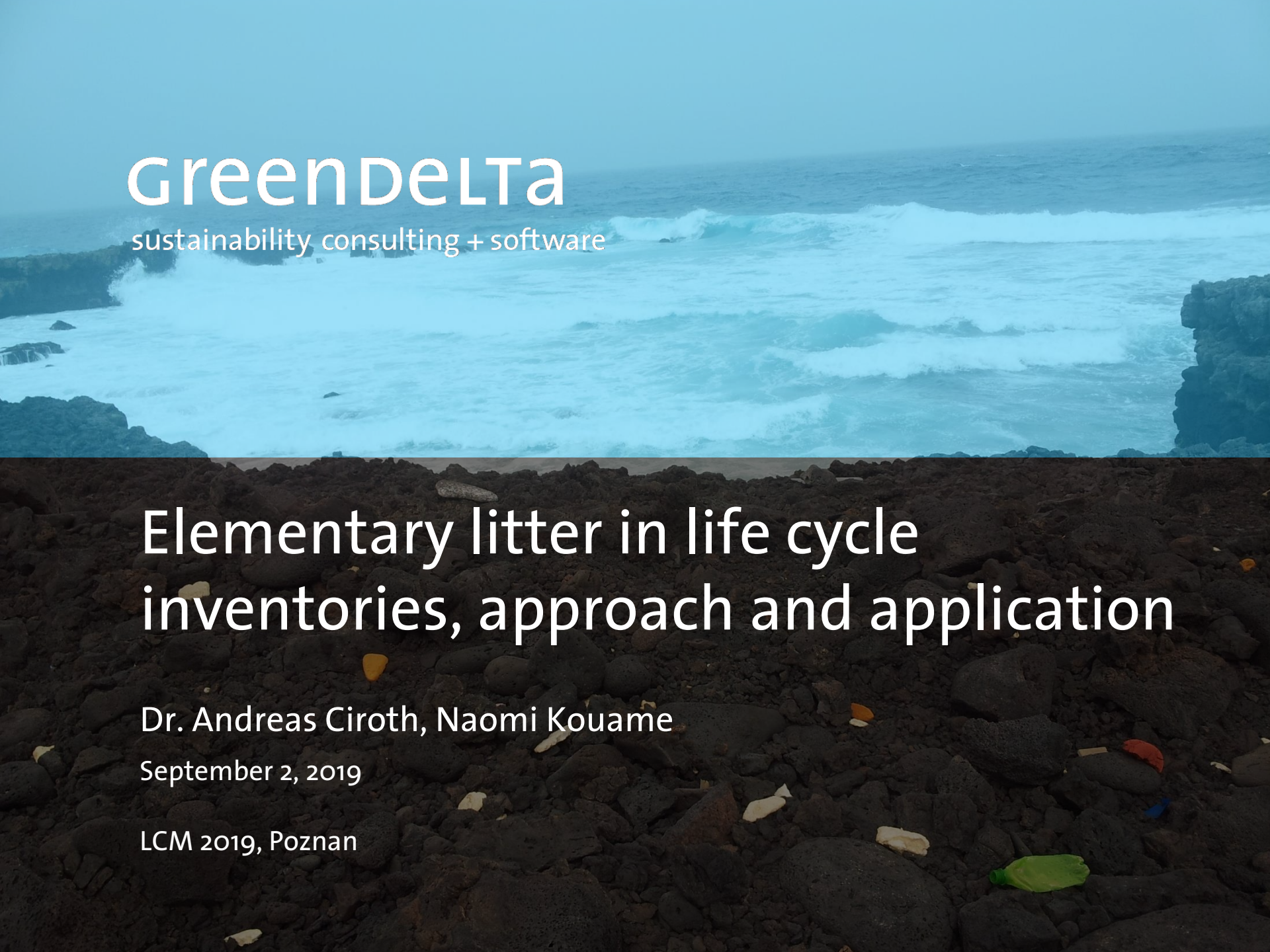

GreenDelta

sustainability consulting + software

# Elementary litter in life cycle inventories, approach and application

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September 2, 2019

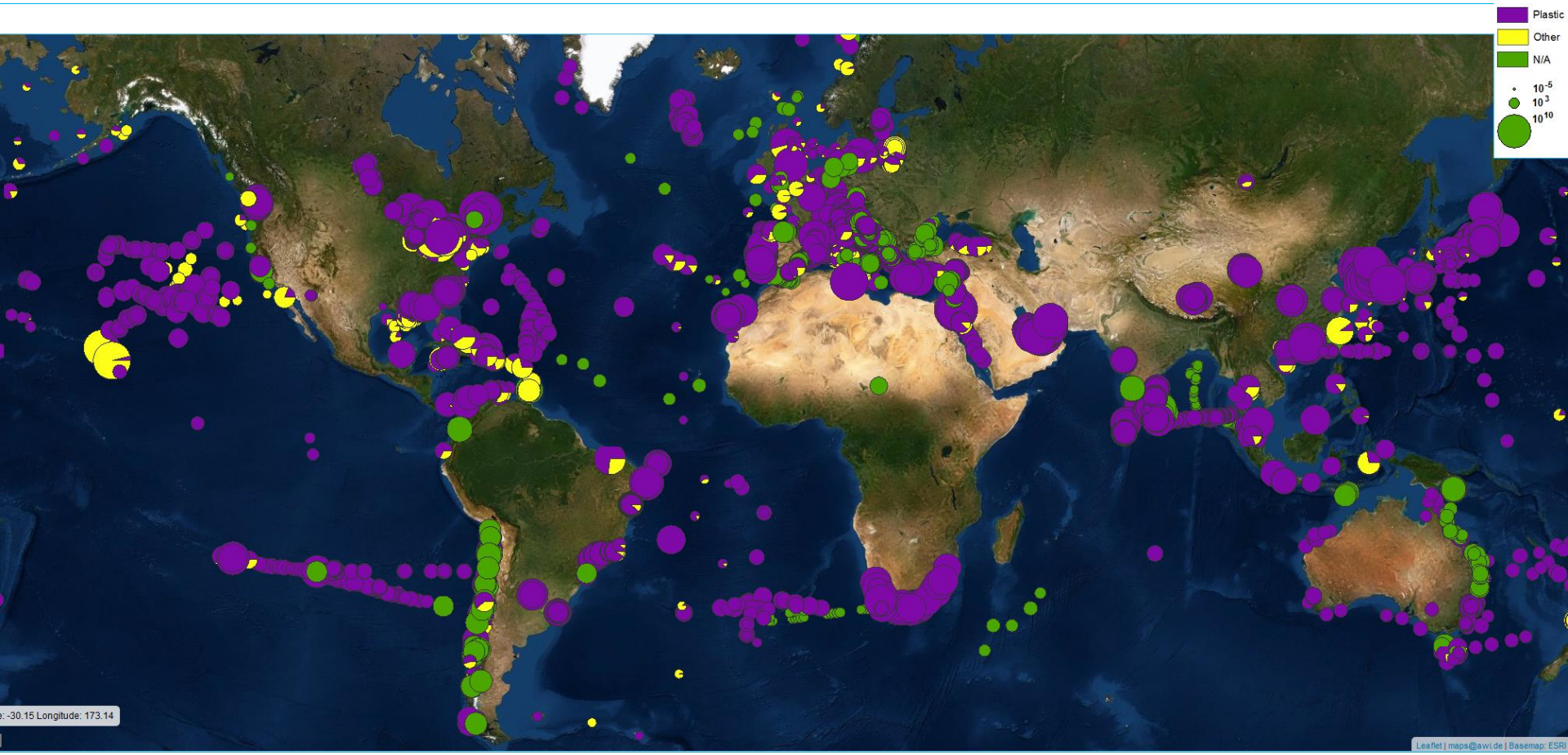
LCM 2019, Poznan

## Content

- the obvious problem of plastic littering, ignored by LCA so far
- a model to include plastic littering in LCA
- application for ecoinvent 3.5, and some example calculations
- next steps, some existing limitations
- conclusions

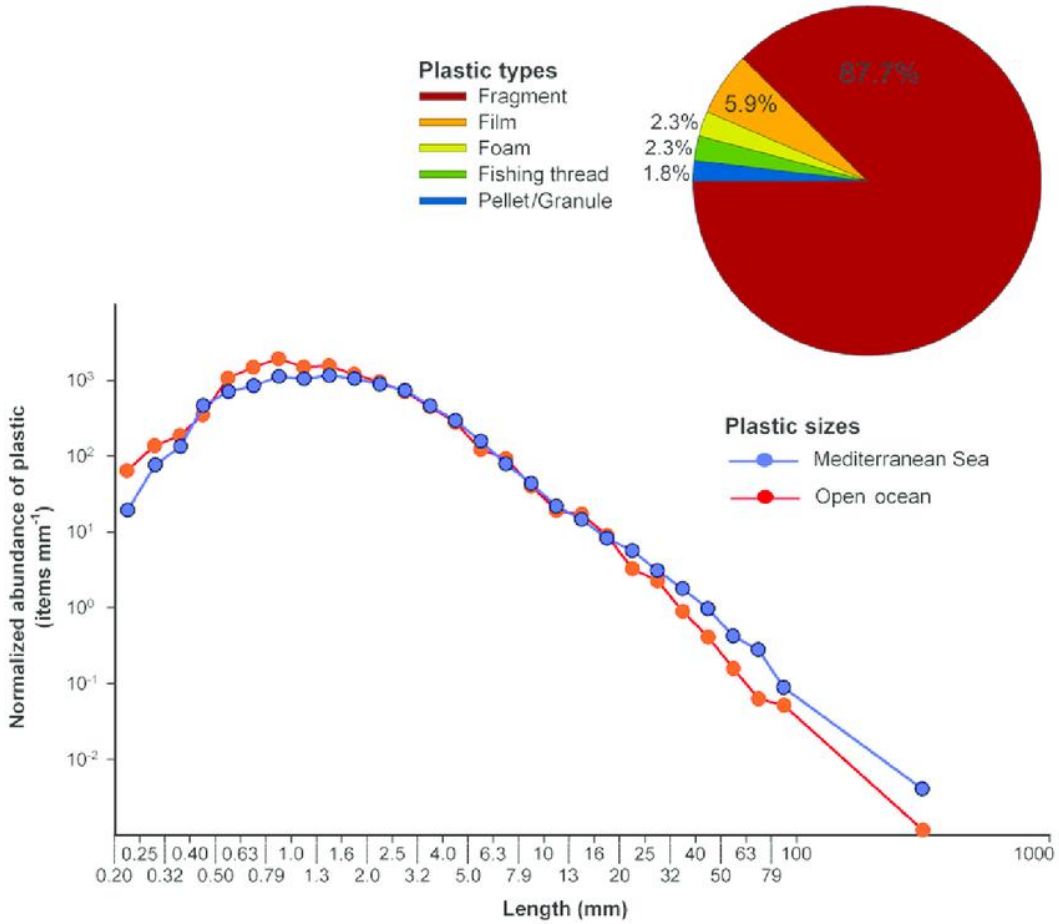

the obvious problem of plastic littering

# Distribution of litter types in different realms (1,036 publications)




Tekman, M.B., Gutow, L., Macario, A., Haas, A., Walter, A., Bergmann, M.: Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, https://litterbase.awi.de/litter

# Distribution of litter type sizes in the Mediterranean sea




Cózar, Andrés & Sanz-Martín, Marina & Marti, Elisa & González-Gordillo, Juan & Úbeda, Bárbara & Á Gálvez, José & Irigoien, Xabier & Duarte, Carlos. (2015). Plastic Accumulation in the Mediterranean Sea.

# Distribution of brake wear type sizes

**Table 1** Overview of literature studies investigating the mass distribution of airborne brake wear particles

| Reference | Type of study | Brake pads tested | Method | Mass size distribution |
|---|---|---|---|---|
| Cha et al. 1983 | Brake dynamometer | Asbestos | Unimodal (2.1–3.3 μm) | |
| Garg et al. 2000 | Brake dynamometer | Semimetallic and NAO | MOUDI (>0.1 μm) | Unimodal (0.1–1.0 μm) |
| Sanders et al. 2003 | Brake dynamometer | Low metallic, semimetallic and NAO | MOUDI–ELPI | Unimodal (4–5 μm) |
| von Uexküll et al. 2005 | Brake dynamometer | Disc and drum (trucks) | Optical particle counter (>0.3 μm) | Unimodal (2–3 μm) |
| Iijima et al. 2007 | Brake dynamometer | NAO | APS (>0.5 μm) | Unimodal (3–6 μm) |
| Iijima et al. 2008 | Brake dynamometer | NAO | APS (>0.5 μm) | Unimodal (2.0 μm) |
| Kukutschová et al. 2011 | Brake dynamometer | Low metallic | APS–SMPS–BLPI | Unimodal (2–4 μm) |
| Harrison et al. 2012 | On-road measurement | Roadside PM | MOUDI | Unimodal (2–3 μm) |
| Kwak et al. 2013 | On-road measurement | Roadside PM | APS (>0.5 μm) | Unimodal (1–10 μm) |

Grigoratos, Theodoros & Martini, Giorgio. (2014). Brake wear particle emissions: a review. Environmental science and pollution research international. 22. 10.1007/s11356-014-3696-8.

# Life Cycle Assessment (LCA)

LCA is often characterised as providing a “full picture”, a comprehensive overview of environmental performance


http://www.saint-gobain-facade-glass.com/sites/default/files/green_buildings/LCA%20leaflet%20Saint-Gobain%20Glass%20English.pdf

# Life Cycle Assessment (LCA)

LCA is often characterised as providing a “full picture”, a comprehensive overview of environmental performance

..and yet still, things like littering and plastic litter especially are ignored in LCA.

# a model to include plastic littering in LCA

# → Including occurring plastic litter in an LCA model, basic ideas

1. Plastic littering occurs due to events, these happen with a given probability

2. The probability depends on the process and on the flow (and maybe other things)

3. The result is a plastic elementary flow released to nature (that however eventually can be picked up afterwards)

# A framework: linking events in LCA inventory

## An example LCA unit process:

transport, passenger car, large size, diesel, EURO 3

| INPUT | Amount | Unit |
|---|---|---|
| diesel, low-sulfur | 0.07624796 | kg |
| passenger car maintenance | 1.08E-05 | Item(s) |
| passenger car, diesel | 0.01333333 | kg |
| **OUTPUT** | **Amount** | **Unit** |
| transport, passenger car, large size, diesel, EURO 3 | 1 | km |
| Carbon dioxide, fossil | 0.23941859 | kg |
| Nitrogen oxides | 8.04E-04 | kg |
| Carbon monoxide, fossil | 7.93E-05 | kg |
| Particulates, < 2.5 um | 3.88E-05 | kg |
| NMVOC, non-methane volatile organic compounds, unspecified origin | 1.91E-05 | kg |

# A framework: linking events in LCA inventory

## An example LCA unit process:

transport, passenger car, large size, diesel, EURO 3, with accident

| INPUT | Amount | Unit |
|---|---|---|
| diesel, low-sulfur | 0.07624796 | kg |
| passenger car maintenance | 1.08E-05 | Item(s) |
| passenger car, diesel | 0.01333333 | kg |
| accident with injury | 0.4*1e-6 | Events* |
| **OUTPUT** | **Amount** | **Unit** |
| transport, passenger car, large size, diesel, EURO 3 | 1 | km |
| Carbon dioxide, fossil | 0.23941859 | kg |
| Nitrogen oxides | 8.04E-04 | kg |
| Carbon monoxide, fossil | 7.93E-05 | kg |
| Particulates, < 2.5 um | 3.88E-05 | kg |
| NMVOC, non-methane volatile organic compounds, unspecified origin | 1.91E-05 | kg |

*This is the value for Germany, for 2017, https://www.bast.de/BASt_2017/EN/Publications/Media/Traffic-and-Accident-Data.pdf?__blob=publicationFile&v=7

# A framework: distinction of littering events, in processes

| littering event probabilities, processes | | closed | open |
|---|---|---|---|
| | examples | in airplane | streetfood |
| use | brushing teeth w. toothpaste w. microplastic | | |
| unforeseen disposal | selling coffee in plastic cup | | |
| accidents | transport, passenger car, EURO 3 | | |

# A framework: distinction of littering events, in processes

| littering event probabilities, processes | | closed | open |
|---|---|---|---|
| | examples | in airplane | streetfood |
| use | brushing teeth w. toothpaste w. microplastic | 0.75* | 1 |
| unforeseen disposal | selling coffee in plastic cup | 0.0001 | 0.1 |
| accidents | transport, passenger car, EURO 3 | 0.001 | 1 |

*system is closed in principle but not for use: toothpaste use in airplane

# A framework: Littering probabilities of flows

| Flow-inherent plastic littering | | |
|---|---|---|
| **class** | **probability** | |
| none | 0 | |
| very low | 0.000001 | |
| low | 0.001 | |
| medium | 0.1 | |
| high | 0.5 | |
| very high | 0.95 | |

# A framework: Littering probabilities of flows

| Flow-inherent plastic littering | | |
|---|---|---|
| **class** | **probability** | **example** |
| none | 0 | electricity |
| very low | 0.000001 | diesel generator |
| low | 0.001 | waste paper, unsorted |
| medium | 0.1 | used laptop computer |
| high | 0.5 | polystyrene scrap, post-consumer |
| very high | 0.95 | tyre wear emissions, lorry |

# (for LCA nerds:

**Table 10.3. Default basic uncertainty (variance $\sigma_b^2$ of the logtransformed data, i.e. the underlying normal distribution) applied to intermediate and elementary exchanges when no sampled data are available; c: combustion emissions; p: process emissions; a: agricultural emissions**

| input / output group | c | p | a | input / output group | c | p | a |
|---|---|---|---|---|---|---|---|
| **demand of:** | | | | **pollutants emitted to air:** | | | |
| thermal energy, electricity, semi-finished products, working material, waste treatment services | 0.0006 | 0.0006 | 0.0006 | $CO_2$ | 0.0006 | 0.0006 | |
| transport services (tkm) | 0.12 | 0.12 | 0.12 | $SO_2$ | 0.0006 | | |
| Infrastructure | 0.3 | 0.3 | 0.3 | NMVOC total | 0.04 | | |
| **resources:** | | | | $NO_X$, $N_2O$ | 0.04 | | 0.03 |
| Primary energy carriers, metals, salts | 0.0006 | 0.0006 | 0.0006 | $CH_4$, $NH_3$ | 0.04 | | 0.008 |
| Land use, occupation | 0.04 | 0.04 | 0.002 | Individual hydrocarbons | 0.04 | 0.12 | |
| Land use, transformation | 0.12 | 0.12 | 0.008 | PM>10 | 0.04 | 0.04 | |
| **pollutants emitted to water:** | | | | PM10 | 0.12 | 0.12 | |
| BOD, COD, DOC, TOC, inorganic compounds ($NH_4$, $PO_4$, $NO_3$, Cl, Na etc.) | | 0.04 | | PM2.5 | 0.3 | 0.3 | |
| Individual hydrocarbons, PAH | | 0.3 | | Polycyclic aromatic hydrocarbons (PAH) | 0.3 | | |
| Heavy metals | | 0.65 | 0.09 | CO, heavy metals | 0.65 | | |
| Pesticides | | | 0.04 | Inorganic emissions, others | | 0.04 | |
| $NO_3$, $PO_4$ | | | 0.04 | Radionuclides (e.g., Radon-222) | | 0.3 | |
| **pollutants emitted to soil:** | | | | | | | |
| Oil, hydrocarbon total | | 0.04 | | | | | |
| Heavy metals | | 0.04 | 0.04 | | | | |
| Pesticides | | | 0.033 | | | | |

Weidema, Bo & Bauer, Christian & Hischier, Roland. (2013). Data quality guideline for the ecoinvent database version 3. Overview and Methodology Ecoinvent. Report 1 St. Gallen: The Ecoinvent Centre, p 75

)

# → overall calculation:

amount of litter in process data set j per flow i=

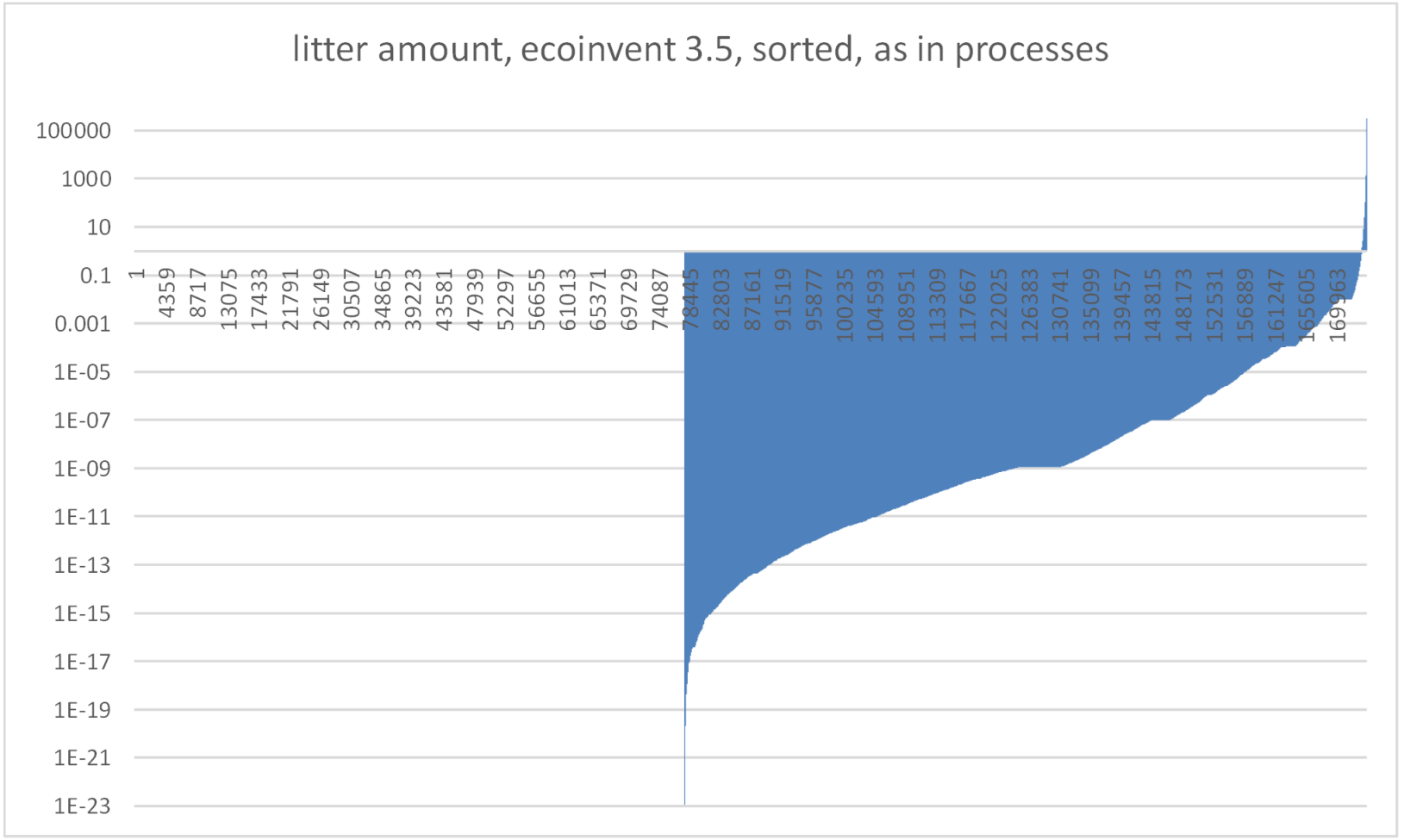
litter probability flow i * litter probability process j * amount of flow i in process data set j

- (convert to mass where needed)
- processes can also be accidents (new process typically not existing in LCA databases)

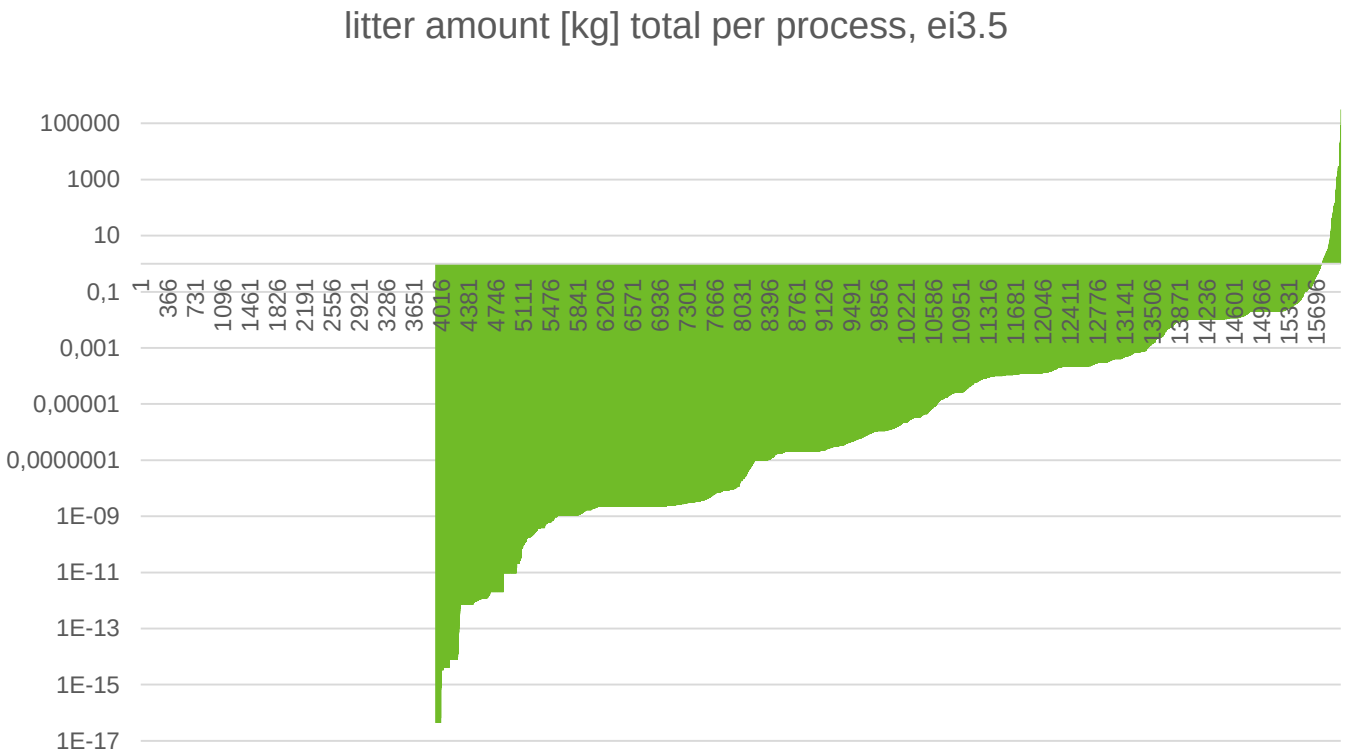
total amount of litter for process j = sum of litter over all flows i of process j

# application to ecoinvent 3.5 (cut-off)

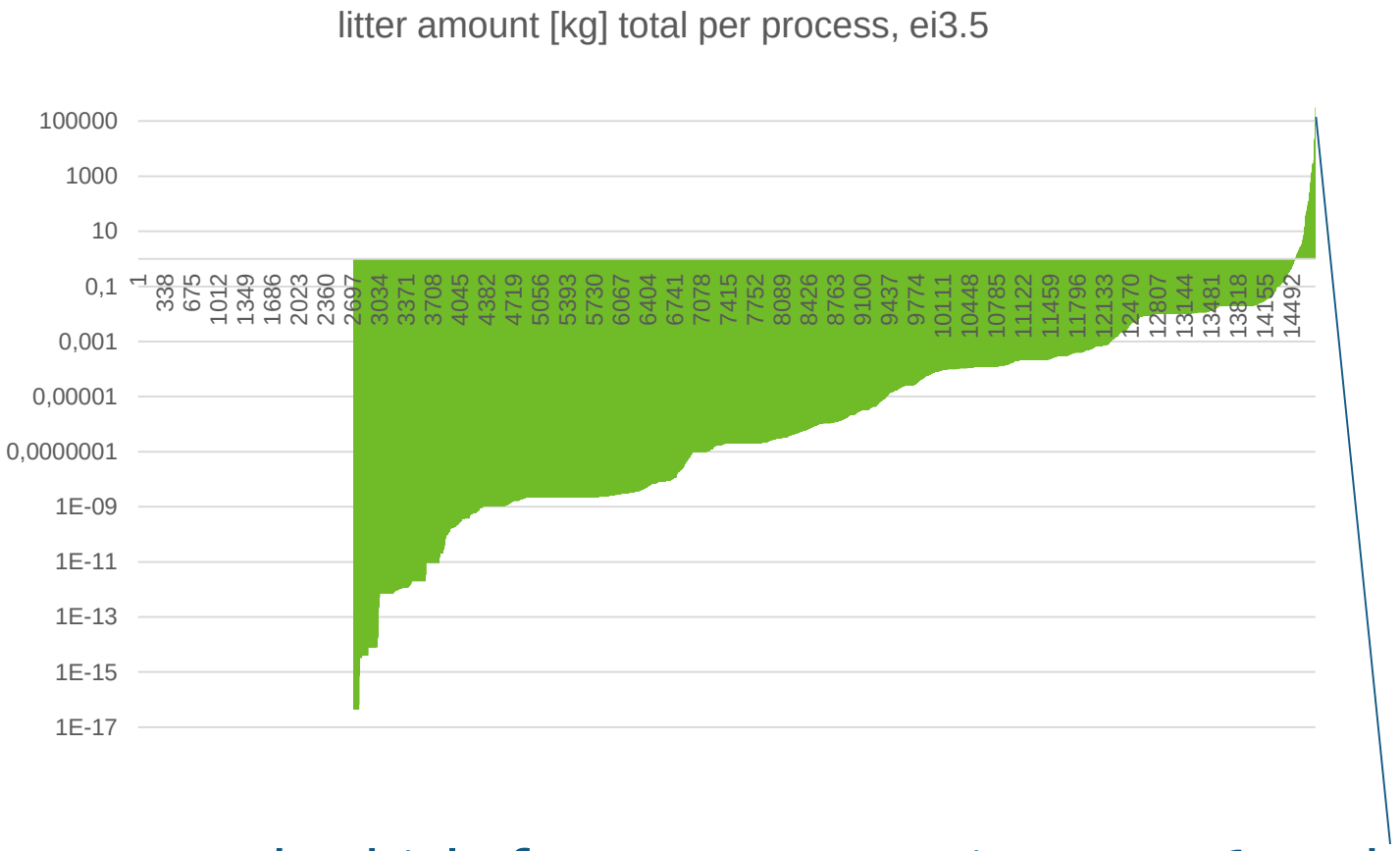
# Results for all exchanges in all flows in ecoinvent 3.5



# Results for all processes, aggregated, in ecoinvent 3.5

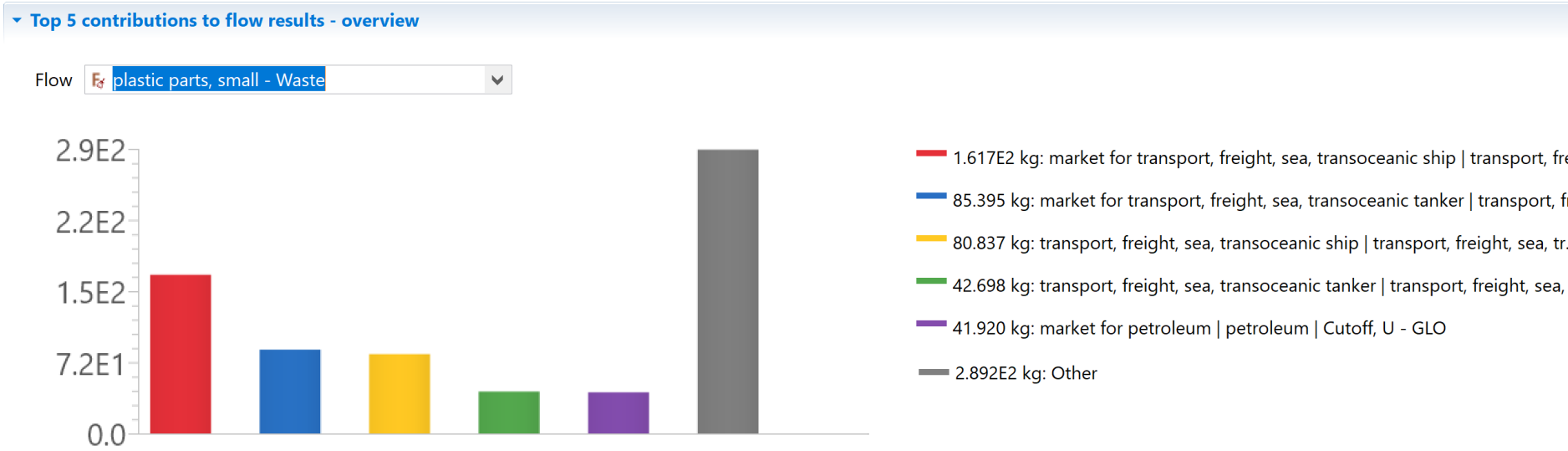


# Results for all processes, aggregated, in ecoinvent 3.5

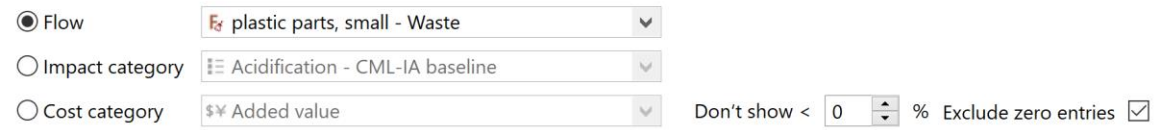



road vehicle factory construction, 314,263.73 kg

# Bus maintenance, CH, ecoinvent 3.5, results for litter (screenshot from openLCA)



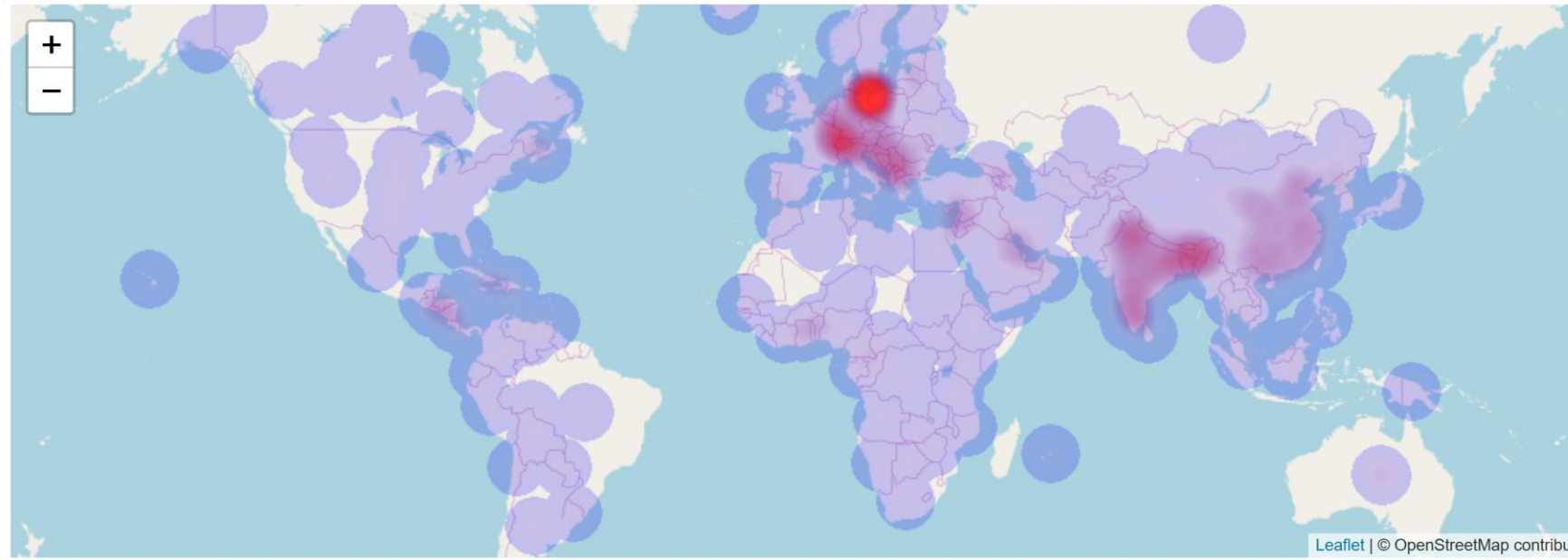
# Bus maintenance, CH, ecoinvent 3.5, results for litter (screenshot from openLCA)




**Contribution tree for locations**

| Location/Process | Amount | Unit |
|---|---|---|
| Global - GLO | 430.63938 | kg |
| Europe, without Russia and Turkey | 62.56167 | kg |
| Rest-of-World - RoW | 60.19042 | kg |
| Europe - RER | 54.34336 | kg |
| Switzerland - CH | 41.20216 | kg |
| Europe without Switzerland | 12.18906 | kg |

**Map**



# existing limitations and next steps

# Further refinement

*(E.g.:)*

- countries –

different littering characteristics not yet considered

| |
|---|
| Africa |
| Alaska Systems Coordinating Council |
| Albania |
| Algeria |
| Aluminium producing area, EU27 and EFTA countries |
| Angola |
| Argentina |
| Armenia |
| Asia |
| Australia |
| Austria |
| Azerbaijan |
| Bahrain |
| Bangladesh |

# Further refinement

*(E.g.:)*

- particle sizes not considered but quite some data available → input from impact model developers?
- the current values are worst case – cleaning and "remediation" activities not considered – could be added

( these plastic litter parts are "borderline" elementary flows and can be recaptured from the technosphere)

# Limitations

*(E.g.:)*

- cigarette butts: very relevant in litter that is found today but (somehow) a smoking truck driver for example is not part of typical LCA datasets
- we need probably a different, “human behaviour” modelling perspective to include some aspect of littering

# Limitations

*(E.g.:)*

- cigarette butts: very relevant in litter that is found today but (somehow) a smoking truck driver for example is not part of typical LCA datasets
- we need probably a different, “human behaviour” modelling perspective to include some aspect of littering

# conclusions

# Conclusions

- an approach was presented to include plastic littering in LCA models
- the approach combines littering event probabilities with flow littering probabilities
- this could close a relevant “blind spot” in LCA
- an application to ecoinvent 3.5 shows so far reasonable results
- it will be refined and then released as add-on
- some aspects require probably a different, additional modelling from a human behaviour perspective (smoking truck driver)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