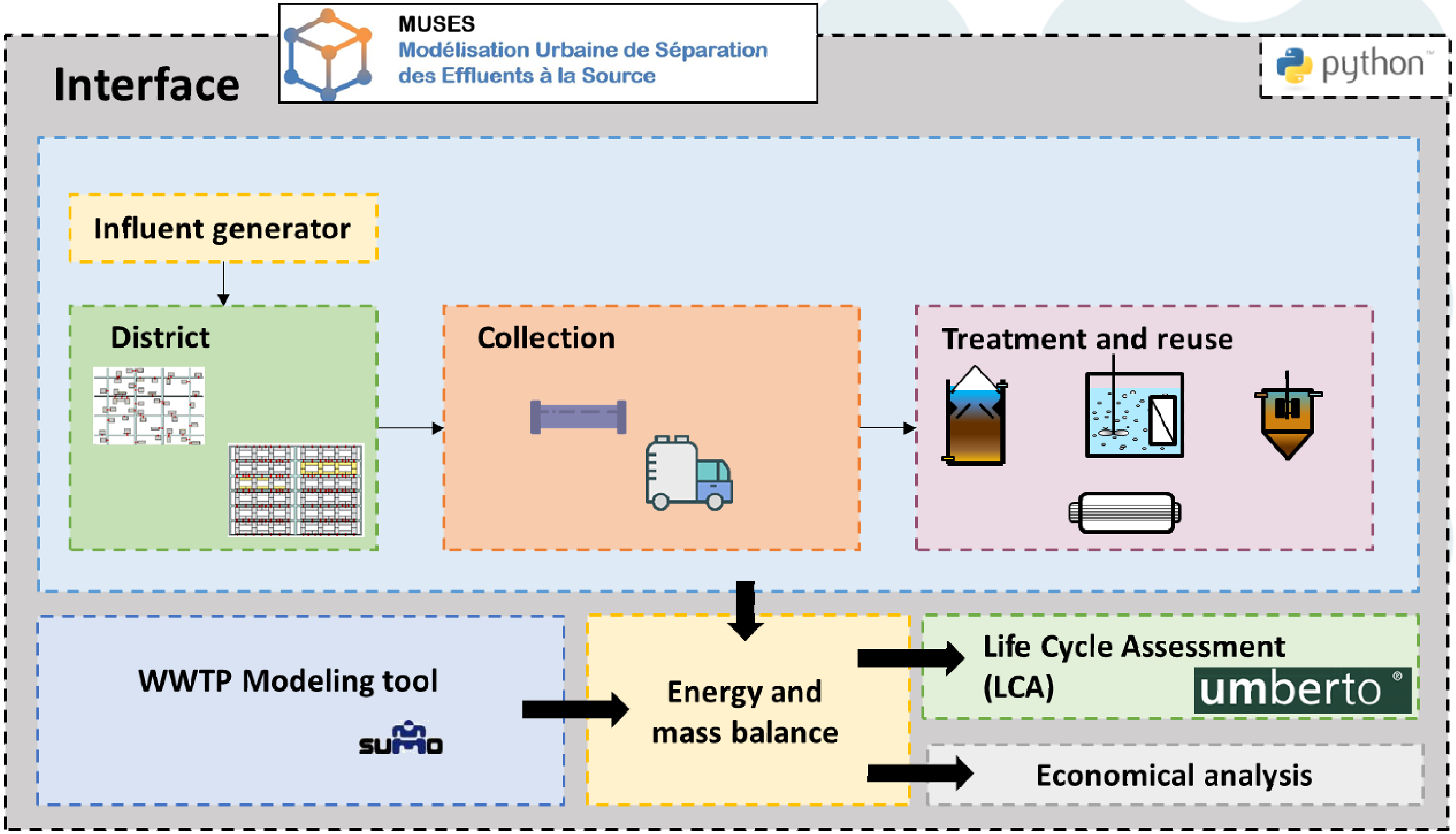


Does urbanism matter ?

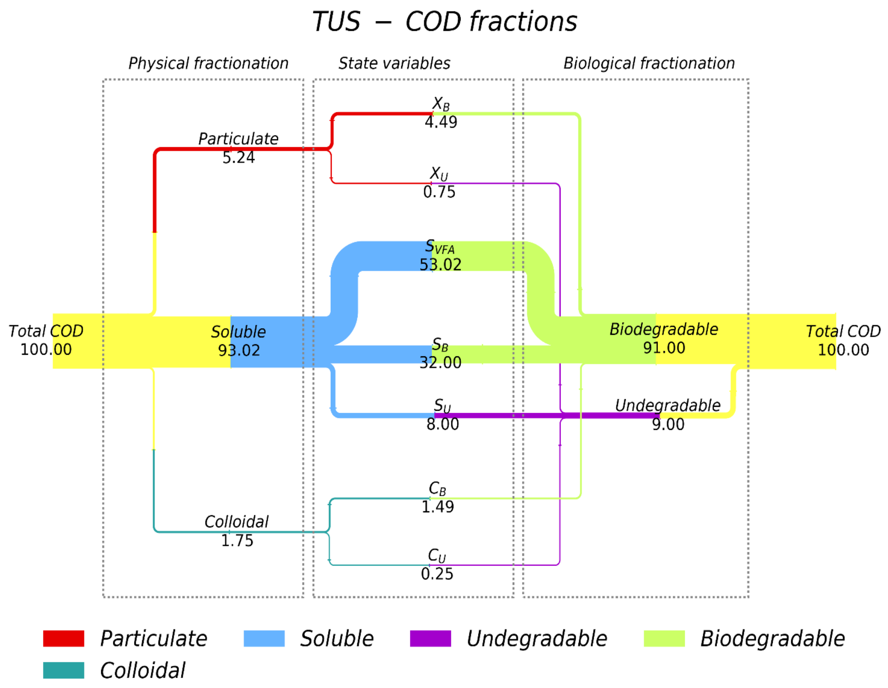


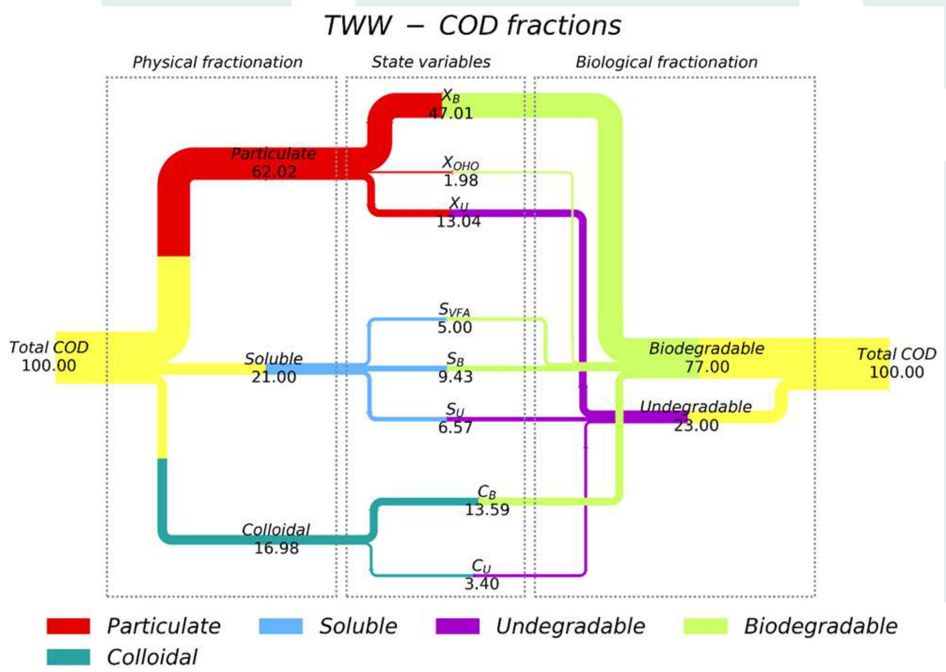



An integrated tool for modelling and evaluation



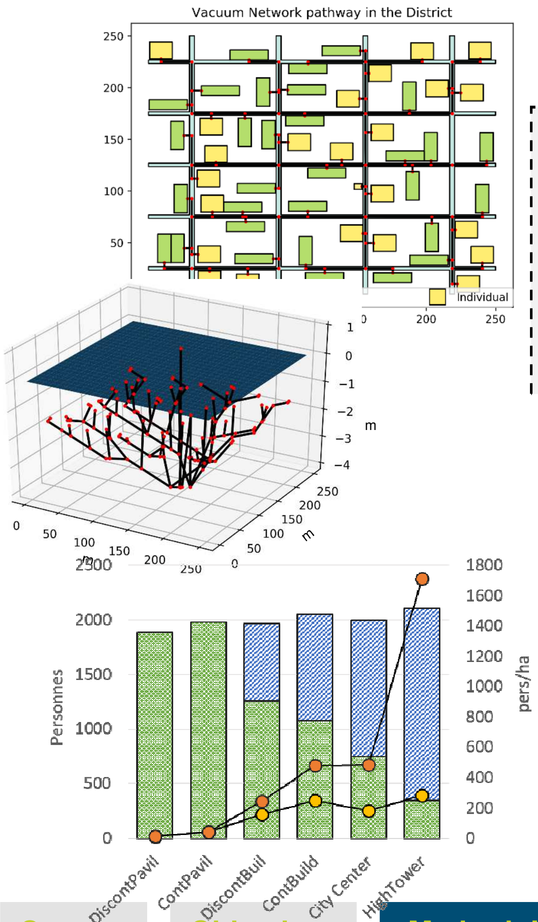
Influent generator

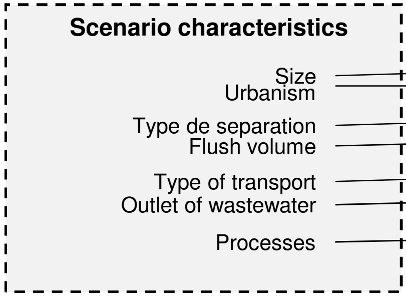


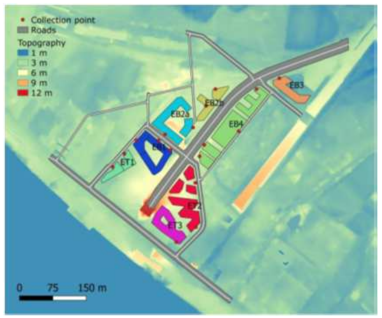


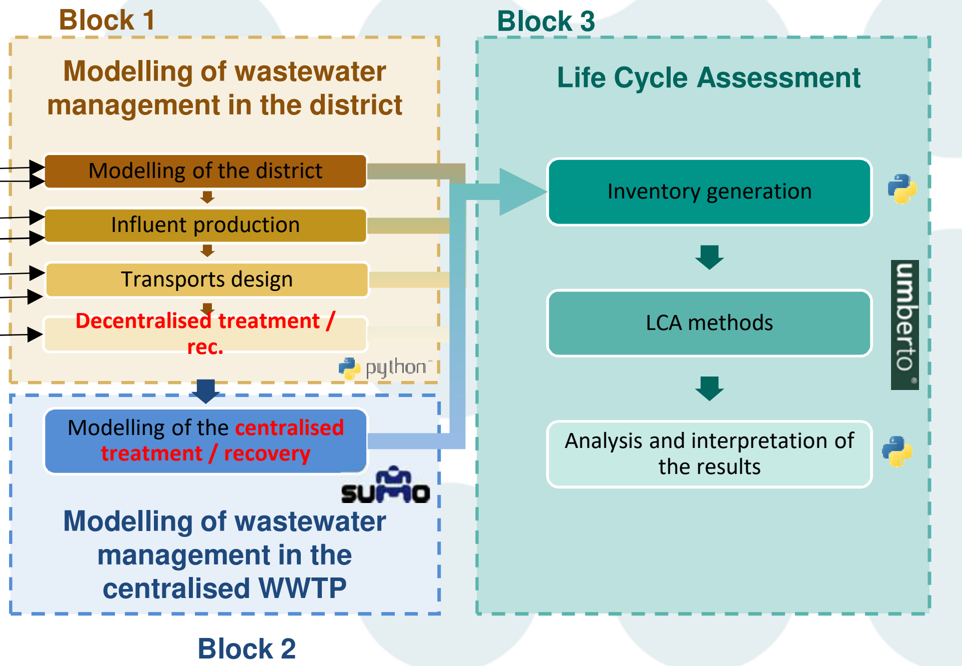
Bisinella de Faria, A.B., Mathilde Besson; Aras Ahmadi; Kai M. Udert, and Mathieu Spérandio. 2020. Dynamic Influent Generator for Alternative Wastewater Management with Urine Source Separation. J. Sustainable Water Built Environ., 6(2)

Influence of urbanism



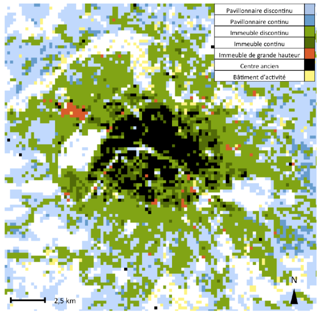


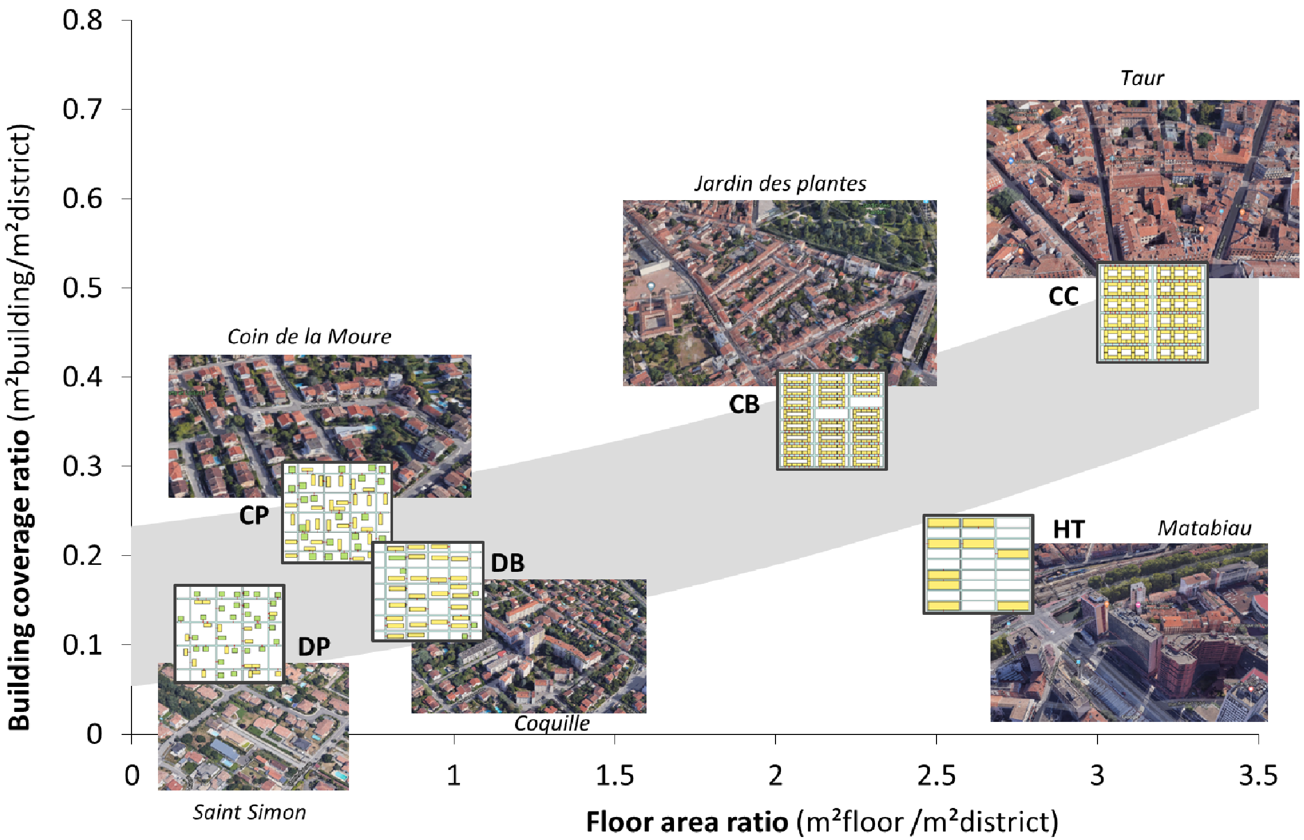




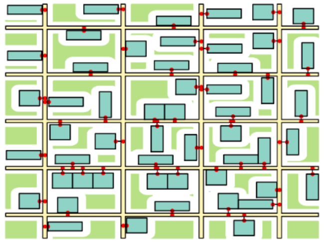
Comparison between districts

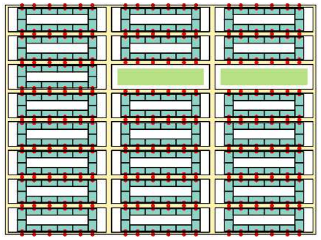
6 Types of urbanism from low to high density

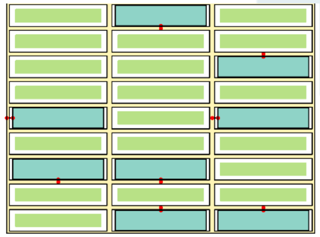




Water reclamation potential (GW) ?? Nutrients (N, P) ??



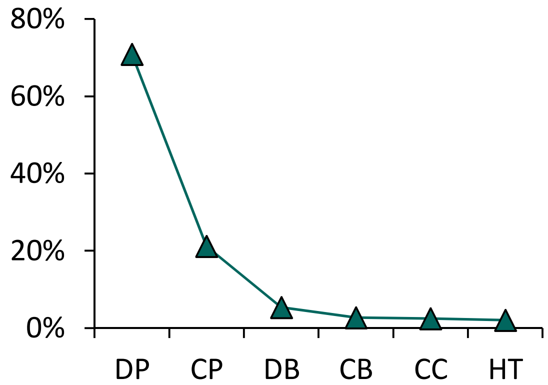




- Planification of actual and future demand
- Vegetal for urban climate regulation ...

Percentage of green area in each urban configurations (Bonhomme, 2013)

	% green area
DP	23 %
CP	18 %
DB	18 %
CB	14 %
CC	10 %
HT	14 %



Recovery rate of greywater as irrigation water at annual basis (for 6 ha district)

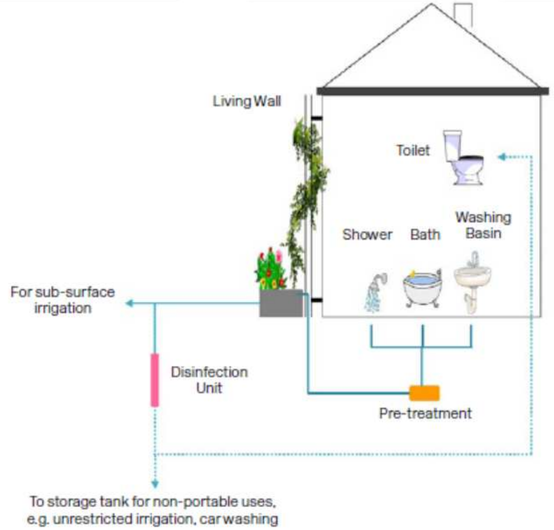
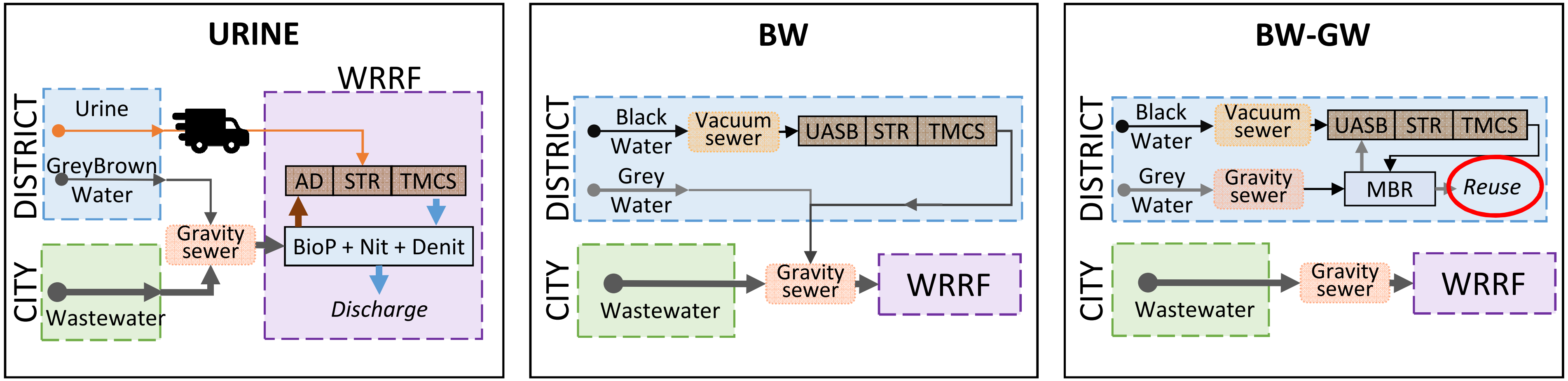


Figure 1.2a Concept of living walls for greywater recycling in domestic premises (adapted from Fowdar et al., 2017)

3 Scenarios : different levels of decentralisation



- **In our scenarios, choice of the technical solution was based on**
  - ✓ technical relevance (minimal TRL 6)
  - ✓ energy consumption
  - ✓ acceptability in dense urban zone

3

Results

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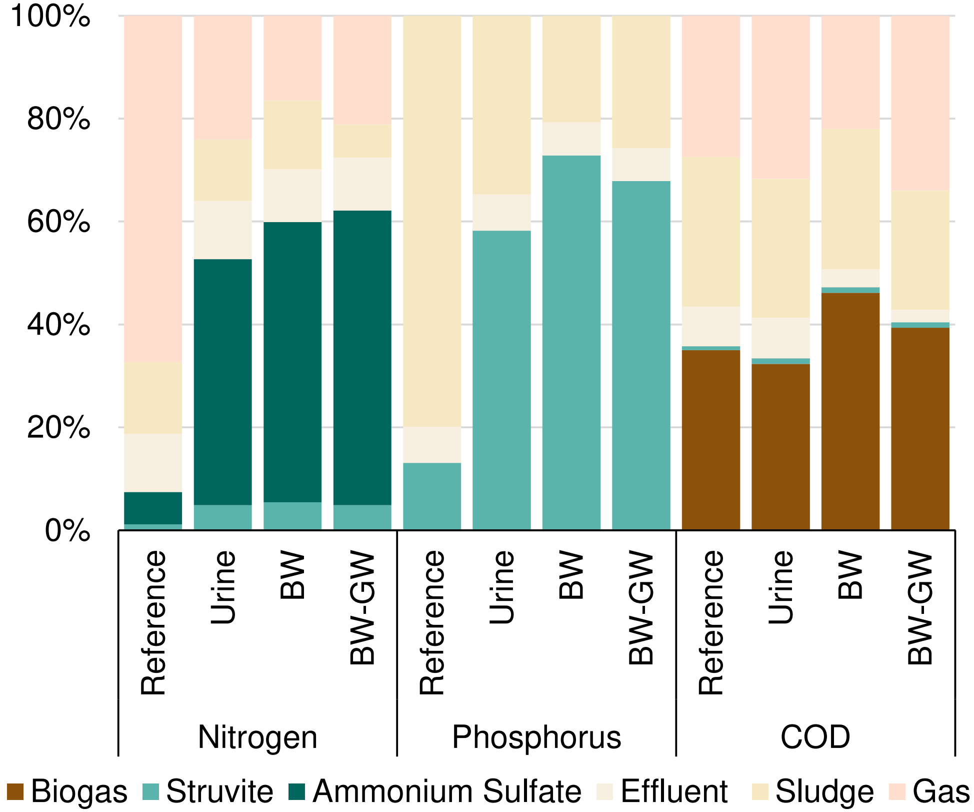
Comparison for one type of district

- **Recovery N, P, COD**

Source separation:
- **N recovery: 7 times higher,**
- **P recovery: 3 times higher**

- Limited impact on COD recovery

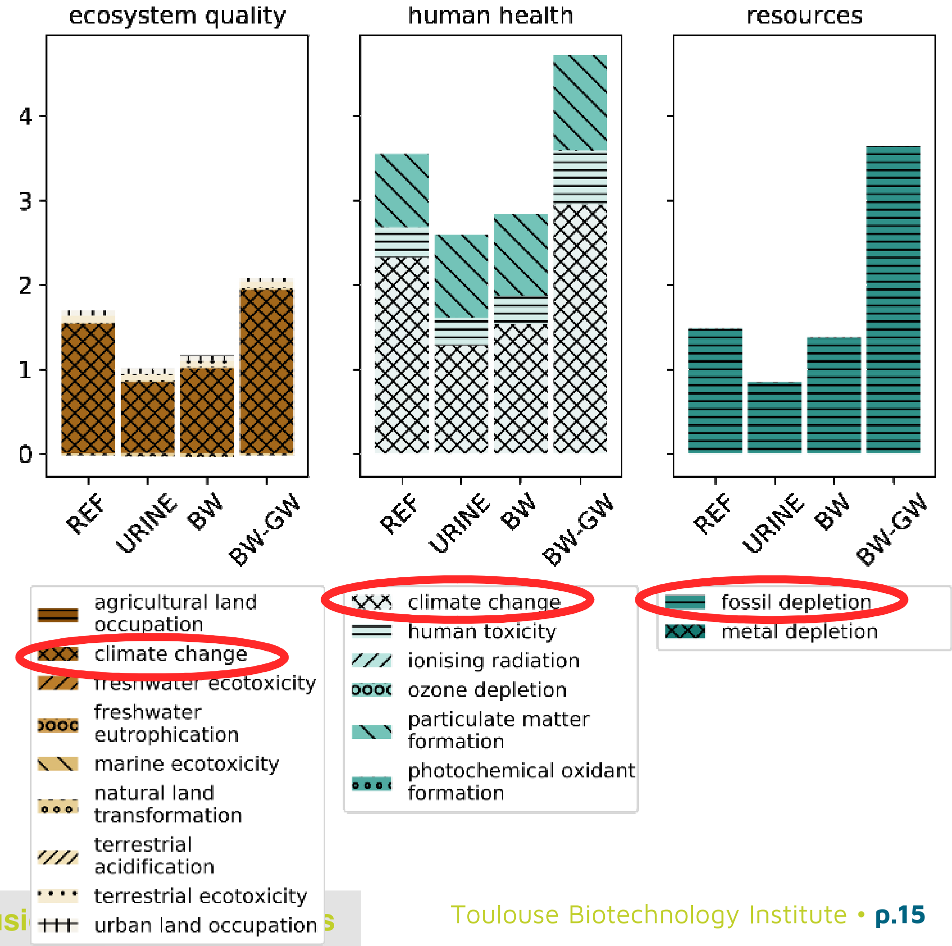


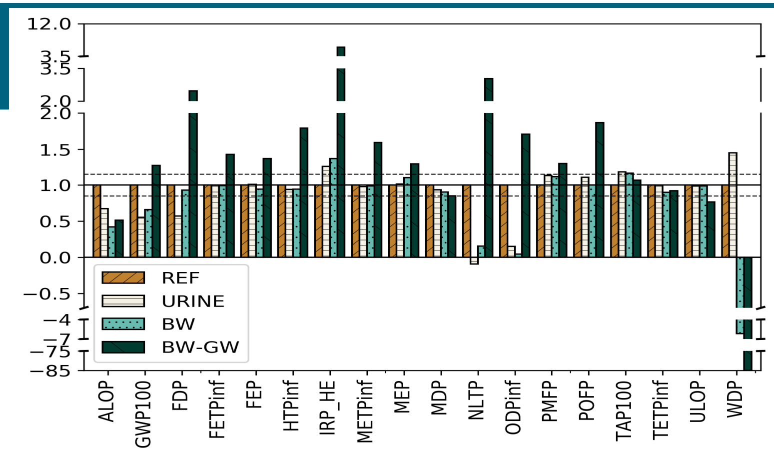
Comparison for one type of district

Life Cycle assessment
Endpoint Method (ReCiPe)

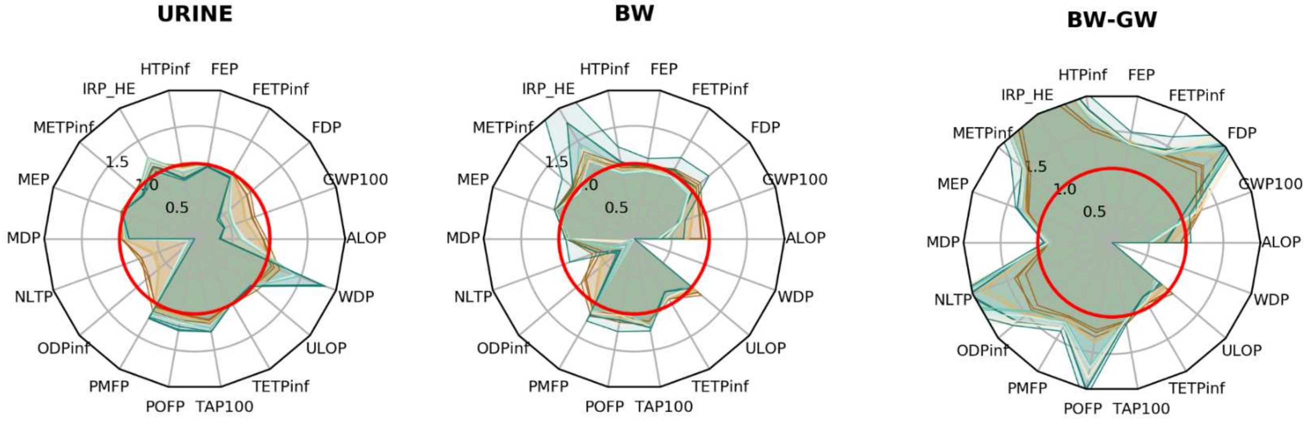
Urine and BW: less damage / ref
BW-GW: more damage / ref

Climate change is the main contributor to damage (Endpoint impact)





Ratio of midpoint impact (Alternative/Reference) for each case study



ALOP: agricultural land occupation (m2a)
GWP100: climate change (kg CO2-Eq)
FDP: fossil depletion (kg oil-Eq)
FETPinf: freshwater ecotoxicity (kg 1,4-DCB-Eq)
FEP: freshwater eutrophication (kg P-Eq)
HTPinf: human toxicity (kg 1,4-DCB-Eq)
IRP_HE: ionising radiation (kg U235-Eq)
METPinf: marine ecotoxicity (kg 1,4-DCB-Eq)
MEP: marine eutrophication (kg N-Eq)
MDP: metal depletion (kg Fe-Eq)
NLTP: natural land transformation (m2)
ODPinf: ozone depletion (kg CFC-11-Eq)
PMFP: particulate matter formation (kg PM10-Eq)
POFP: photochemical oxidant formation (kg NMVOC)
TAP100: terrestrial acidification (kg SO2-Eq)
TETPinf: terrestrial ecotoxicity (kg 1,4-DCB-Eq)
ULOP: urban land occupation (m2a)
WDP: water depletion (m3)

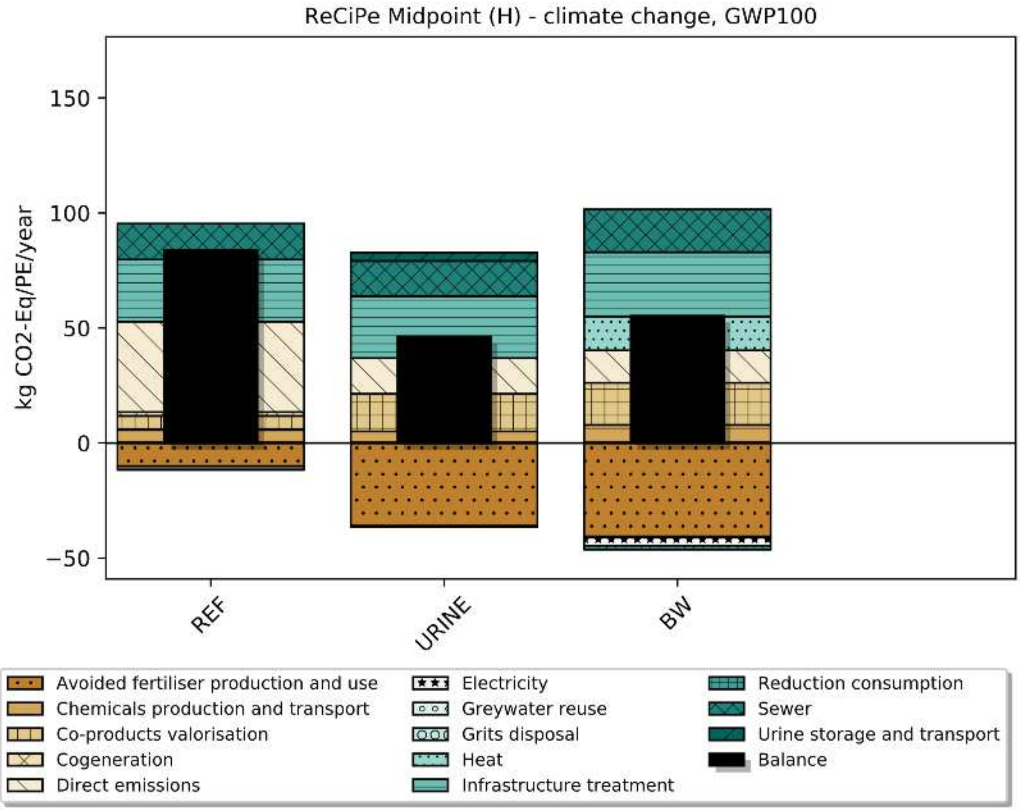
1. Comparison for one type of district

Climate change impact

Main contributor at Endpoint method

Major impact due to Nitrogen :

- **Benefit of N fertilizer substitution**
- **Decrease of N_2O emissions**



1. Comparison for one type of district

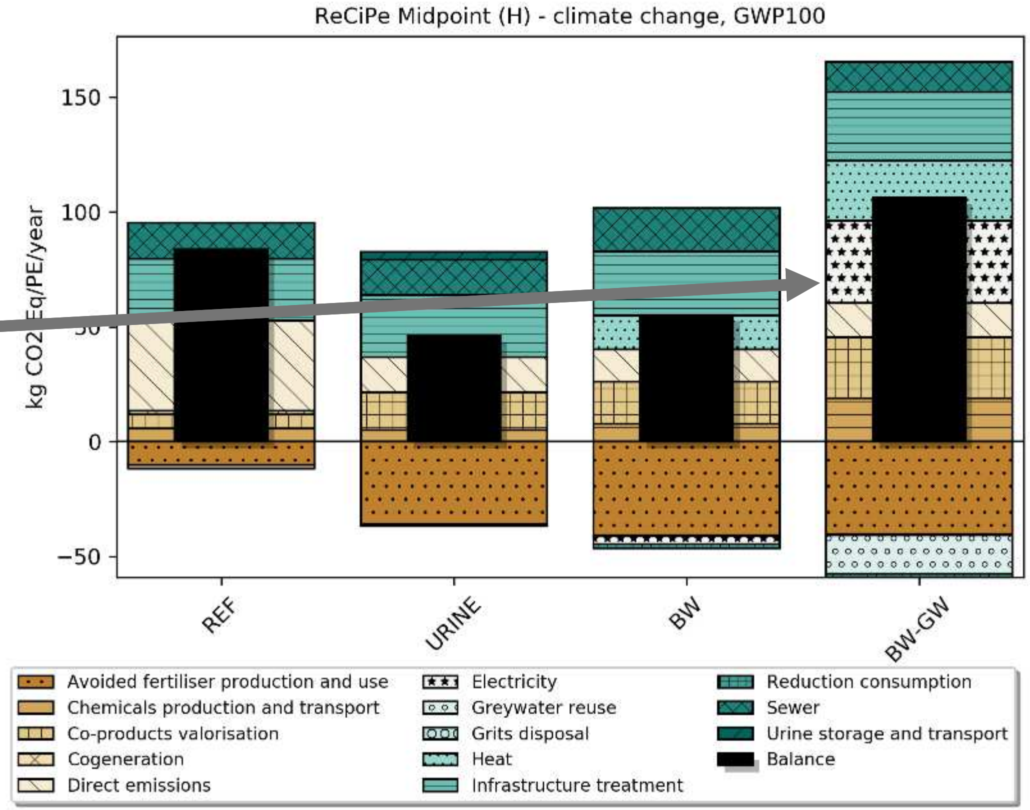
Climate change impact

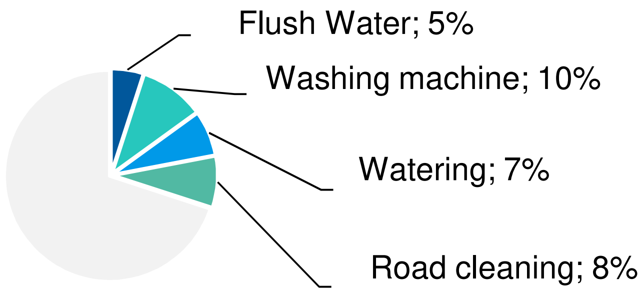
(kgCO_2eq/year/PE)

Midpoint Method (ReCiPe, H)

Membrane bioreactor: 1.5 kWh/m^3
(but from 0.4 to 8 kWh/m^3)

-> Need Natural Based Systems ?

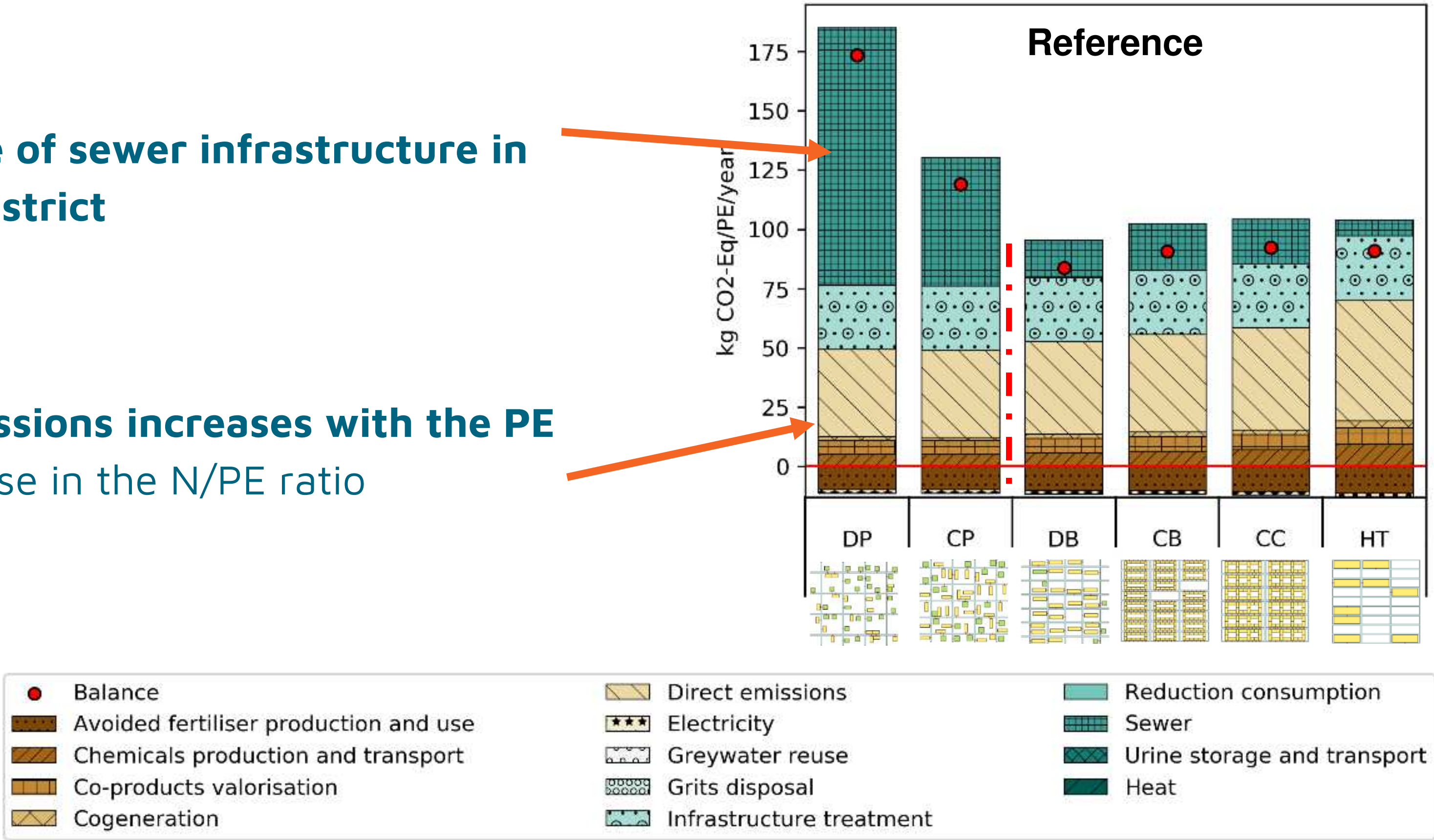




2. Comparison between districts

- **Strong influence of sewer infrastructure in the low dense district**

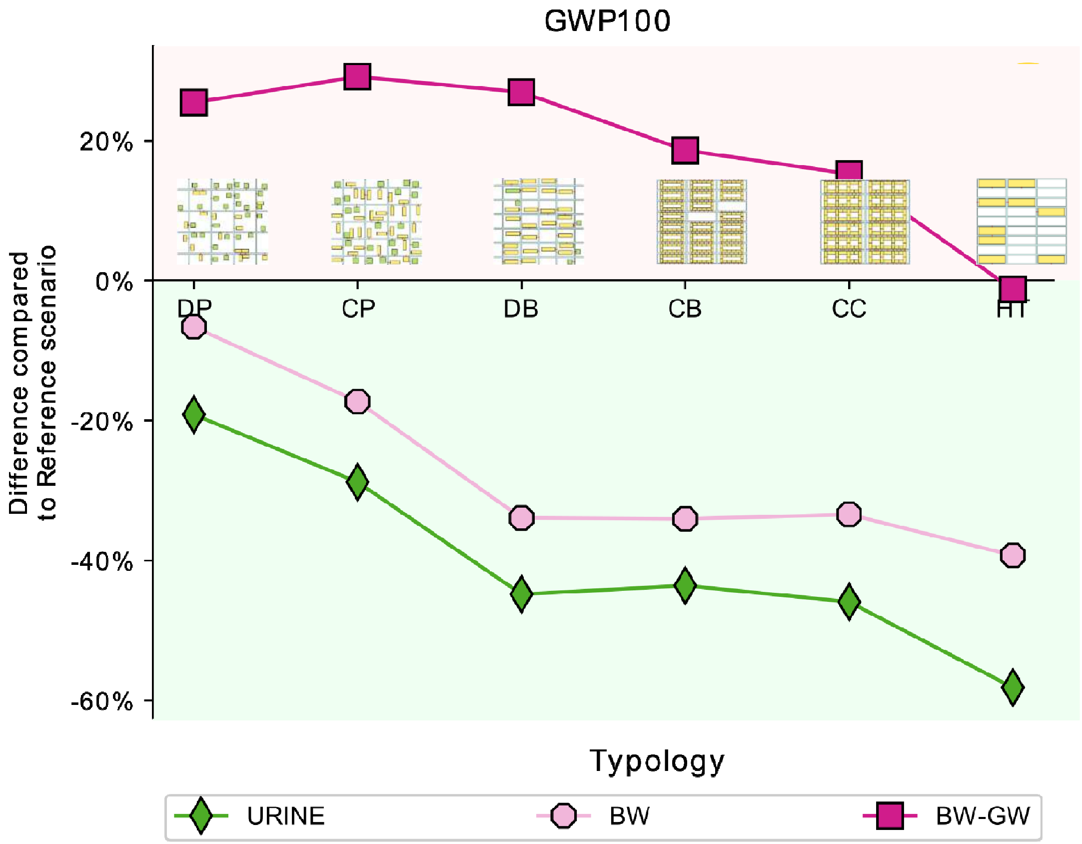
- **The direct emissions increases with the PE density,** increase in the N/PE ratio



2. Comparison between districts

Comparison with the reference scenario for climate change

- **BW-GW Scenario**
  - More than 20% of degradation for the small density
  - Similar balance than Reference for high tower district
- **Urine and BW scenarios**
  - less than 20% of improvement (transport,
  - For the other districts more than 30% of improvement



5

Conclusions and Perspectives

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Conclusions

- **Source separation (urine, black water) can significantly decrease environmental impacts (GHG) but scenarios and technologies matter**
- **Greywater reuse can be negative for climate change. Energy and size matter (decentralisation level)**
- **Urbanisms matters !**
- **Need for: Case studies, extending the focus (NBS, greywater and rainwater) and criteria**