

Putting micropollutants, energy, nutrients and GHG emissions on an equal basis: An LCA approach

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Putting micropollutants, energy, nutrients and GHG emissions on an equal basis

A life cycle assessment (LCA) approach

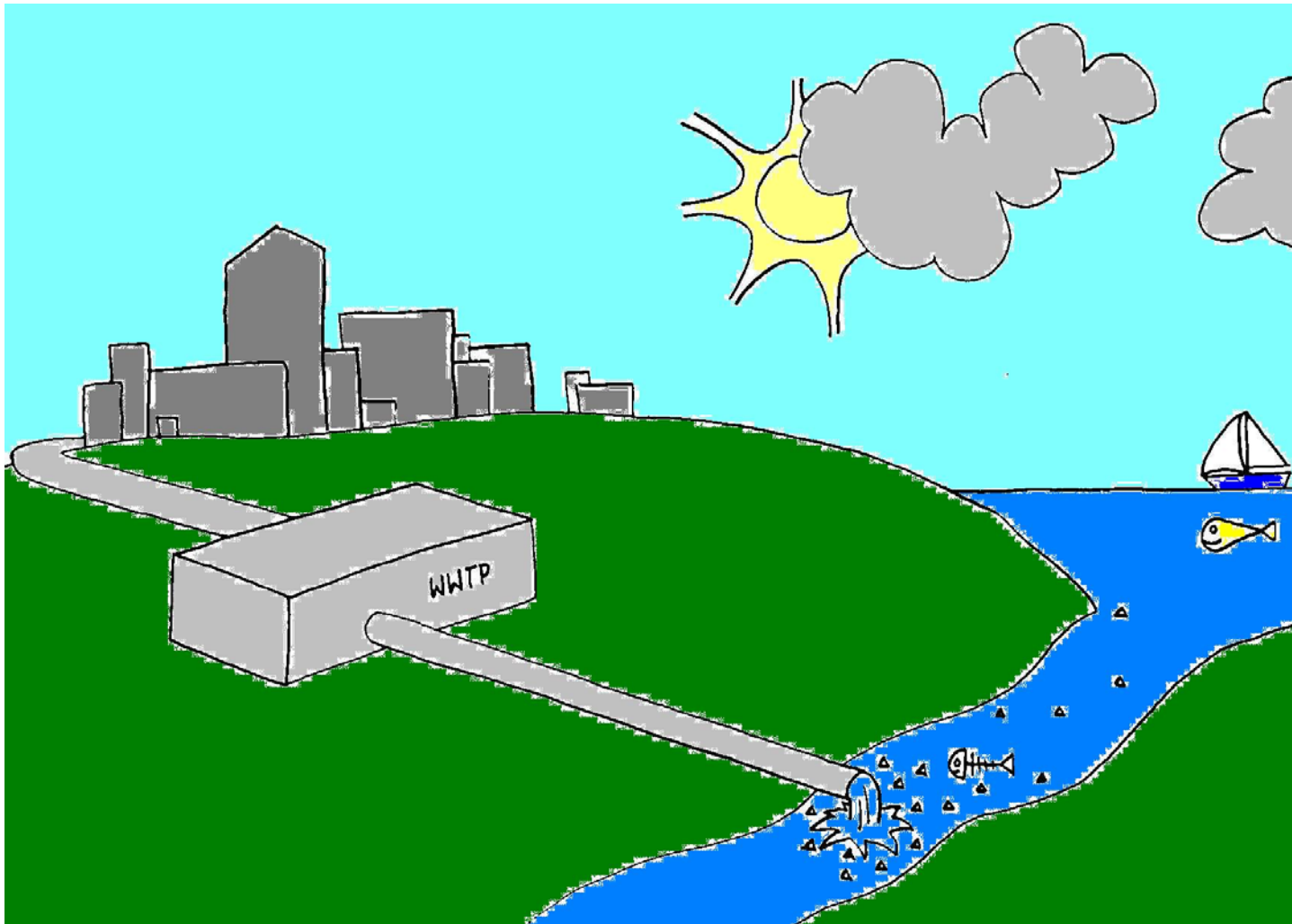
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International
Water Association

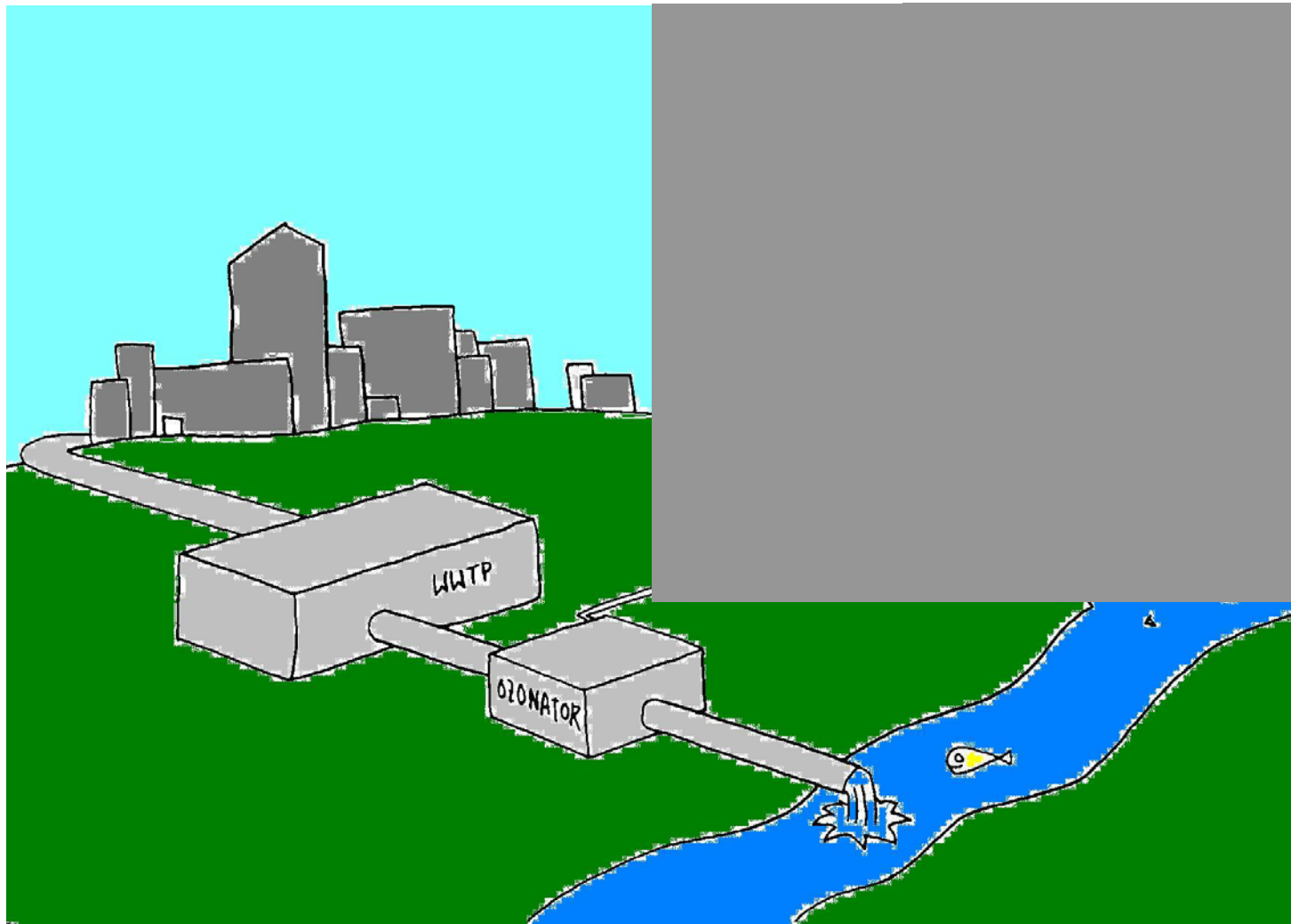
Problem



Peter Augusto Hansen

Putting micropollutants, energy, nutrients and GHG emissions....(Larsen HF)

Sustainable solution or sub-optimisation?



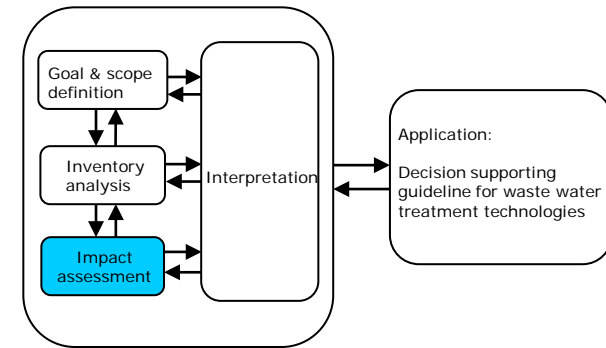
Peter Augusto Hansen

Putting micropollutants, energy, nutrients and GHG emissions....(Larsen HF)

Characteristics of LCA

- A decision supporting tool
- Focus on services typically represented by a product (the “functional unit”, fu). **In this case: Treatment of one cubic meter waste water (all impacts related to this unit)**
- Comparative (relative statements). **In this case: Comparing induced impacts with avoided impacts regarding e.g. ozonation and PAC addition**
- Holistic perspective
 - life cycle from cradle to grave
 - all relevant environmental impacts or damages to ‘areas of protection’. In this case:
 - **Global warming**
 - **Nutrient enrichment (eutrofication)**
 - **Acidification**
 - **Ecotoxicity**
 - **.....**
- Aggregation over time and space
 - life cycle is global
 - life cycle may span over decades or even centuries

Life cycle impact assessment (LCIA)



Classification: “What does this emission contribute to?”

- Assignment of emissions to impact categories according to their potential effects
 - Global warming (e.g. CO₂, CH₄)
 - Acidification (e.g. NO₂, SO₃)
 - Ecotoxicity (e.g. pharmaceuticals, heavy metals)
 - Human toxicity (e.g. benzene, PAH's)
 -

Characterisation: “How much may it contribute?”

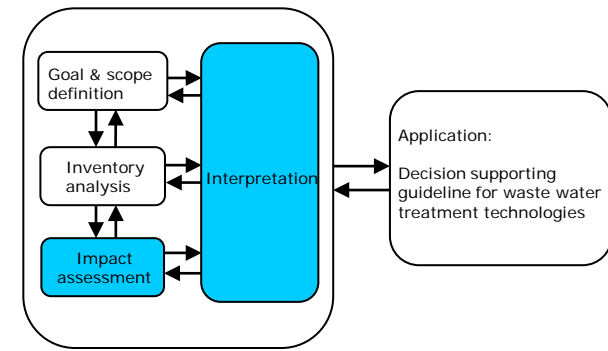
- Quantification of contributions to the different impact categories by estimating impact potentials, IPs (e.g. multiplying the characterisation factors (CFs) for each chemical by the emitted amount (Q) per functional unit (fu):

$$IP = Q * CF$$

- Example (GWP):

| Substance | Q (g/fu) | CF (g CO ₂ -eq/g) | IP (g CO ₂ -eq/fu) |
|-----------------------------------|----------|------------------------------|-------------------------------|
| Carbon dioxide (CO ₂) | 250 | 1 | 250 |
| Methane (CH ₄) | 10 | 25 | 250 |
| Total | | | 500 |

Life cycle impact assessment (LCIA) and interpretation



Normalisation: “Is that much?”

- Expression of the impact potentials relative to a reference situation (person-equivalence, PE), e.g. normalisation reference (NR) for GWP: 8,700 kg CO₂-eq/pers/year. The normalised impact potential (nIP):

$$nIP = IP/NR$$

| Impact category | NR (CO ₂ -eq/pers/year) | IP/fu (kg CO ₂ -eq/fu) | nIP (mPE/fu) |
|----------------------|------------------------------------|-----------------------------------|--------------|
| Global warming (GWP) | 8700 | 0,5 | 0,057 |

Valuation: “Is it important?”

- Assignment of weights (weighting factors, WFs) to the different impact potentials (EDIP: political reduction targets), e.g. for global warming a targeted 10 years reduction of 20% => $WF=1/(1-0.2) = 1.3$. The weighted impact potential (wIP):

$$wIP = nIP*WF$$

| Impact category | WF | nIP (mPE/fu) | wIP (mPET/fu) |
|----------------------|-----|--------------|---------------|
| Global warming (GWP) | 1,3 | 0,057 | 0,074 |

Interpretation: “Which alternative is better and what determines it?”

- E.g. is ozonation worth it in an environmental sustainability context or should we avoid it?

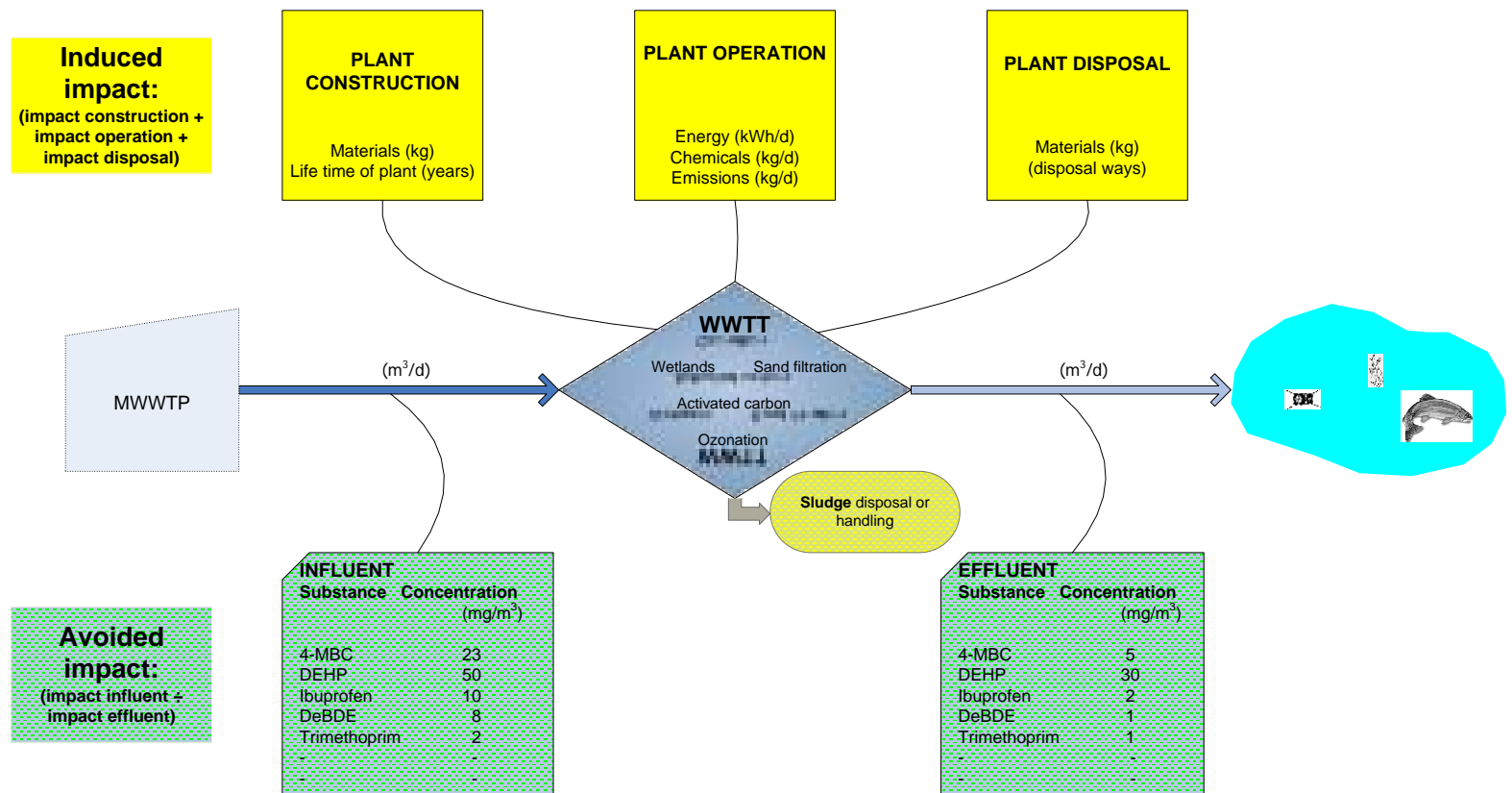
Normalisation references (NRs) and weighting factors (WFs) for the LCA method EDIP97

| Impact category | Unit for impact | Normalisation reference (NR, 1994) 1 PE | Region | Weighting factor (WF, 2004) 1 PET |
|-------------------------|--------------------------------------|--|--------|--------------------------------------|
| Ecotoxicity water | Cubic meter water | 352.000 m ³ /capita/year | EU-15 | 1,18 |
| Ecotoxicity soil | Cubic meter soil | 964.000 m ³ /capita/year | EU-15 | 1 |
| Human toxicity water | Cubic meter water | 52.200 m ³ /capita/year | EU-15 | 1,3 |
| Human toxicity soil | Cubic meter soil | 127 m ³ /capita/year | EU-15 | 1,23 |
| Photochemical oxidation | Kg C ₂ H ₄ -eq | 25 kg/capita/year | EU-15 | 1,33 |
| Nutrient enrichment | Kg NO ₃ ⁻ -eq | 119 kg/capita/year | EU-15 | 1,22 |
| Acidification | Kg SO ₂ -eq | 74 kg/capita/year | EU-15 | 1,27 |
| Global warming | Kg CO ₂ -eq | 8.700 kg/capita/year | Global | 1,12 |

Stranddorf et al. 2005

LCA approach used in the EU project Neptune for environmental sustainability assessments of WWTTs

Avoided against induced impacts



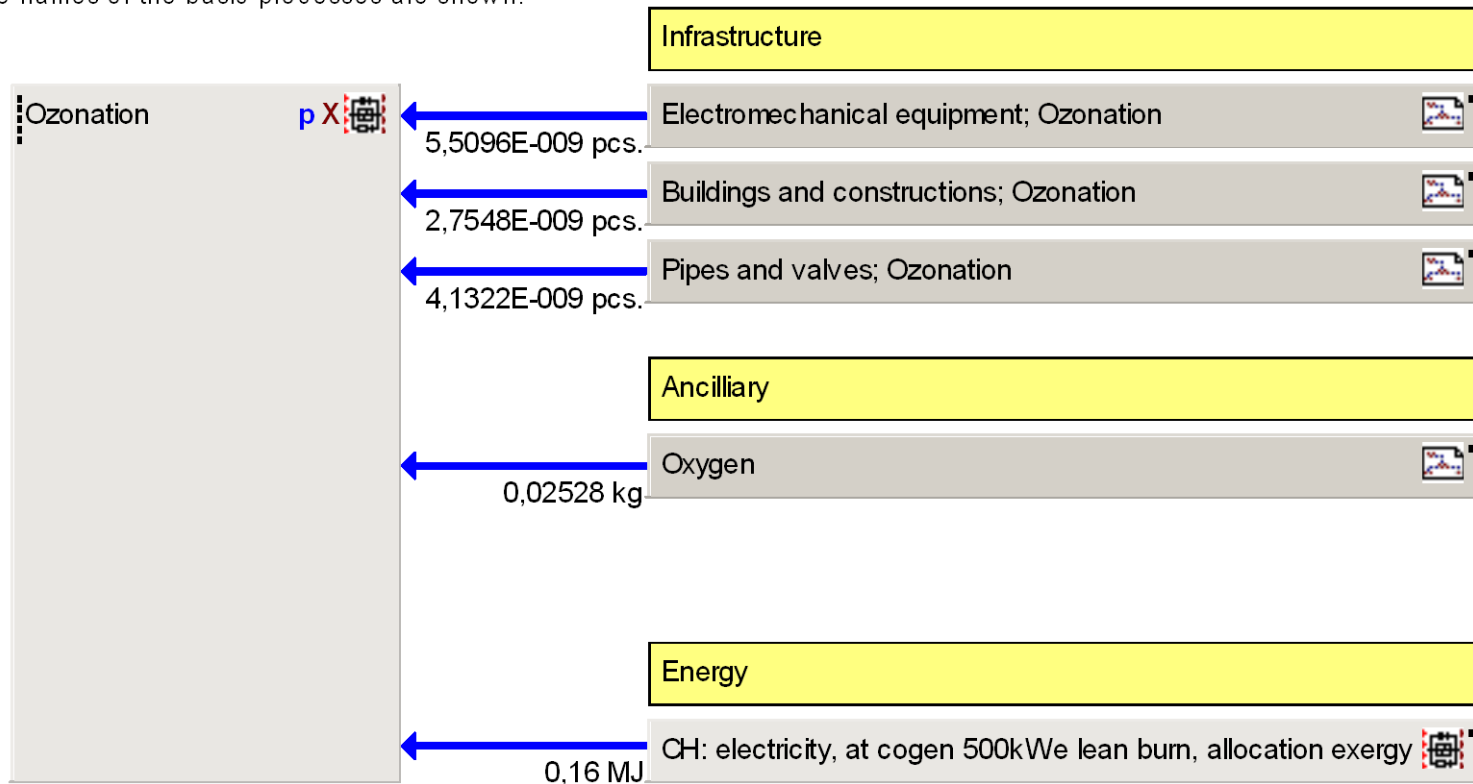
Modelling LCA on ozonation; Main plan

(physical inventory)

Ozonation (3.2gO3/m3WW)

GaBi 4 process plan: Reference quantities

The names of the basic processes are shown.

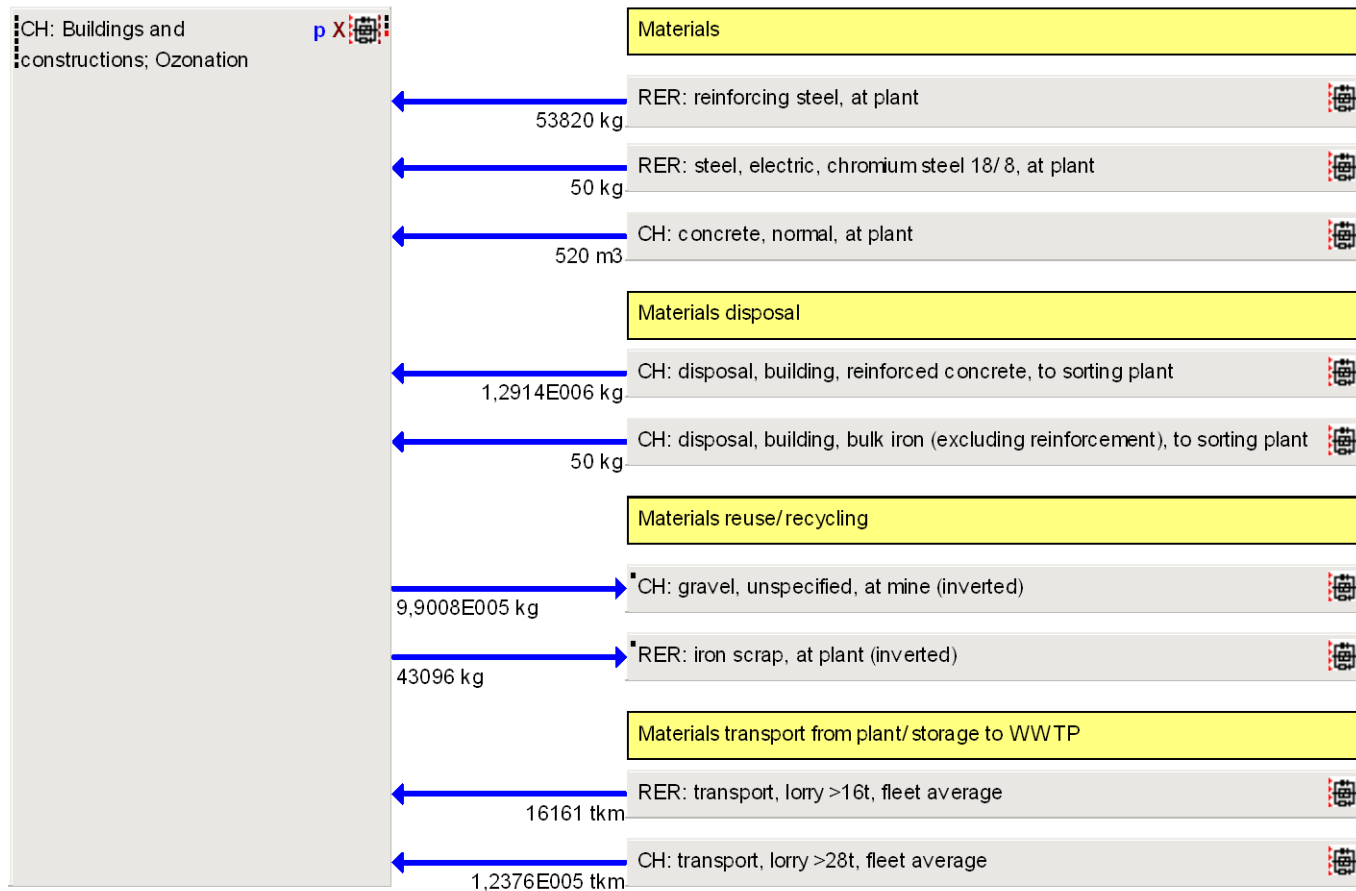


Modelling LCA on ozonation; Sub-plan (physical inventory)

Buildings and constructions; Ozonation

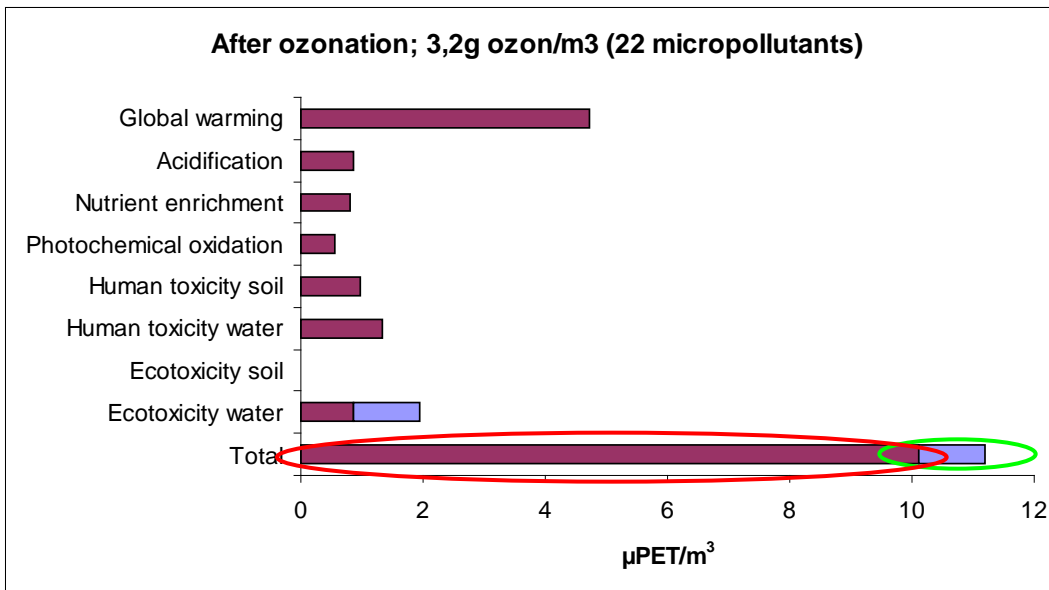
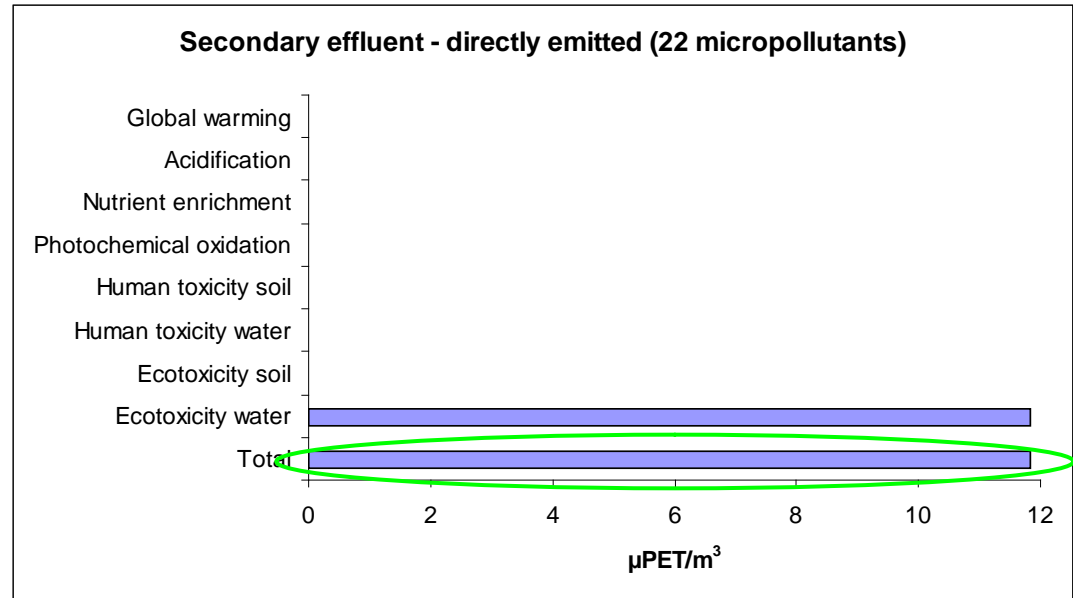
GaBi 4 process plan:Reference quantities

The names of the basic processes are shown.



LCA impact profiles

(weighting factor = 1 for all impact categories)
(22 micropollutants)



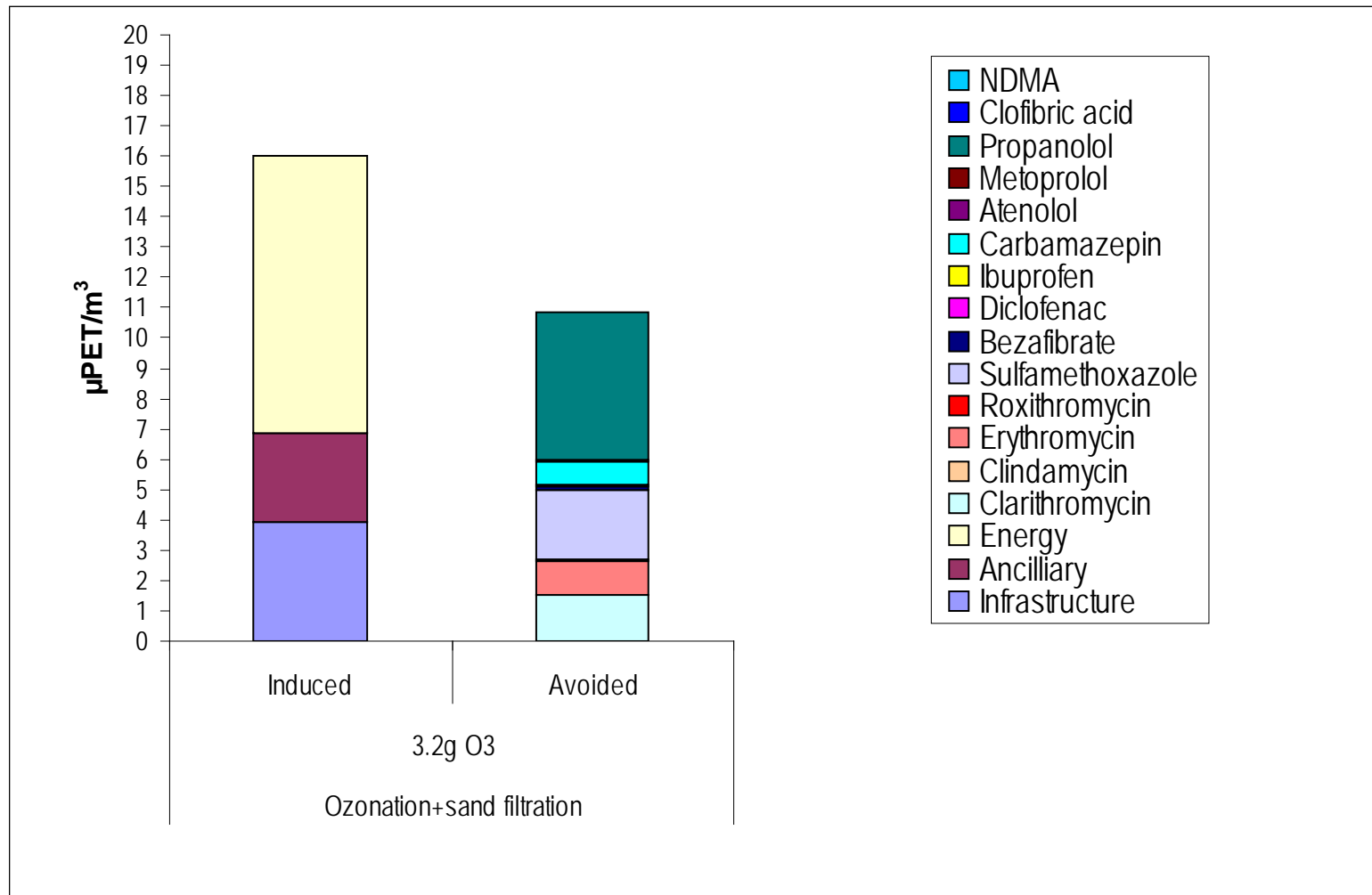
Avoided: 10,7 μPET/m³

Induced: 10,1 μPET/m³

Environmental sustainability profile; ozonation + sand filtration

(22 micropollutants, only significant ones shown)

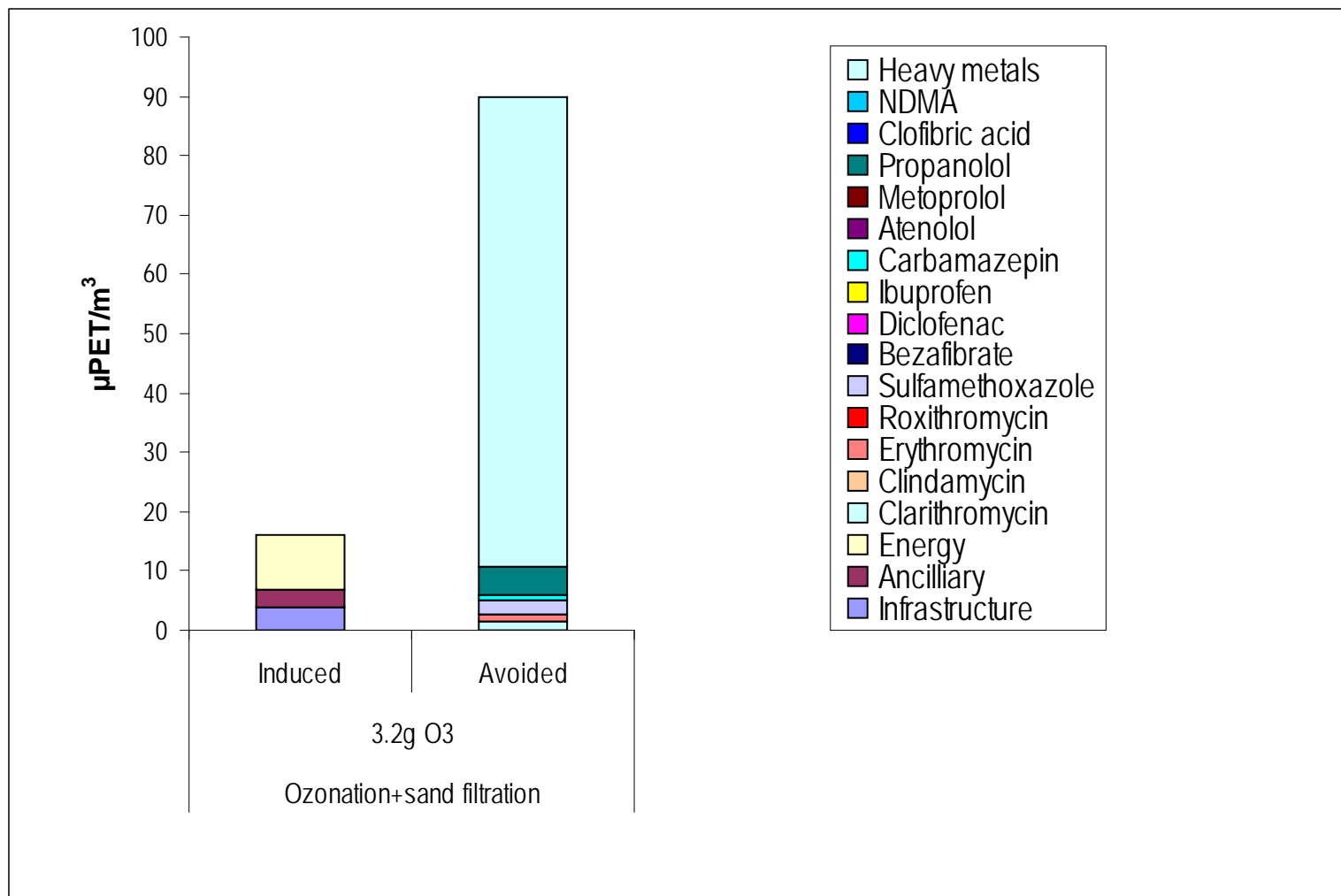
(weighting factor = 1 for all impact categories)



Environmental sustainability profile; ozonation + sand filtration

(Including removal of metals in sand filter)

(31 micropollutants (only significant ones shown); weighting factor = 1 for all impact categories)



Environmental sustainability profile; ozonation + sand filtration (including both metal and phosphorus removal)

(31 micropollutants + P (only significant ones shown); weighting factor = 1 for all impact categories)

