



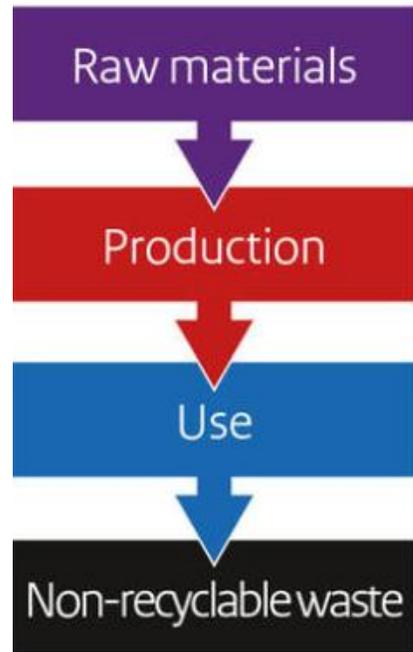
# Circular economy of water from buildings to wastewater treatment plants

Julien Le Roux & Régis Moilleron

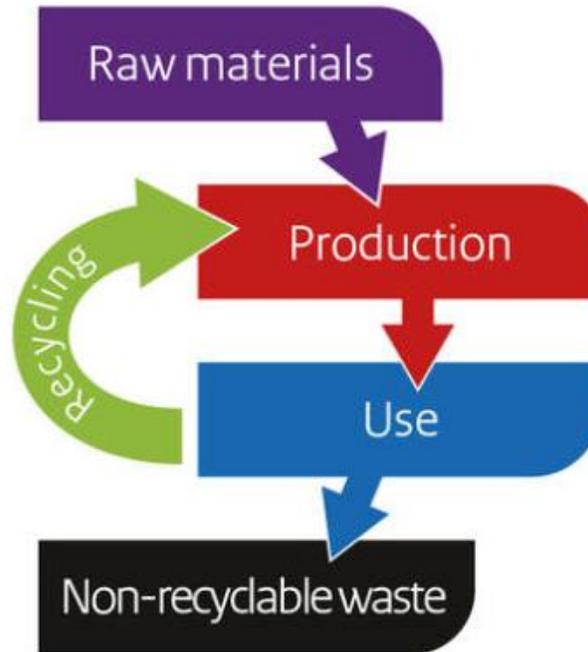


# From linear economy to circular economy

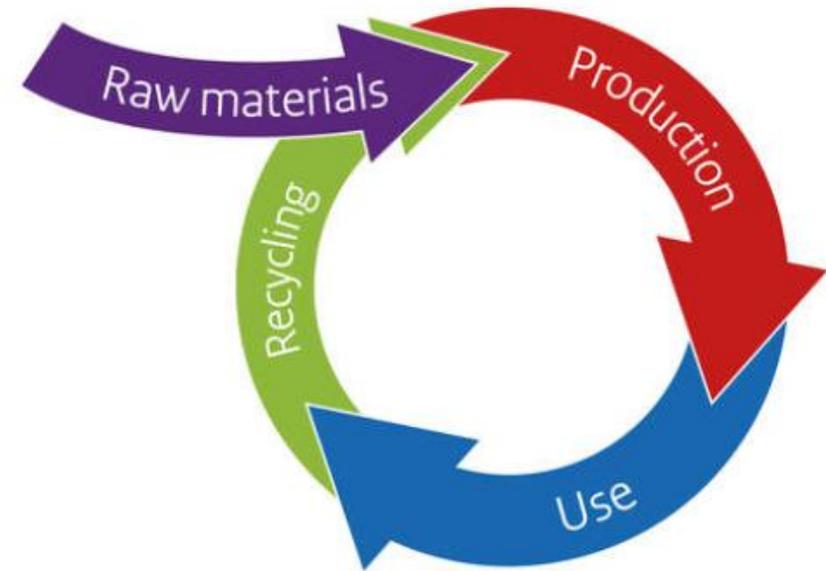
## *Linear* Economy



## *Reuse* economy



## *Circular* economy

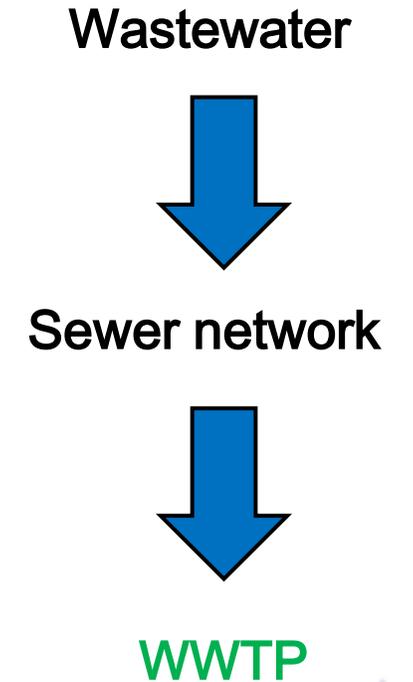
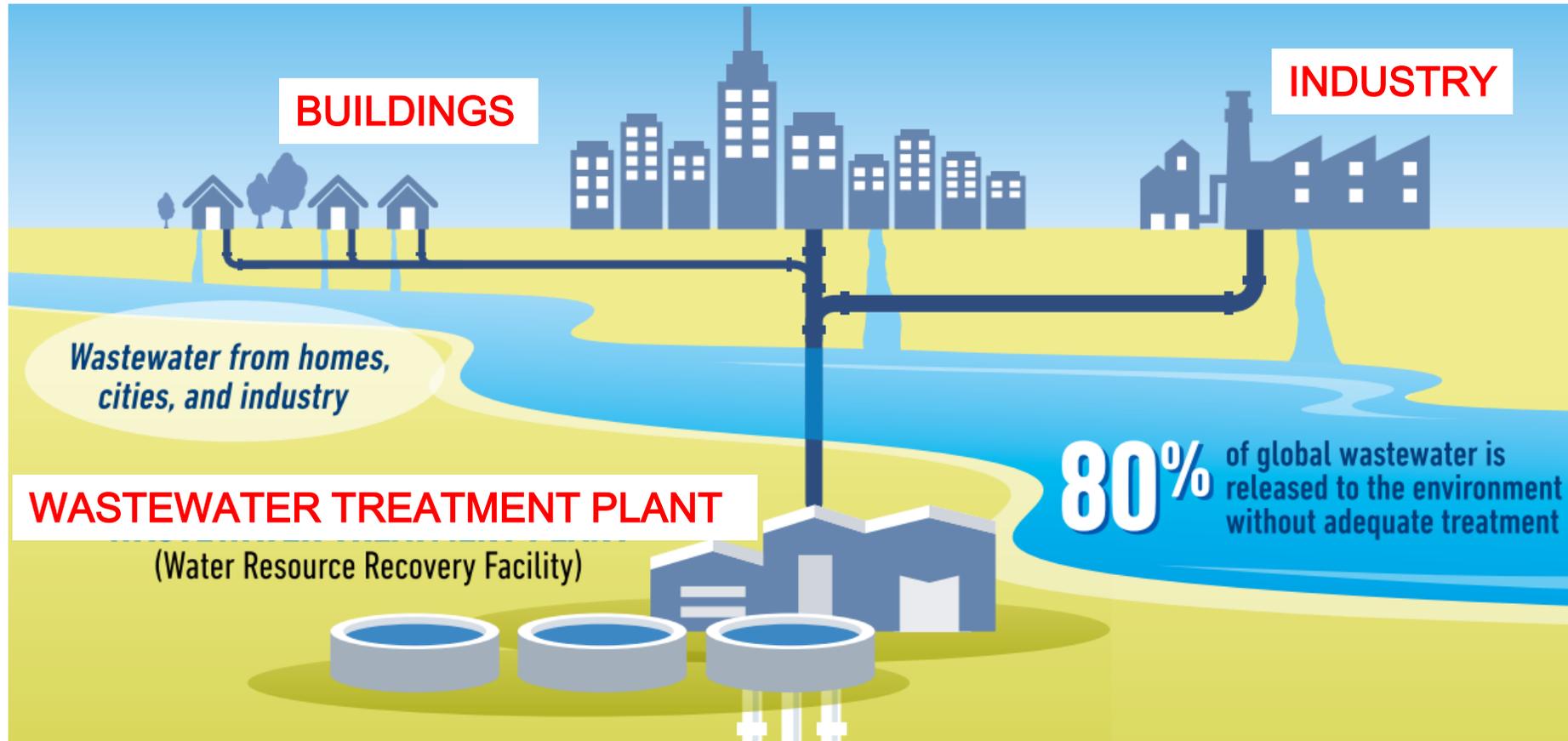


No concern on product's ecological footprint  
Prioritizing profits over sustainability

Reducing waste, promoting reuse and recycling material production

# Implementation of circular economy to wastewater field

## General scheme



# Implementation of circular economy to wastewater field

## General scheme

The **WWTP** becomes **a water resource facility**

- **WATER**

- Nutrient recycling*

- Reduce both fertilizers demand & consumption of water and energy.

- Water reuse*

- Agriculture and land irrigation, toilet flushing, groundwater replenishing

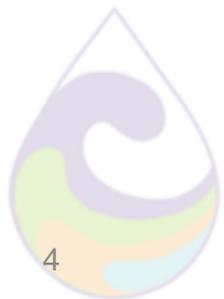
- **SLUDGE**

- Biosolids*

- Phosphorous recycling (struvite precipitation)

- Energy recovery*

- Biogas production from anaerobic digestion



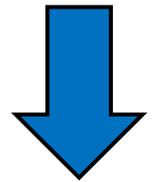
# Implementation of circular economy to wastewater field

## *Alternative scheme*

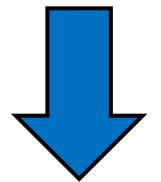
Circular approaches can be implemented at different levels:

- *Dwellings*
  - Energy recovery from greywater to produce hot water → energy savings
- *Buildings*
  - Energy recovery from greywater to produce hot water → energy savings
  - Reuse of greywater after phytoremediation for toilet flushing → water savings
    - Phyte'up project*
  - Separation at source of urine → nutrients recovery,
    - OCAPI project*
- *Sewer network*
  - Energy savings for public facilities (swimming pools, gyms, offices...)
- *Wastewater treatment plant*

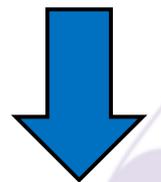
Dwellings



Buildings



Sewer network

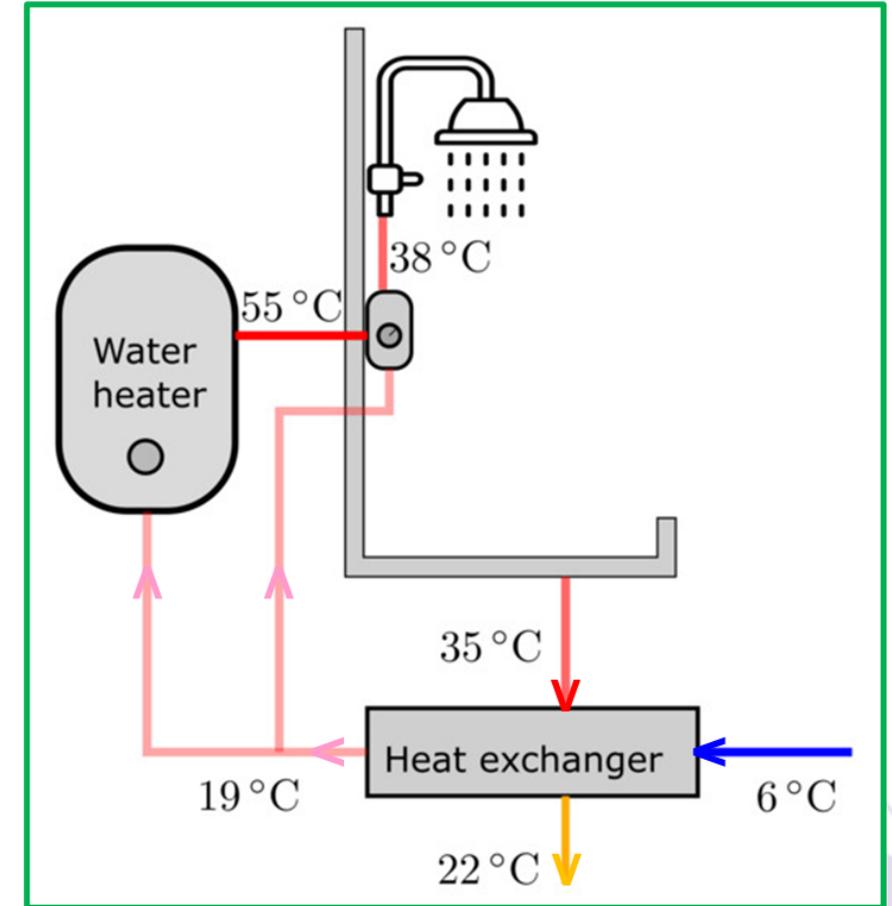
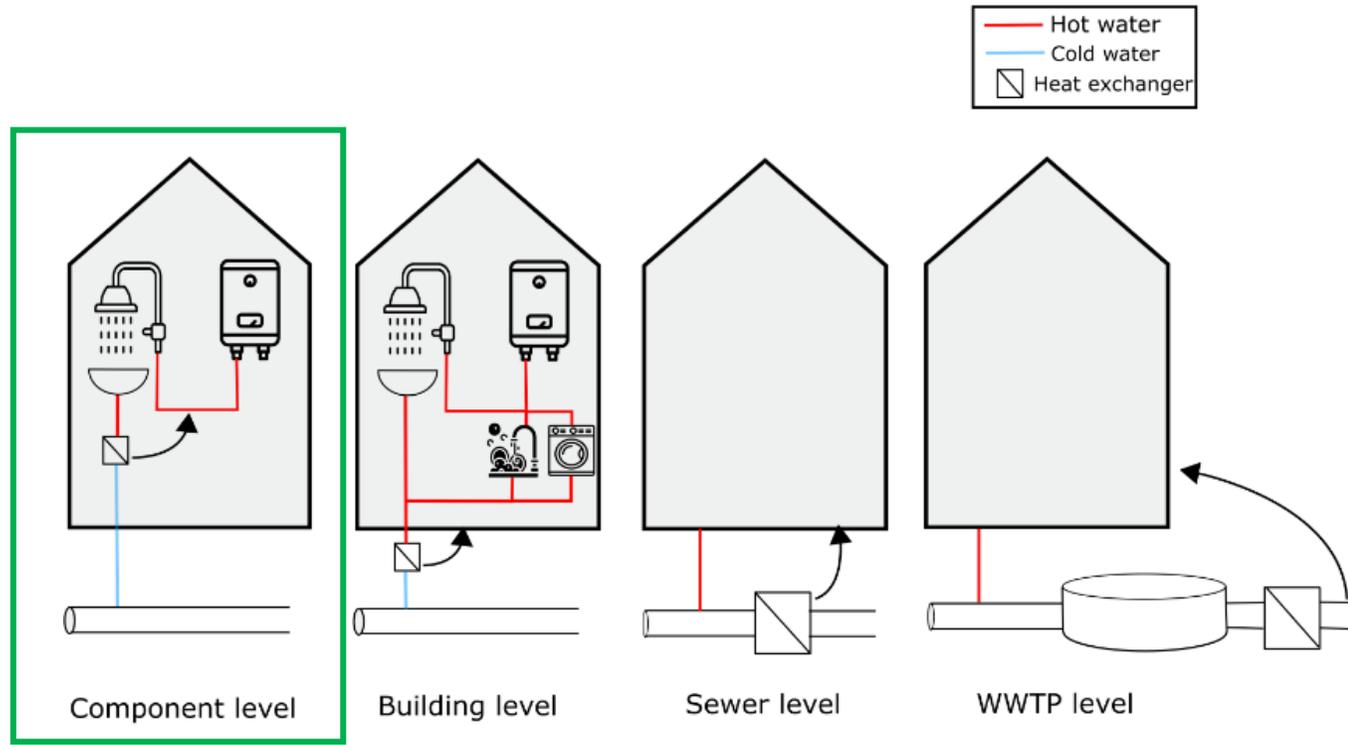


WWTP

# Implementation of circular economy to wastewater field

## *Alternative scheme*

Heat recovery at different scales

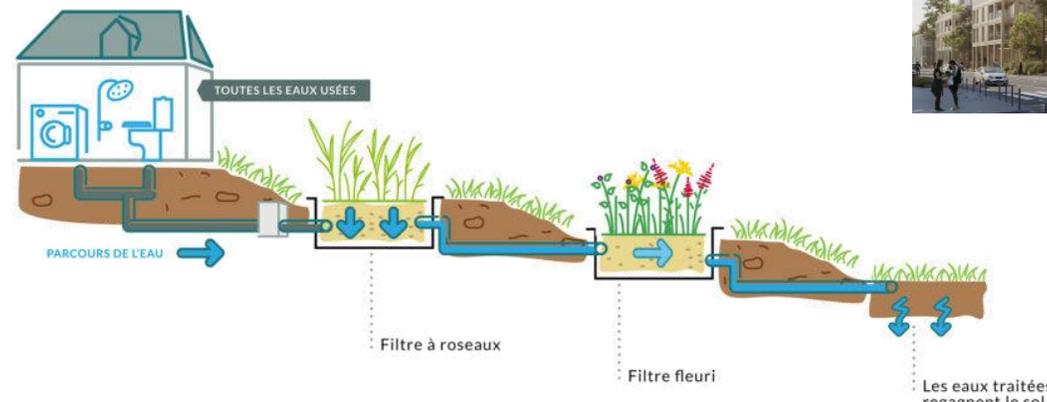


*The shower component*

# Building level - Phyte'up project

## *General principle*

- Reuse of greywater in buildings
  - Heat recovery, toilet flushing, greenspace irrigation
  - Restrictive regulations... evolving
    - Main obstacle: what quality(s) for what use(s)?
- Adaptation of the principle of phytoremediation in a context of reduced or even non-existing land availability...
  - Transfer to roof: constraints?
  - How to reproduce the filtration processes?



# Building level - Phyte'up project



## *Rooftop phytoremediation*

- Environmental benefits
  - Cooling in summer and warming in winter by 1 to 3°C
  - Increase of biodiversity
- Benefits for users
  - Reduction in water consumption (20% minimum - 32%)
  - Reduction in the volume of water returned to the sanitation network
  - Awareness of the impact of everyday practices on the quality of gray water

## *Demonstrators under construction*

Collective housing  
for social landlord

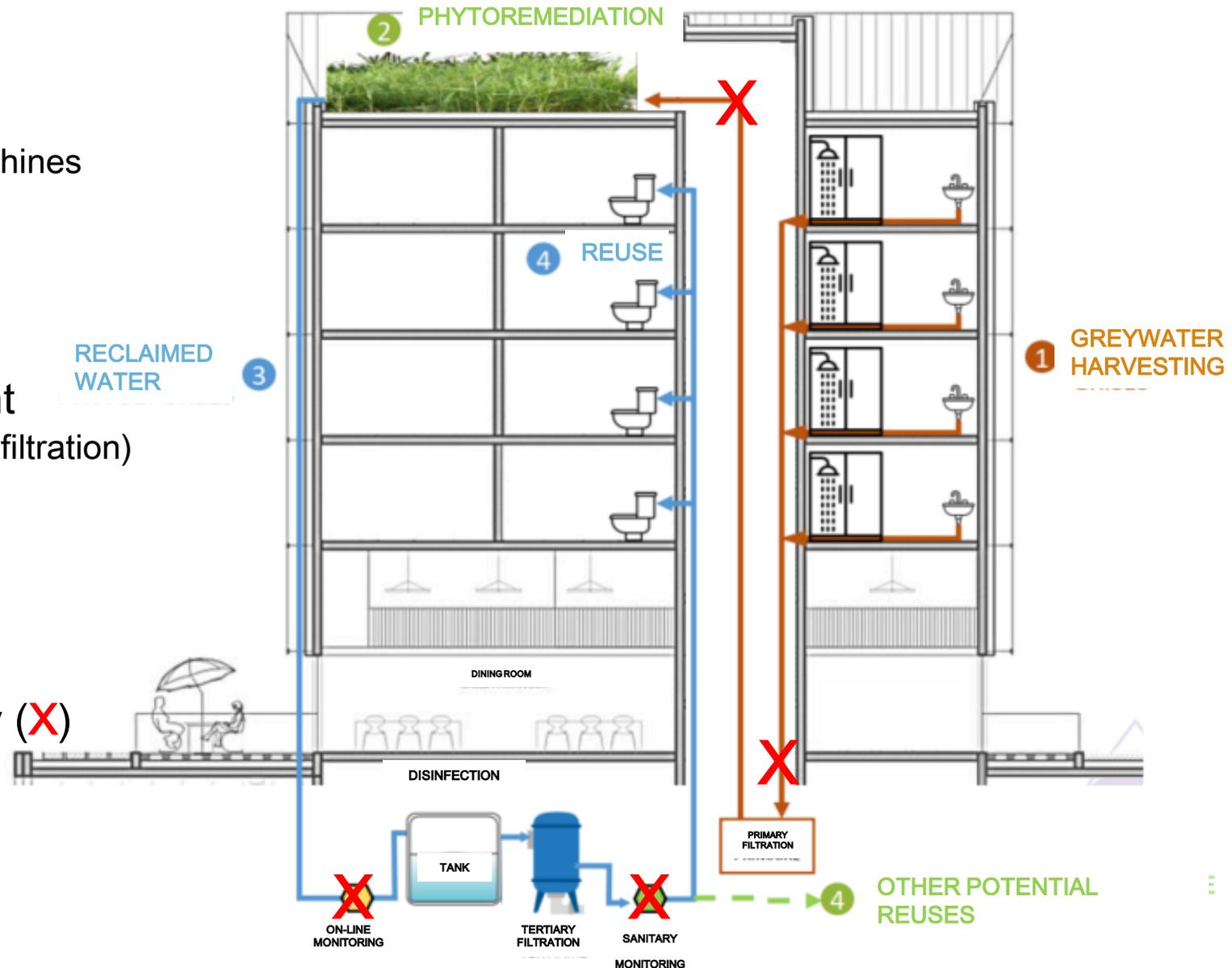


# Building level - Phyte'up project



## Demonstrator principles

1. Greywater harvesting
  - From showers & washing machines
  - *Pre-treatment* (filtration)
2. Phytoremediation
3. Reclaimed water treatment
  - *Post-treatment* (disinfection & filtration)
4. Reuse within buildings
  - Toilet flushing
  - Greenspace irrigation
5. Monitoring of water quality (X)
  - Raw greywater
  - Reclaimed water
  - Disinfected water

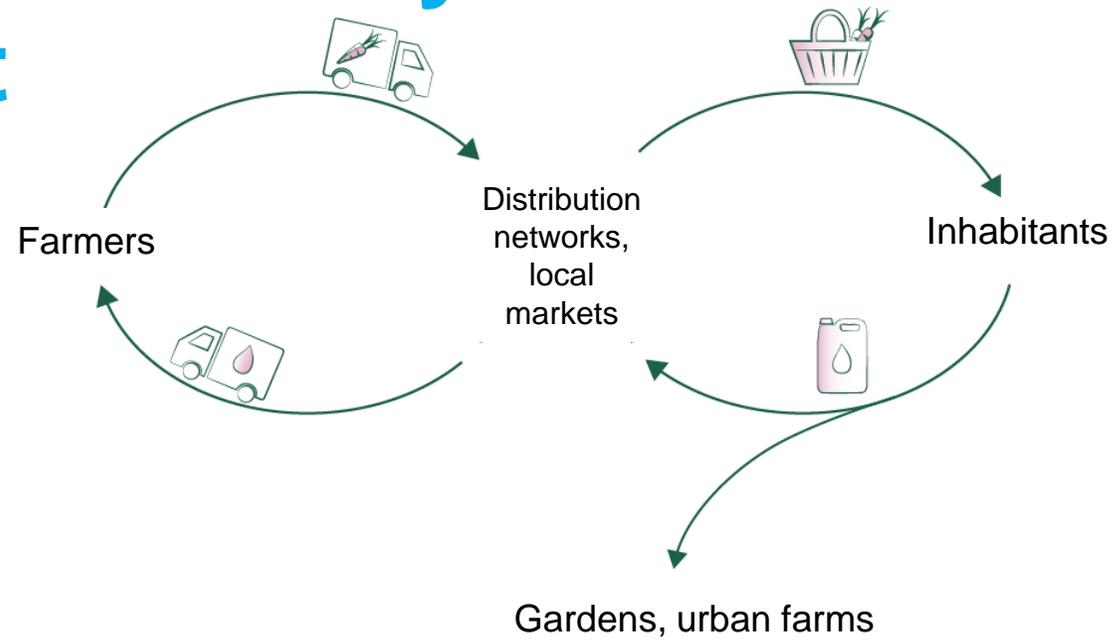


# Building level - and beyond : OCAPI project



**OCAPI**

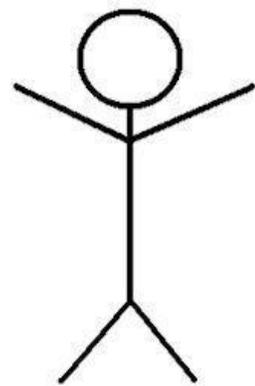
[www.leesu.fr/ocapi](http://www.leesu.fr/ocapi)



Yearly needs



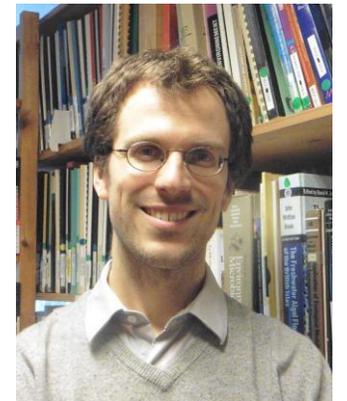
4,6 kg of N  
(proteins)



4 kg of N  
(urea)

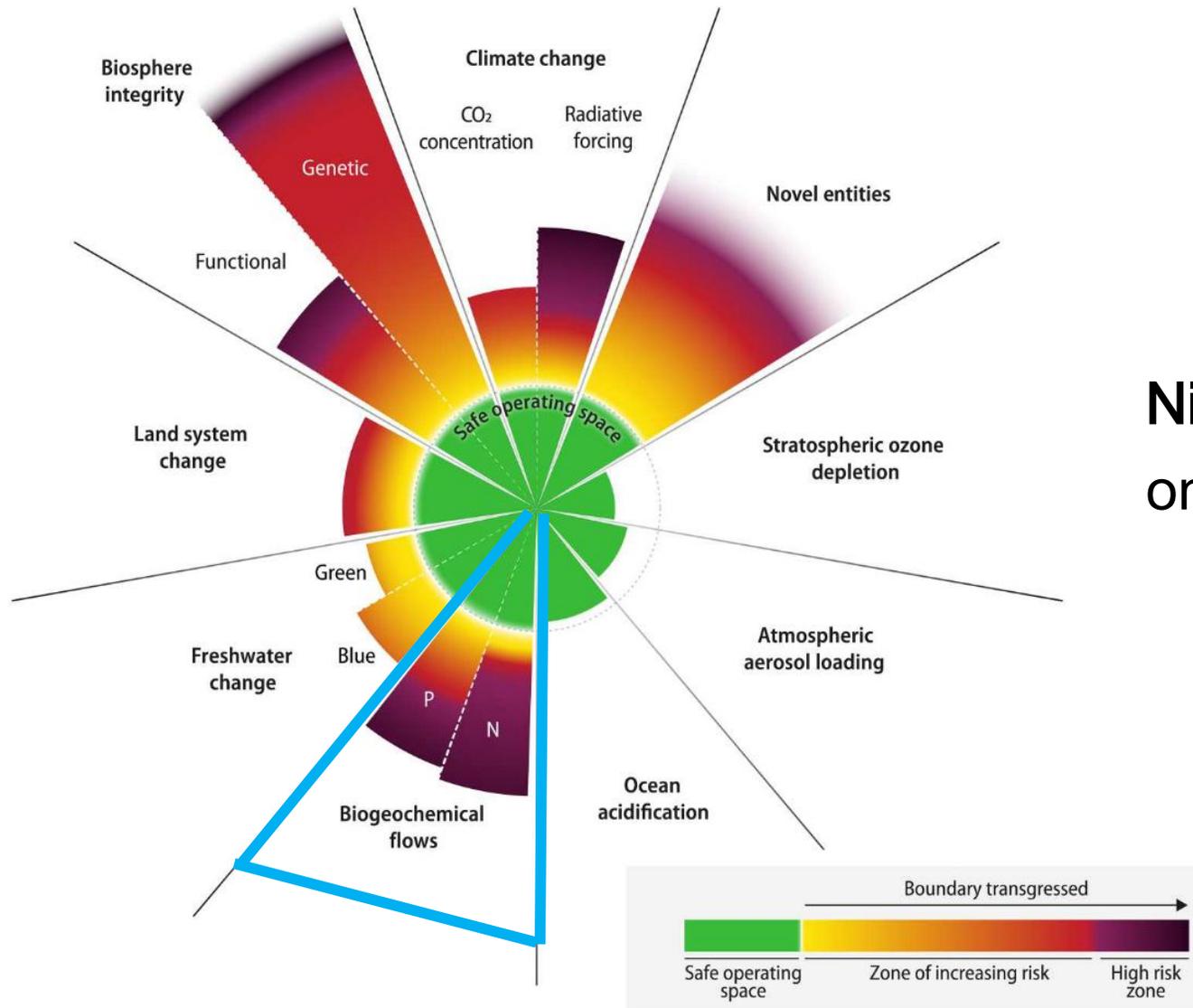


0,6 kg de N



Fabien Esculier:  
PhD thesis in 2018  
Researcher at Leesu

# Planetary boundaries



**Nitrogen and phosphorus cycles:**  
one of the six transgressed boundaries



# The nitrogen path to our plates

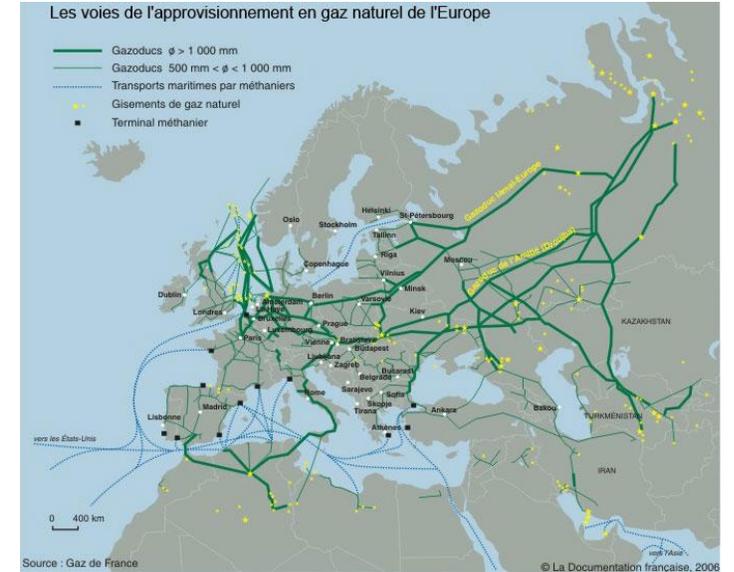


→  
 $N_2$

Haber-Bosch process



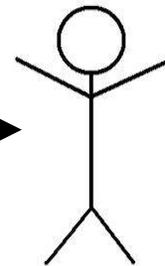
←  
Methane  
(natural gas)



Chemical fertilizers ↓



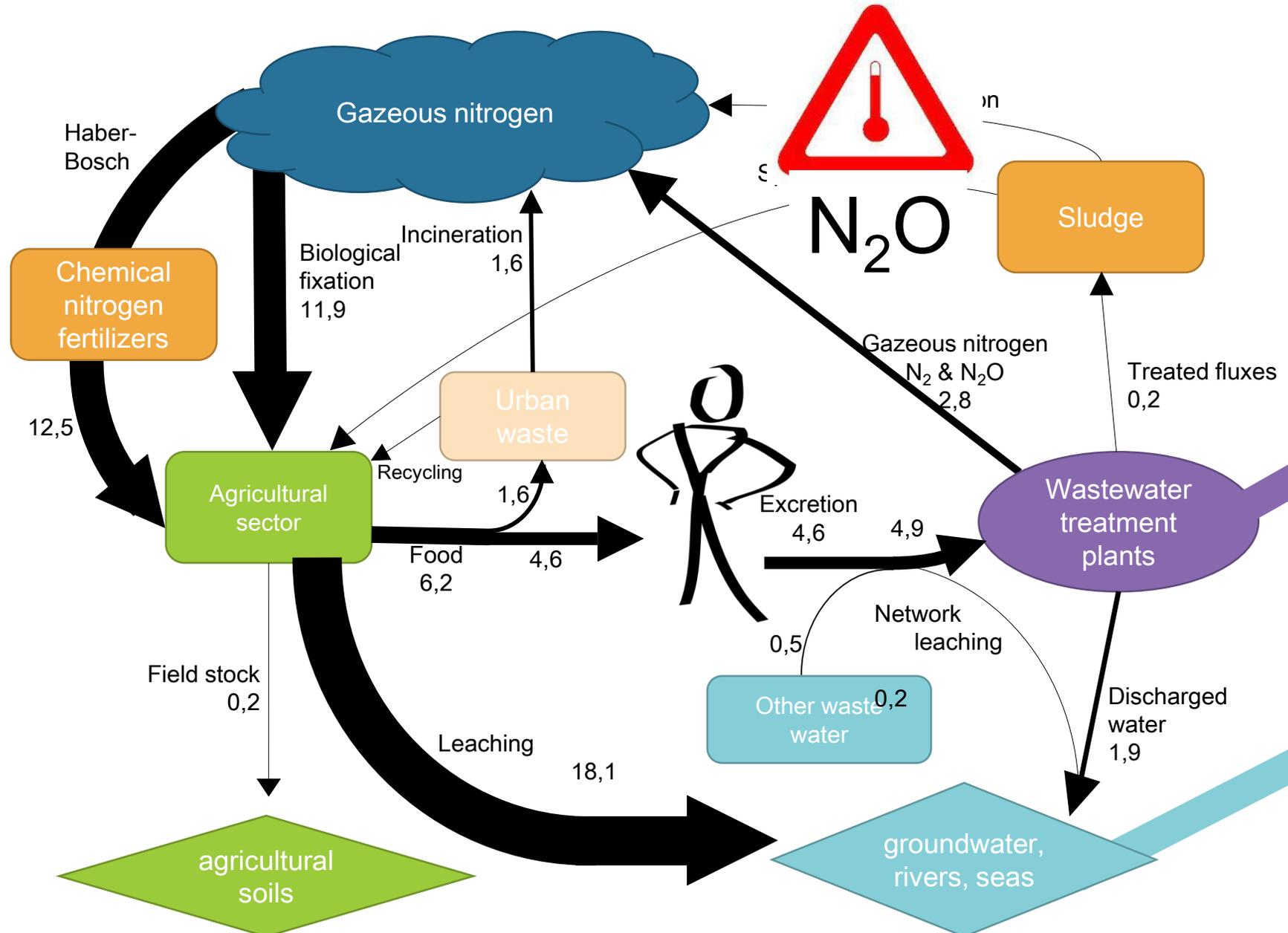
20-50 kg N



5 kg N



# A crazy nitrogen cycle? (kgN/year/inhab)



**eutrophication**

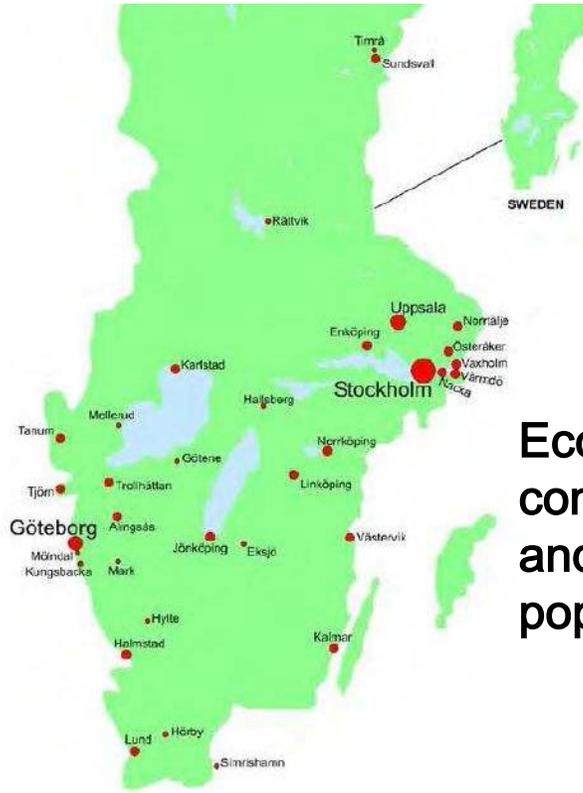
The collage illustrates the environmental impact of nitrogen. The top photo shows a river with a thick green algal bloom. The middle heatmap shows high nitrogen loads (red/orange) in Western Europe. The bottom photo shows a tractor clearing debris on a beach, likely related to coastal management.

# A few examples: Sweden, since 1990



2006 : (Vinneras, 2013)

- 120.000 dry toilets with urine separation
- 15.000 water-closets with urine separation



**Eco-villages with  
committed residents  
and a low density of  
population**

(1995-2006)



# Switzerland: EAWAG since 1996



Nitrification + distillation



Aurin (authorized for agriculture in Switzerland)



# Netherlands



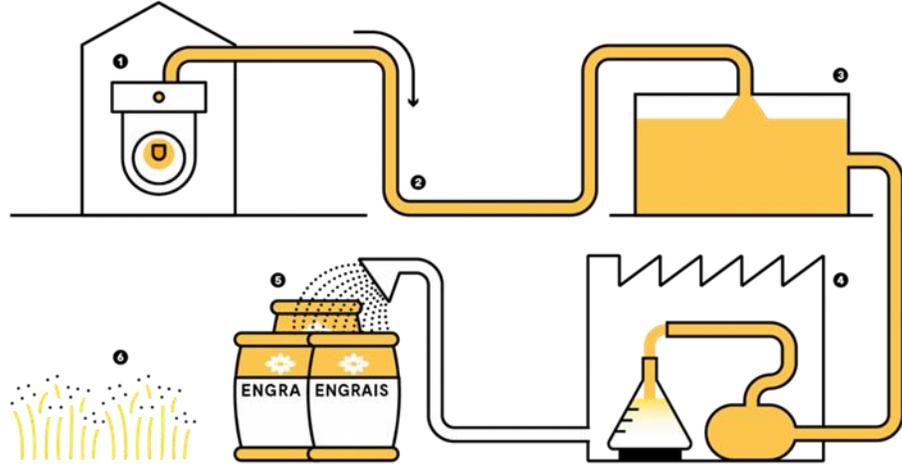
Ammonium sulfate and struvite  
synthesis from urine (Saniphos)



# France



P&Ma



47 000 L/y:  
Used for green  
spaces in Paris



Saint-Vincent-de-Paul neighborhood - Paris  
2018-2020 then 2024: 1<sup>st</sup> project for whole  
neighborhood (600 dwellings)  
with urine diversion



# Paris-Saclay - Urinagri project



Valorisation agricole des urines humaines

Essais en cours sur le Plateau de Saclay



Saclay, Ferme de la Martinière (Avril 2022)



# Experimental building with urine separation



- 18-20 m<sup>3</sup> / year
- Spreading on 1 ha
  - 6 story building
  - 10 men's urinals
  - intermediate storage tank
  - Nitrification filter (Pitribon)
  - Activated carbon filter
  - Final storage
  - Spreading twice a year





2022: first study with **wheat** to know the efficiency of urine fertilizer

2023: **corn** field study to determine the impact on productivity (Trou Salé farm / Julien Thierry)

Med-UrinAgri Project started in 2023: wheat and determine accumulation of **pharmaceuticals in soil**

- Four tests:
  - Reference (no nitrogen)
  - Non-treated urine
  - Treated urine
  - Aurin (treated)
- Target screening analyses (INRAE)
- Non-target screening (LEESU)



# Conclusion: new paradigms for water management

- Possibilities of **circularity** in the WWTP
- Potential efficient **solutions** at other scales (at the source, in buildings...)



**BUT**

- **Obstacles:** **regulation** (quality of reclaimed water in buildings must be the same as tap water), **infrastructure in place** difficult to modify (sewer networks)
- **Levers:** integration of new solutions in **sewer networks** (heat exchangers), and in **new buildings** (source separation)

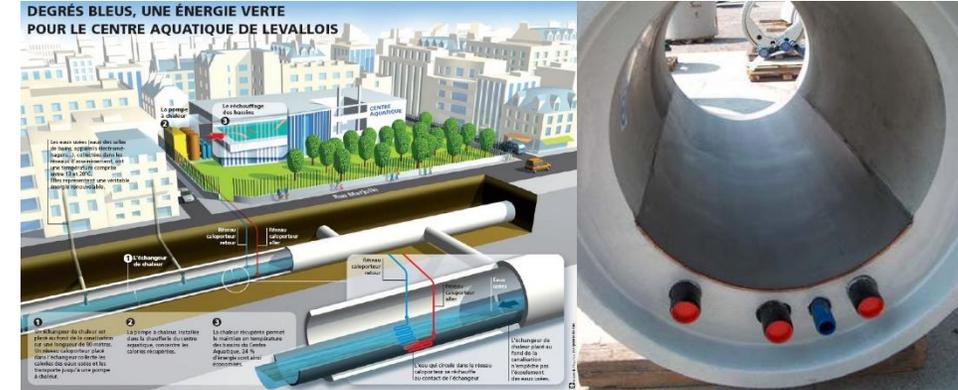


# Conclusion: new paradigms for water management

Make stakeholders aware that other approaches than centralized systems exist and have proven their efficiency

**Citizen acceptance** and involvement is critical!

Combination of **engineering sciences** and **social sciences**



Swimming pool heated with wastewater

Sewer trunk with heat exchanger



# Hvala na pažnji



[www.smartwatertwin.pmf.uns.ac.rs](http://www.smartwatertwin.pmf.uns.ac.rs)

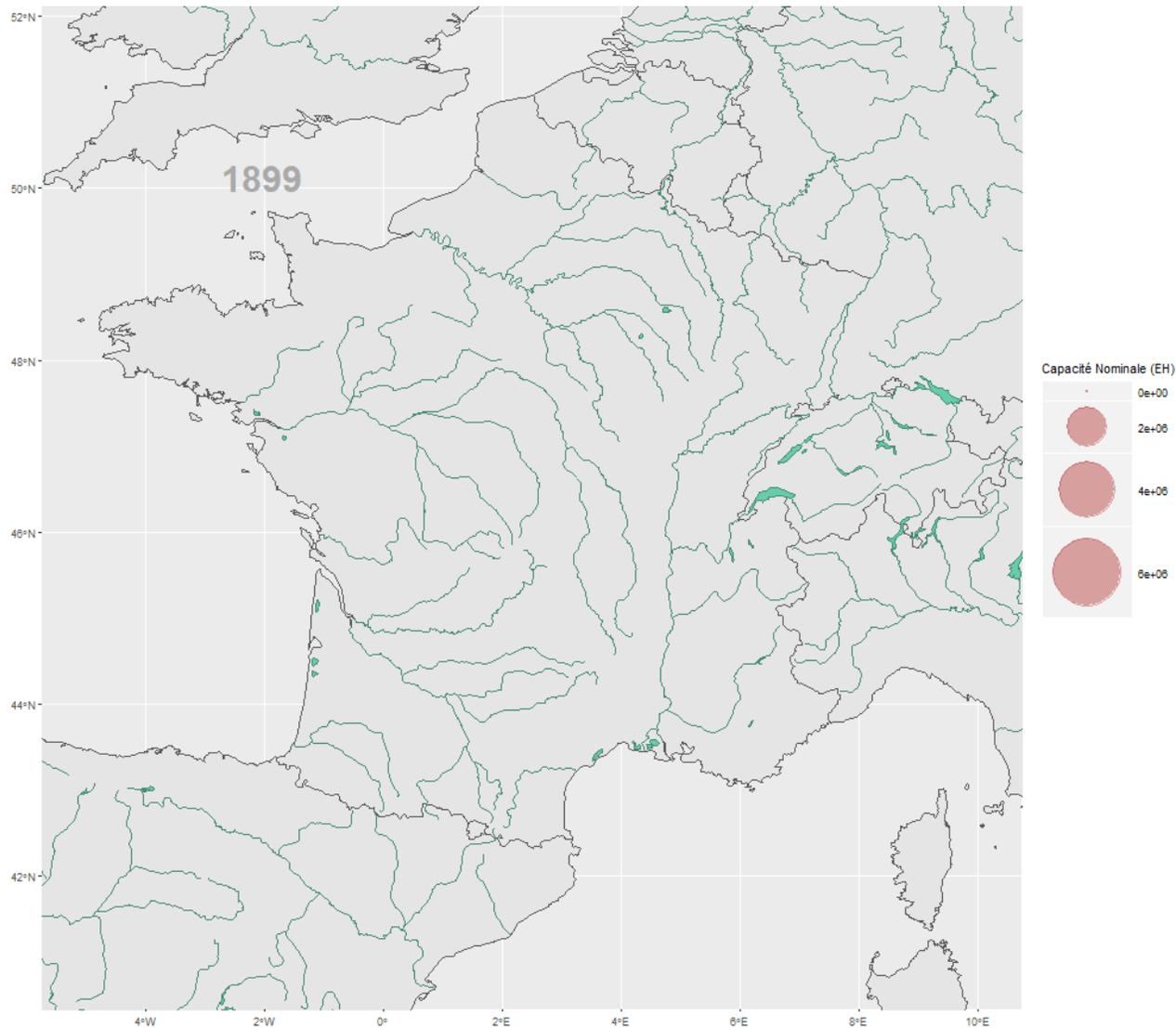


[smartwatertwin@pmf.uns.ac.rs](mailto:smartwatertwin@pmf.uns.ac.rs)



Funded by  
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geo.data.gouv.fr

~ 22 000 WWTPs in France

~ 100 million inh. equivalents

~80% compliance with regulation

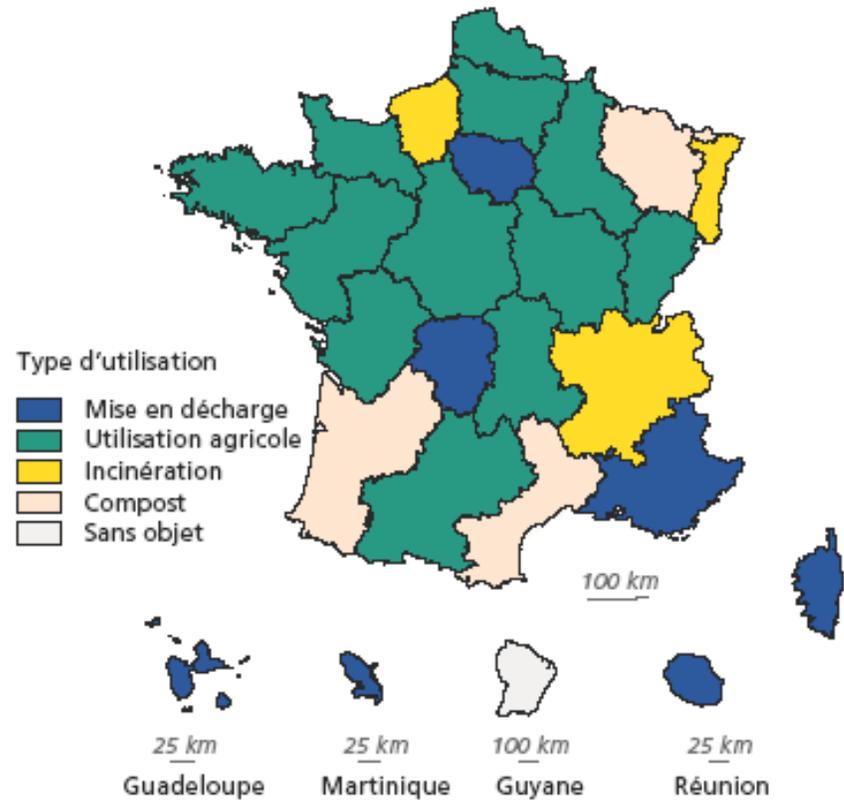
60% with N/P removal (3<sup>ary</sup> treatment)

20% with C removal only (2<sup>ndary</sup>)

60% of sludge used in agriculture



### Utilisation principale des boues en 2004 par région



Source : Ifen-Scees, enquête Eau 2004.

## Main use of sludge in each region

## Mostly used in agriculture

