2012/09/20 - Gelsenkirchen

Environmental assessment of pharmaceuticals treatment alternatives

Final conference

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CRTE/CRPHT

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   b. Results

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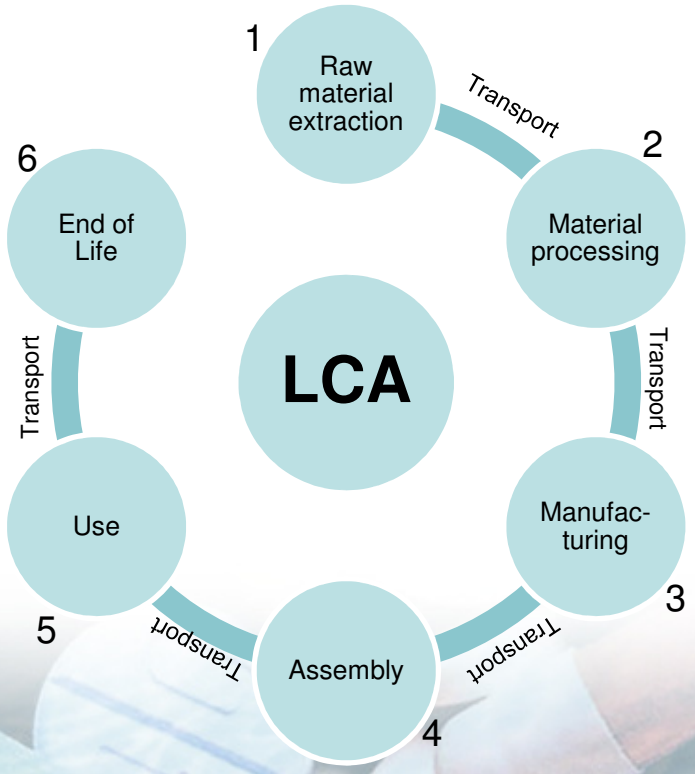
1. Introduction
a. What is LCA?

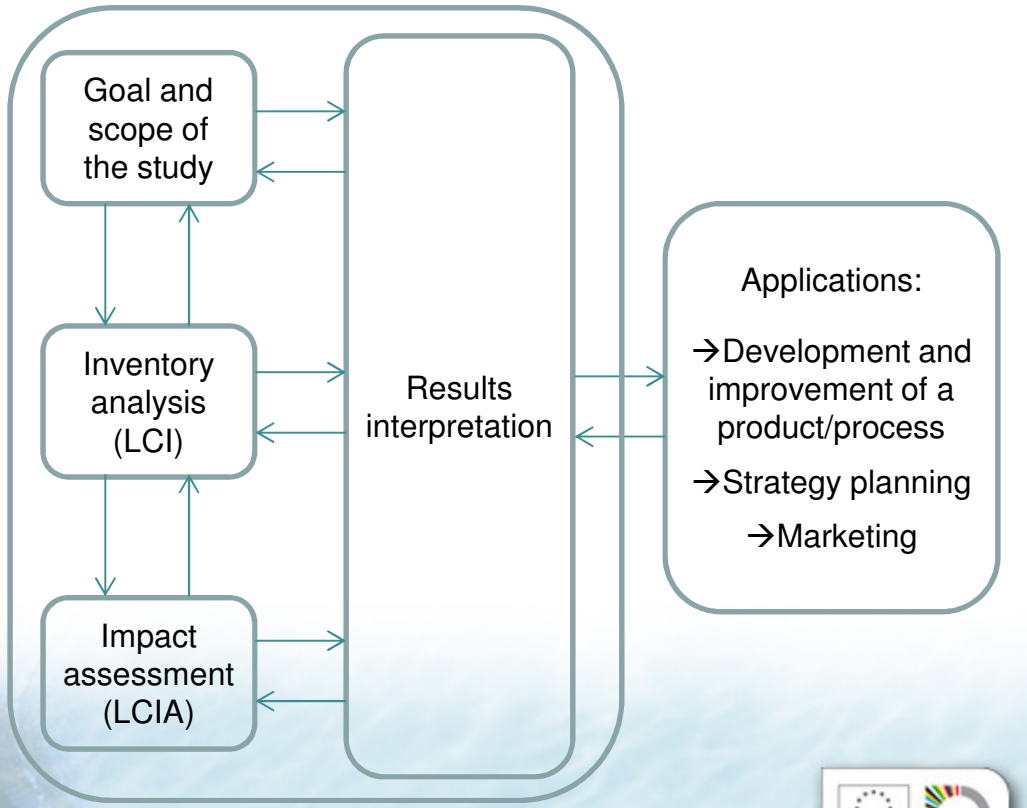
Life Cycle Assessment (LCA)

Tool for decision support, ISO 14040 and ISO 14044

Life cycle perspective



LCA structure

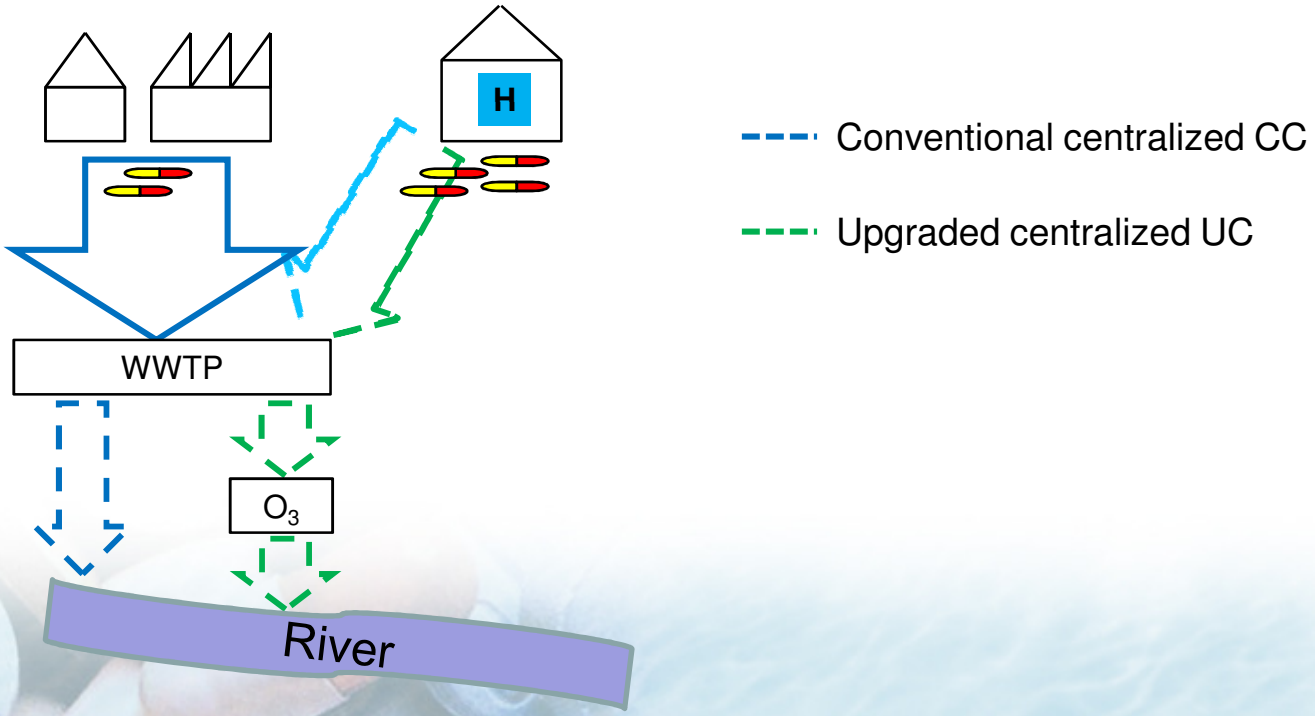


ISO standards (2006). Environmental Management – Life Cycle Assessment
ISO 14040 Principles and Framework, ISO 14044 Requirements and guidelines.

1. Introduction
b. Aim of the study

Environmental impacts comparison of the pharmaceuticals treatment alternatives:

- Centralized or decentralized treatment?
- Use of an advanced technology? Which one?



WWTP: Wastewater treatment plant MBR: Membrane Biological Reactor
O3: Ozonation UV: Ultraviolet radiation AC: Activated carbon adsorption

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b. Aim of the study

Environmental impacts comparison of the pharmaceuticals treatment alternatives:

- Centralized or decentralized treatment?
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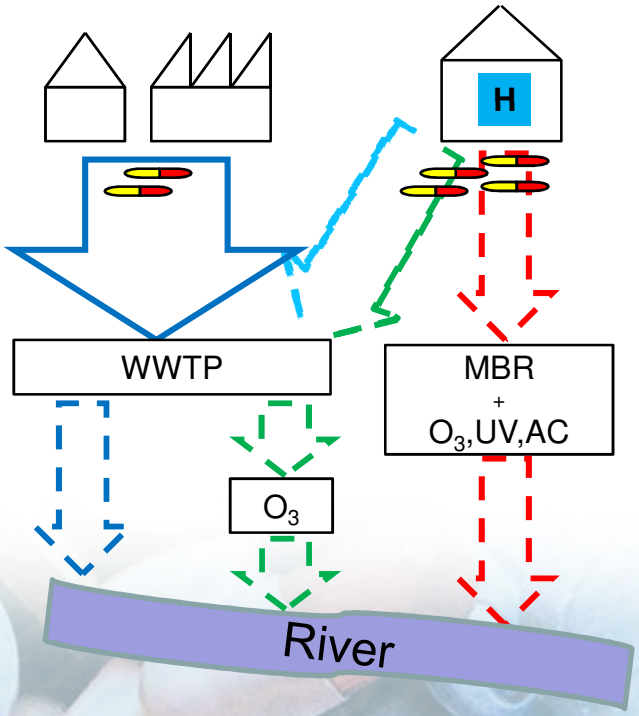


Conventional centralized CC

Upgraded centralized UC

Conventional and decentralized C+D_XX
XX = O_3, UV or AC

WWTP: Wastewater treatment plant MBR: Membrane Biological Reactor
O3: Ozonation UV: Ultraviolet radiation AC: Activated carbon adsorption

1. Introduction
c. Framework

Indicator = Generated – avoided impact

Comparison of technologies at the decentralized plant (D_O3, D_AC and D_UV)		
2 impact assessment methods	Common practice	
	Adaptation of state-of-the-art	
Comparison of scenarios (CC, UC and CC+D)		
2 impact assessment methods	Common practice	
	Adaptation of state-of-the-art	

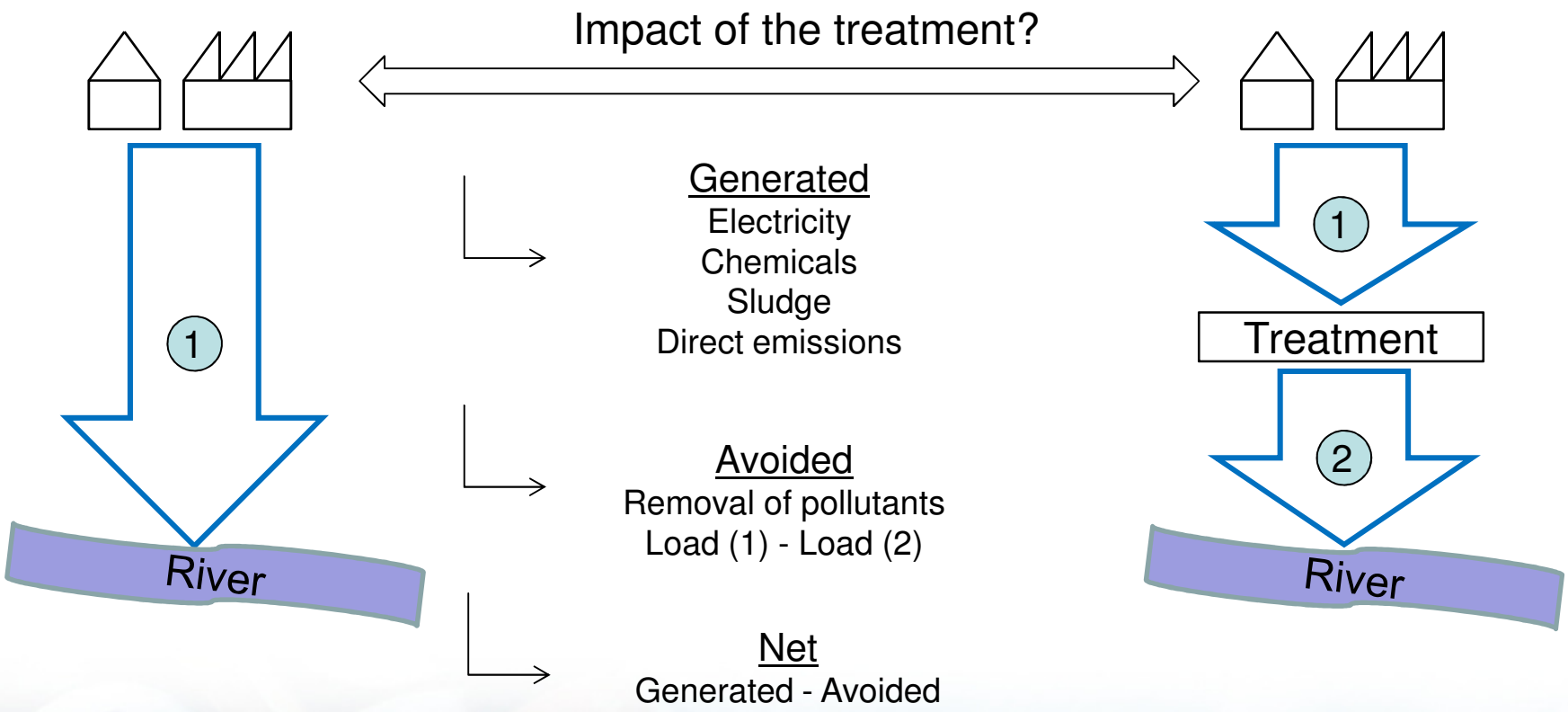
2. Conventional LCA

Indicator = Generated impact / Efficiency

Comparison of technologies at the decentralized plant (D_O3, D_AC and D_UV)		
2 impact assessment methods	Common practice	
	State-of-the-art	
Comparison of scenarios (CC, UC and CC+D)		
2 impact assessment methods	Common practice	
	State-of-the-art	

3. Eco-efficiency approach

2. Conventional LCA
a. Calculation principle



All the impacts are referred to the functional unit: treatment of 1 m^3 of wastewater

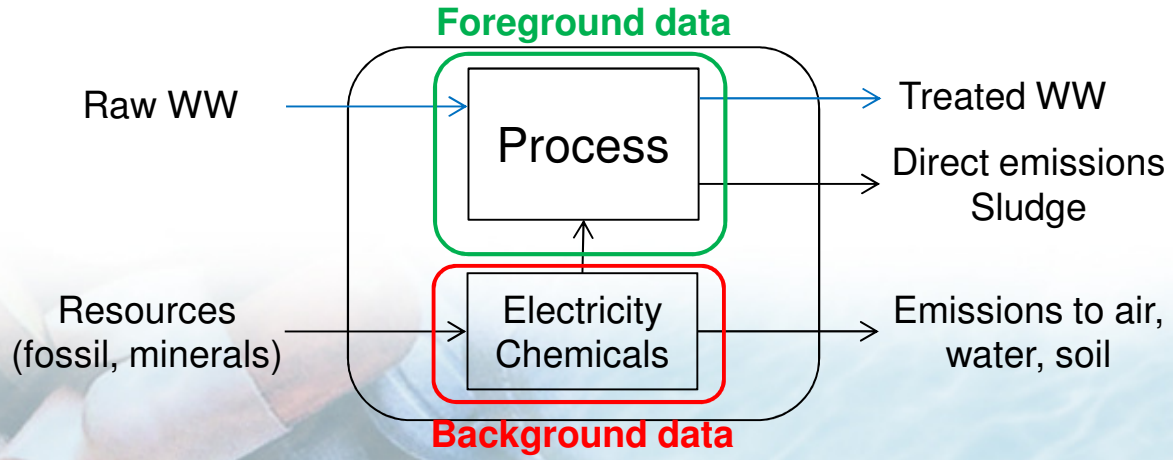
2. Conventional LCA
b. Life Cycle Inventory (LCI)

<u>Foreground data</u>

Directly used by the process (e.g. consumption of electricity = 1 kWh/m^3)
Data from partners (CH, DE, LU, NL)
If high variation observed for consumption values, min and max are considered.
Removal of: nitrogen, phosphorous, 10 pharmaceuticals and 24 heavy metals
Wastewater composition data from Luxembourg

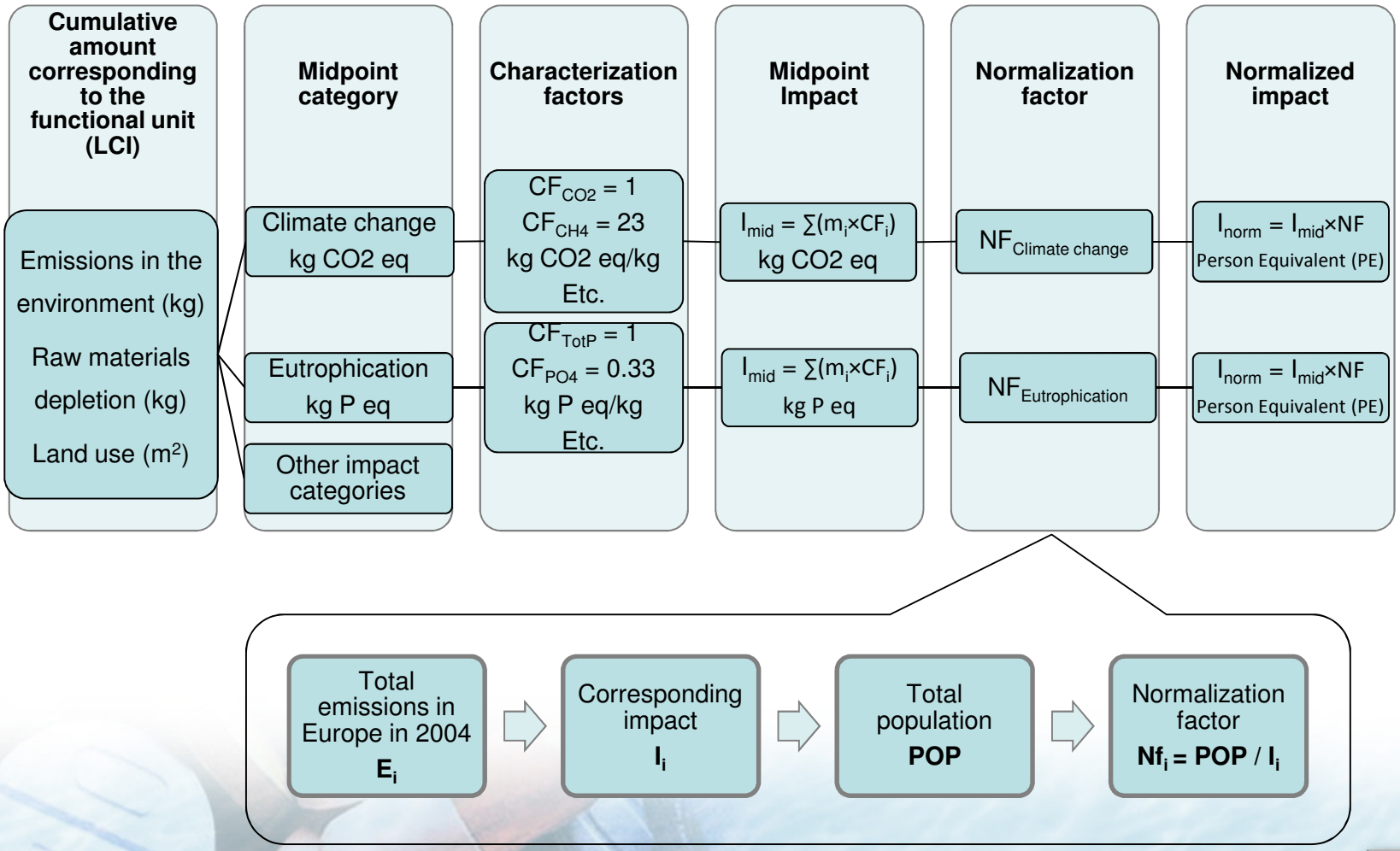
<u>Background data</u>

Lifecycle of process inputs (e.g. lifecycle for the production of 1 kWh of electricity)
Ecoinvent[1] database (most commonly used)



[1]Ecoinvent database v2.2 (http://www.ecoinvent.ch/)

2. Conventional LCA
c. Life Cycle Impact Assessment (LCIA)



2. Conventional LCA
c. Life Cycle Impact Assessment (LCIA)

EDIP method

Developed in 1997 and updated in 2003[1]
14 midpoint impact categories

Pharmaceuticals toxicity

Fate
- Henry's law constant
- Biodegradability
- Bioaccumulation

Effect
- PNEC[2]
- Assessment factor (type of endpoint, representativeness and quality of data)

USEtox method

Developed in 2008[3]
Scientific consensus on toxicity
3 midpoint impact categories

Pharmaceuticals toxicity

Fate
- Multimedia model
- 12 physico-chemical properties

Effect
- EC50[4]
- Extrapolation factors (if required endpoint not available)

+

ReCiPe method

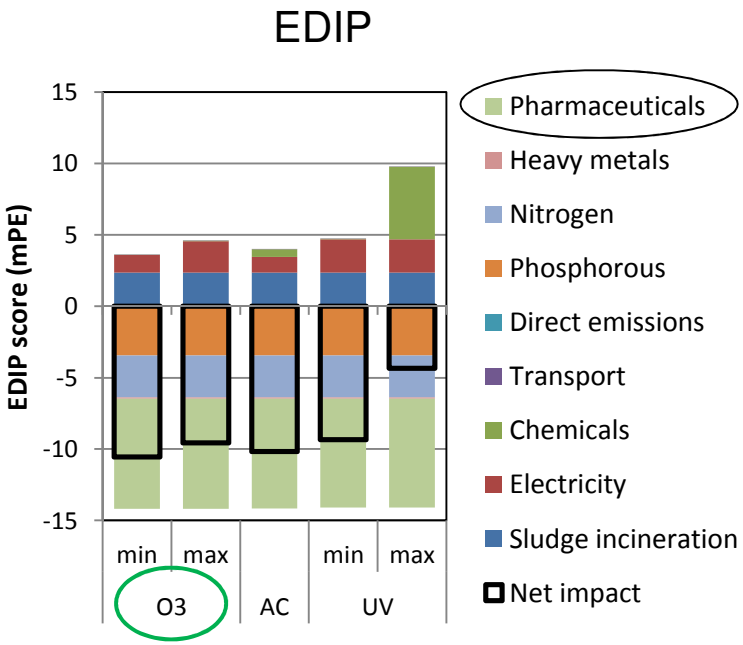
Developed in 2008[5]
16 midpoint impact categories

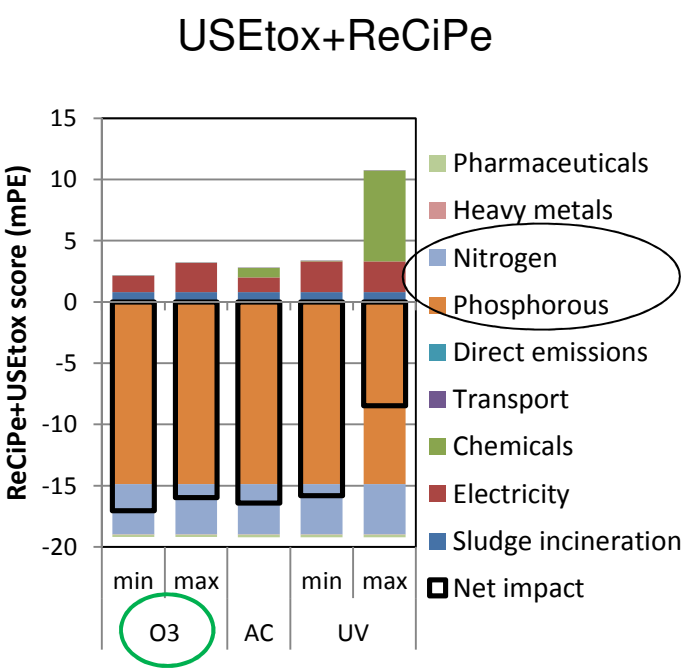
[1]Potting and Hauschild (2005). Background for spatial differentiation in LCA impact assessment – The EDIP2003 methodology.
[2]PNEC: Predicted No Effect Concentration
[3]Rosenbaum et al. (2008). USEtox-the UNEP-SETAC toxicity model: recommended characterization factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. Int J LCA.
[4]EC50: Effect concentration which affects 50% of the population
[5]Goedkoop et al. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level.

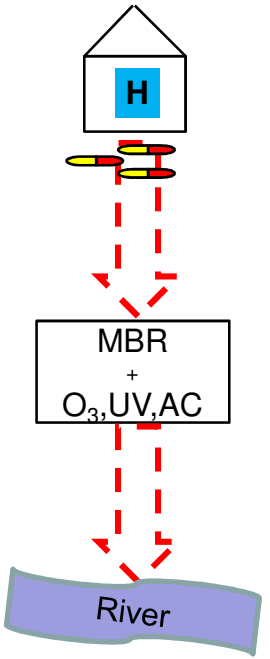
2. Conventional LCA
d. Results

pills
Pharmaceutical Input and Elimination from Local Sources

Comparison of technologies







Small differences observed
Ozonation preferable

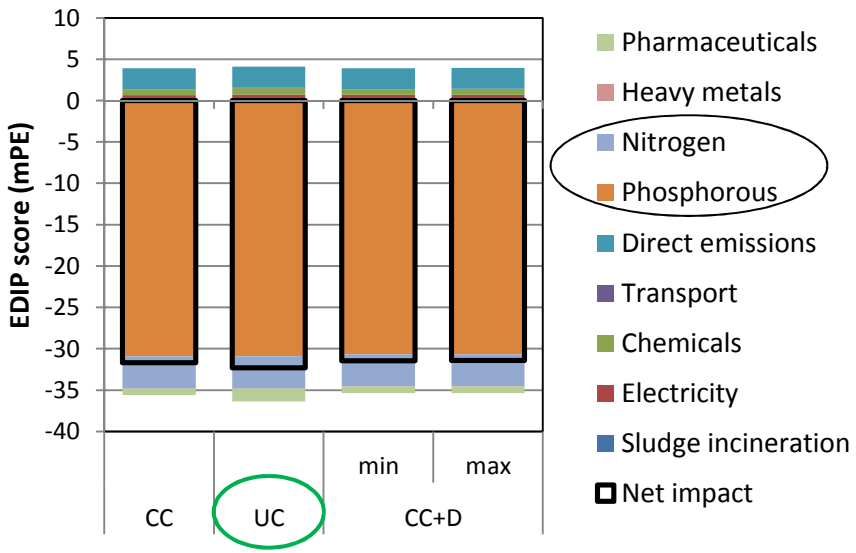
mPE: milli Person Equivalent
O3min: ozonation with minimal electricity consumption O3max: ozonation with maximal electricity consumption
AC: activated carbon adsorption
UVmin: ultraviolet radiation with minimal H2O2 consumption UVmax: ultraviolet radiation with maximal H2O2 consumption

2. Conventional LCA
d. Results

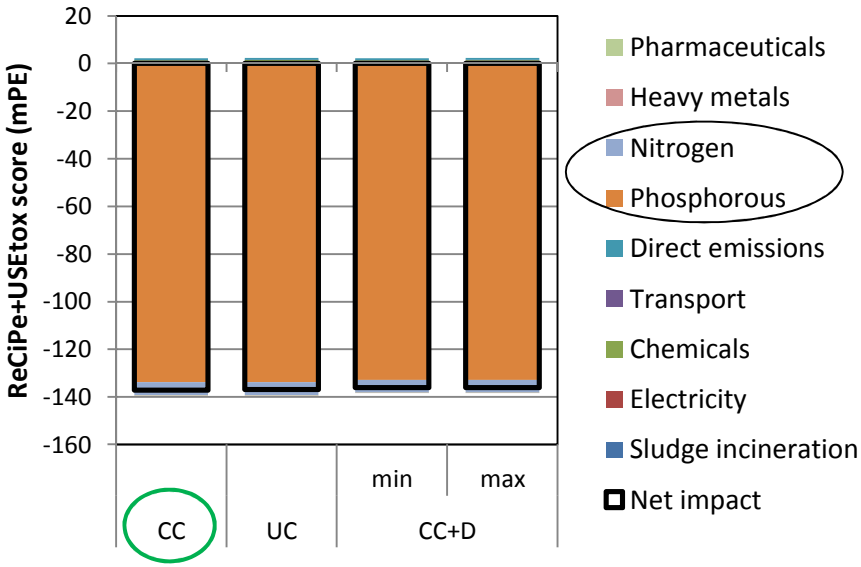
pills
Pharmaceutical Input and Elimination from Local Sources

Comparison of scenarios

EDIP



USEtox+ReCiPe



Very small differences observed
Different conclusions according to the method

mPE: milli Person Equivalent
CC: Conventional centralized UC: Upgraded centralized
CC+Dmin: Decentralized with optimized MBR and O3 CC+Dmax: Decentralized with non-optimized MBR and UV

2. Conventional LCA
d. Results

Sensitivity analysis

Pharmaceuticals removal

- Data from all the partners and from literature
- Very small variation (0.5% with EDIP and 0.001% with ReCiPe+USEtox), conclusions unchanged

Operational data of scenario UC

- Data from DE or CH
- Better performance for the Swiss plant but does not affect the conclusions

Volume percentage from hospital

- Data from Limoges (FR), LU and CH
- Higher the volume from hospital source, higher the impact

2. Conventional LCA
e. Limitations

Limitation of the toxicity assessment

Limitation	Comments
Representativeness of toxicity tests	Specific effects of pharmaceuticals: endocrine disrupter or bacteria resistance
	Tests for human toxicity
Availability of data	Validity and reliability of the tests with limited description
	Extrapolation from acute to chronic data
	Lowest toxicity value very sensitive to the available data
Relevance of assessment factors	Intraspecies and interspecies differences
Missing considerations	Formation of metabolites and transformation products

2. Conventional LCA
e. Limitations

Other limitations

- Small number of substances considered at present

- Elimination of heavy metals and nutrients during post-treatment
  - Activated carbon
  - Sand filtration after ozonation

- Uncertainties on the foreground data
  - Variability of the consumption of electricity or chemicals between partners
  - Sampling method for wastewater measurements

3. Eco-efficiency approach
a. Calculation principle

Pharmaceuticals not assessed within LCA (to decrease uncertainties)

Eco-Efficiency Indicator (EFI):

$$EFI = \frac{I}{R}$$

Generated impact
→ LCI: Electricity, chemicals, sludge, emissions
→ LCIA: EDIP and ReCiPe

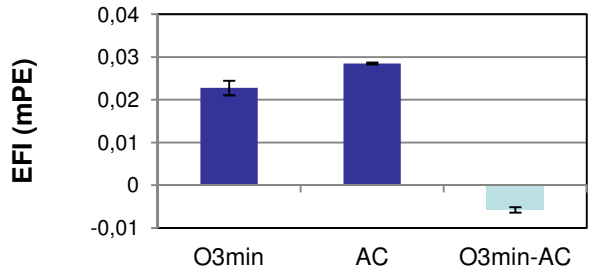
Efficiency of the treatment
→ Average removal of pharmaceuticals
→ Standard deviation

Standard deviation (EFI) calculated from Standard deviation (R)

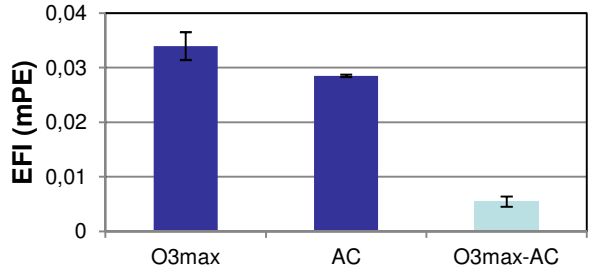
The scenarios are compared pairwise, taking into account the uncertainty on EFI, via a statistical test (based on the amplitude of the 95% confidence intervals)

3. Eco-efficiency approach
b. Results

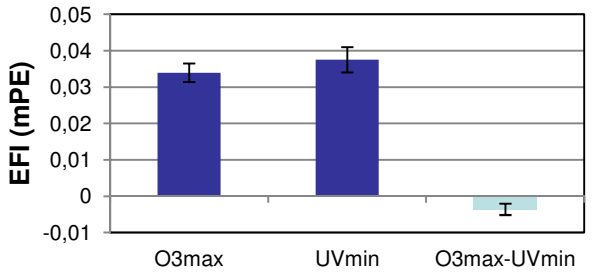
Comparison of technologies



O3min > AC



AC > O3max



O3max > UVmin

O_3min > AC > O_3max > UVmin

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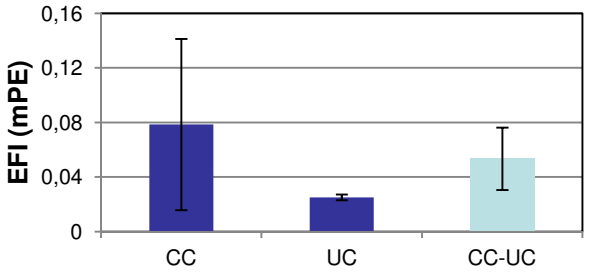
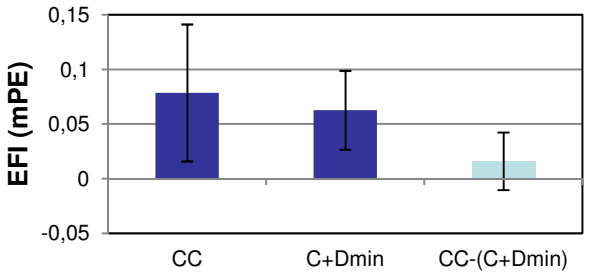
3. Eco-efficiency approach
b. Results

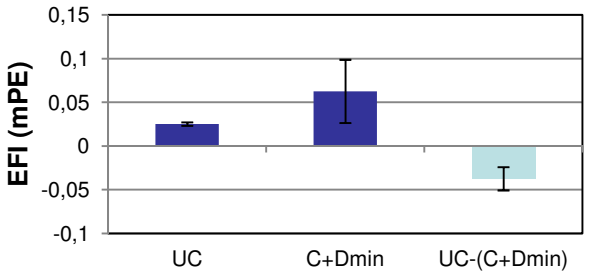
Comparison of scenarios



⇨ Upgraded Centralized > Conventional Centralized



⇨ Conventional Centralized ~ Conventional + Decentralized



⇨ Upgraded Centralized > Conventional + Decentralized

Upgraded Centralized > (Conventional Centralized ~ Conventional + Decentralized)

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4. Conclusions

Indicator = Generated – avoided impact

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Comparison of scenarios (CC, UC and CC+D)		
2 impact assessment methods	Common practice	Upgraded centralized
	Adaptation of state-of-the-art method	Conventional centralized

Indicator = Generated impact / Efficiency

Comparison of technologies at the decentralized plant (D_O3, D_AC and D_UV)		
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	State-of-the-art	Ozonation

Comparison of scenarios (CC, UC and CC+D)		
2 impact assessment methods	Common practice	Upgraded centralized
	State-of-the-art	Upgraded centralized

4. Conclusions

These results have to be interpreted carefully:

- Toxicity impact of pharmaceuticals
  - High uncertainties on the assessment (also observed in literature)
  - Further improvements for future research

- The results are valid within the scope of the study (objectives, assumptions and limitations)

- The choice for a technology or for a decentralized plant would depend on other criteria and local constraints

Thank you for your attention

Igos E., Benetto E., Venditti S., Koehler C., Cornelissen A., Moeller R., Biwer A. Is it better to remove pharmaceuticals in decentralized or conventional wastewater treatment plants? A life cycle assessment comparison. ***Accepted for publication*** in Science of the Total Environment (August 2012).

Igos E., Benetto E., Venditti S., Koehler C., Cornelissen A. Comparative and integrative environmental assessment of advanced wastewater treatment processes based on an average removal of pharmaceuticals***. Accepted for publication*** in Water Science and Technology (August 2012).