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sustainability consulting + software

openLCA

Rethinking Additives in Plastic LCA: Predictive openLCA Workflows for an underrepresented Material Class

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GreenDelta GmbH

Motivation

CNN Health

Millions of preterm births and thousands of infant deaths linked to plastic chemical

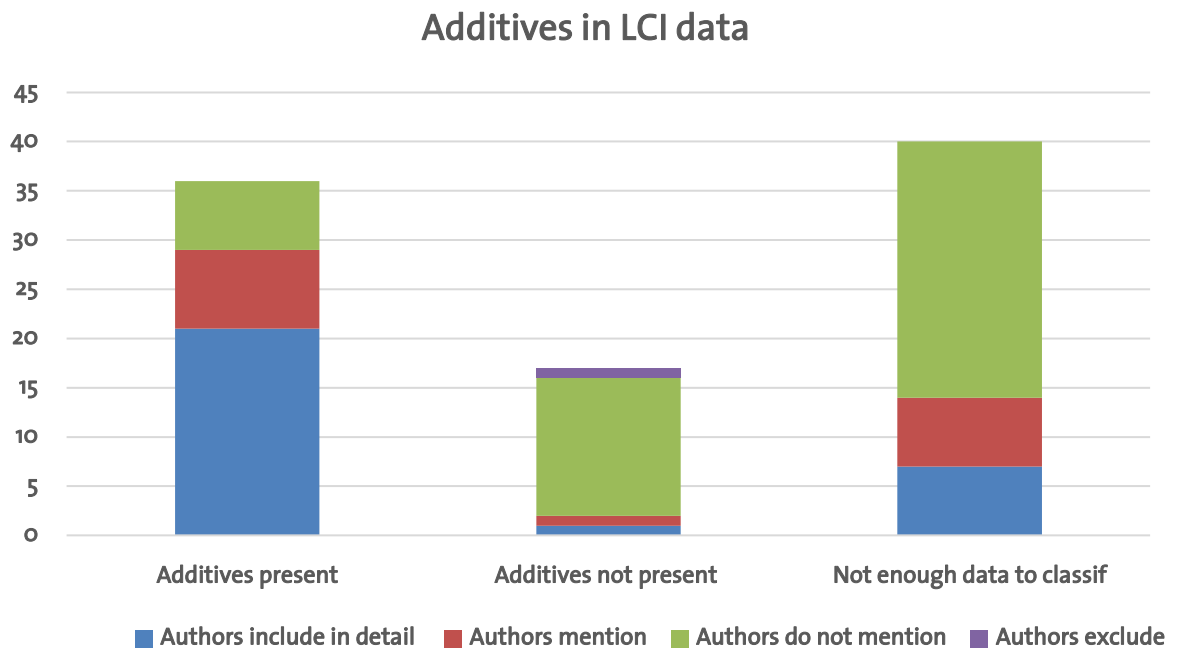
Two chemicals used to make plastic more flexible are linked to nearly 2 million **premature births** and the deaths of 74,000 newborns worldwide in 2018, according to a new study.

(Jennifer Brückner/picture alliance/Getty Images)

"This is a dangerous class of chemicals," said Dr. Leonardo Trasande, senior author of the new study and the Jim G. Hendrick, M.D., Professor of Pediatrics at NYU Langone's Grossman School of Medicine in New York City.

"In the context of all the efforts that we're taking to have more babies born in the United States, we should also make sure that babies are born healthy," said Trasande, who is also a professor of population health and director of the Division of Environmental Pediatrics and the Center for the Investigation of Environmental Hazards at NYU Langone Health.

https://edition.cnn.com/2026/03/31/health/phthalates-infant-death-prematurity-wellness (**10.04.26**)



However, if data was present in 40% of the datasets, aggregated additives or utilized generic proxy data (generic disclosures) to model additives. Further, generic disclosures of additives limit what can be understood about their environmental and human health impacts

Logan et al., J. Ind. Ecol. 2024 Aug 16;28(6):1582–1597.

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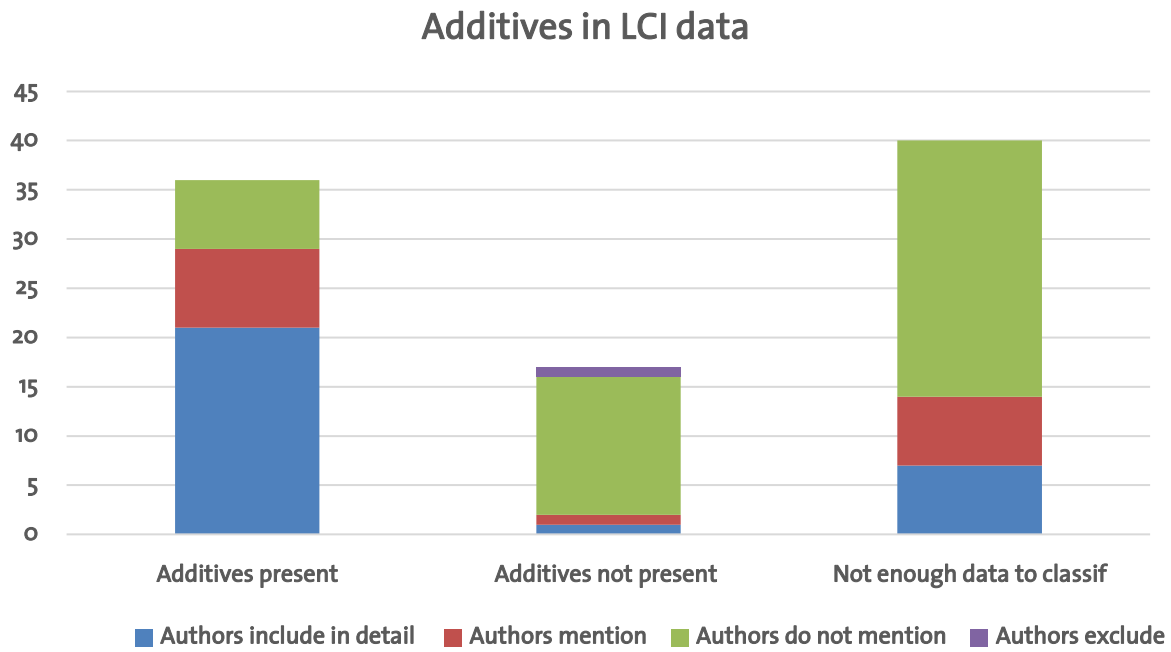
Motivation

Additive classification term	Source for classification term	Examples of additives (OECD, 2019)
Additives for processability	OECD (2019)	Plasticizers, lubricants, blowing agents
Surface protector / modifier	OECD (2019)	Antistatic agents, antifriction agents, adhesion-improving agents, anti-fog agents
Material protectants	OECD (2019)	Antioxidants, light stabilizers, ultraviolet-absorbing agents, thermostabilizers
Physical–chemical property improvers	OECD (2019)	Flame retardants, fillers / reinforcement materials
Functionalization agents	OECD (2019)	Coloring agents

OECD (2019). Complementing document to the emission scenario document on plastic additives: Plastic additives during the use of end products [OECD Series on Emission Scenario Documents No. 38].



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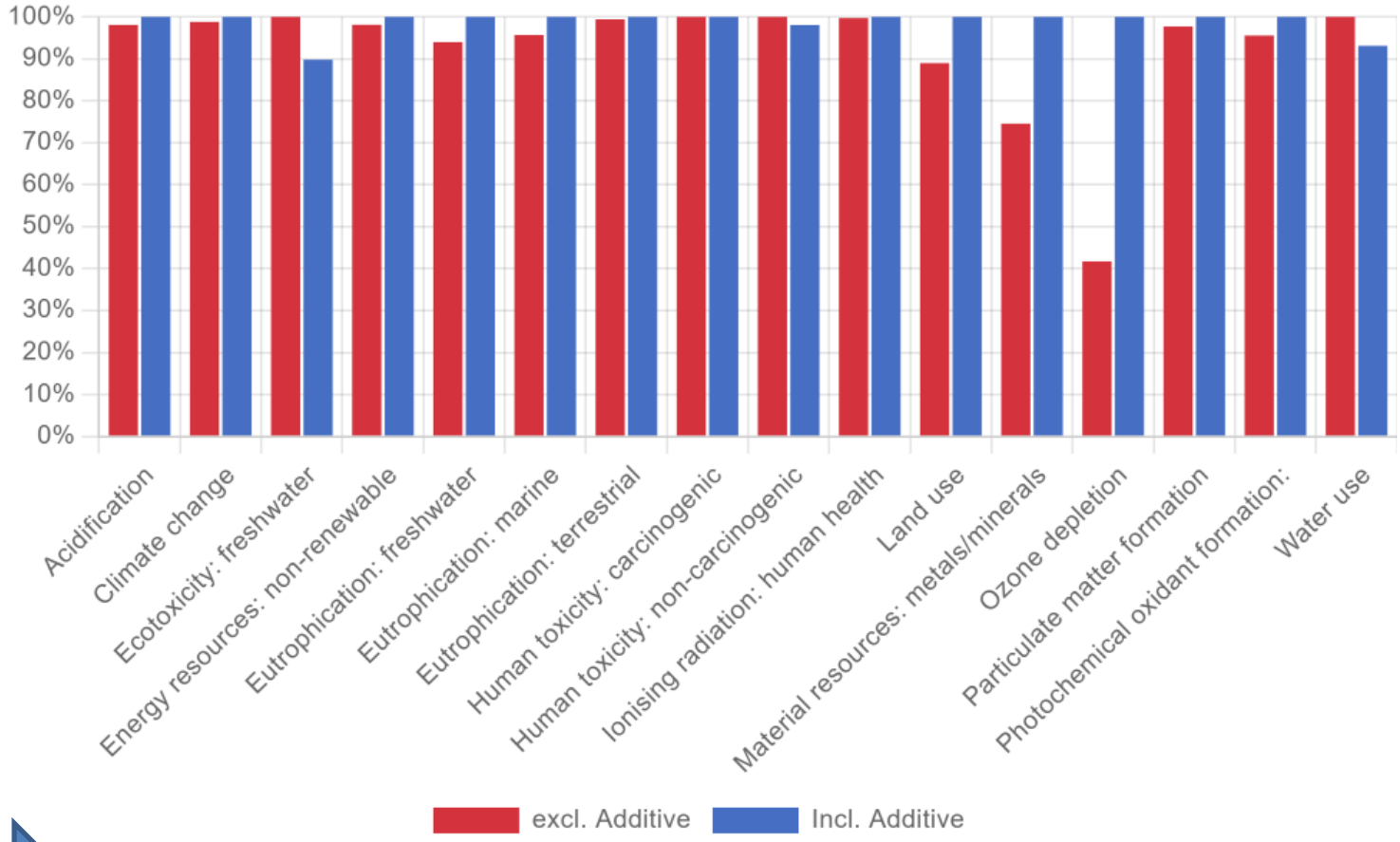
Plastic Functional Units

Author, Year	Product	functional unit	Scope	Reference	Additive, Scope
JRC, plastic case study (2022)	Agricultural mulching films (LDPE, starch, PLA)	To provide mulching and associated agronomic functions to 1 hectare of agricultural land cultivated in the EU for one growing season	Cradle-to-grave	Amount of mulching film required to fulfil the functional unit	Excluded production, influence EoL (direct)
JRC, plastic case study (2022)	Beverage bottles (HDPE, PET, PEF)	To contain and deliver 1000 L of beverage to the final consumer in Europe, with product-specific bottle systems sized to provide that service	Cradle-to-grave	Amount of bottles and packaging components needed to fulfil the functional unit	No
JRC, SSbD case study (2023)	PVC gasket with different additives	To provide an airtight seal between one glass jar and its metal cap, able to last for the whole shelf-life of the food content of the jar, and which is suitable for the contact with oily food	Cradle-to-grave	1 kg of PVC	Yes (stochiometric), Production
PRIMUS D6.3 (2025)	Interior (rABS, rPC), Cooling (rEPDM/rPP), Fridge (rHIPS), Sealing (rEPDM)	a plastic part at factory gate, performing the usual functionality of the same plastic part with no recycled content	Cradle-to-gate	Mass of plastic part	Yes, stochiometric

What are the impacts of additives? It depends!

JRC, plastic case study (2022) on mulching films

This sensitivity analysis evaluates the **effects of excluding additives** (mainly plasticisers) from the composition [...]. This choice was made considering the uncertainties and approximations performed in the modelling of additives [...]. For the purpose of simplicity, the exclusion was limited to the **Polymer Production stage** [...] while for **End of Life modelling the composition was not changed**.



"Additives (25w%) holds rather small overall contribution"

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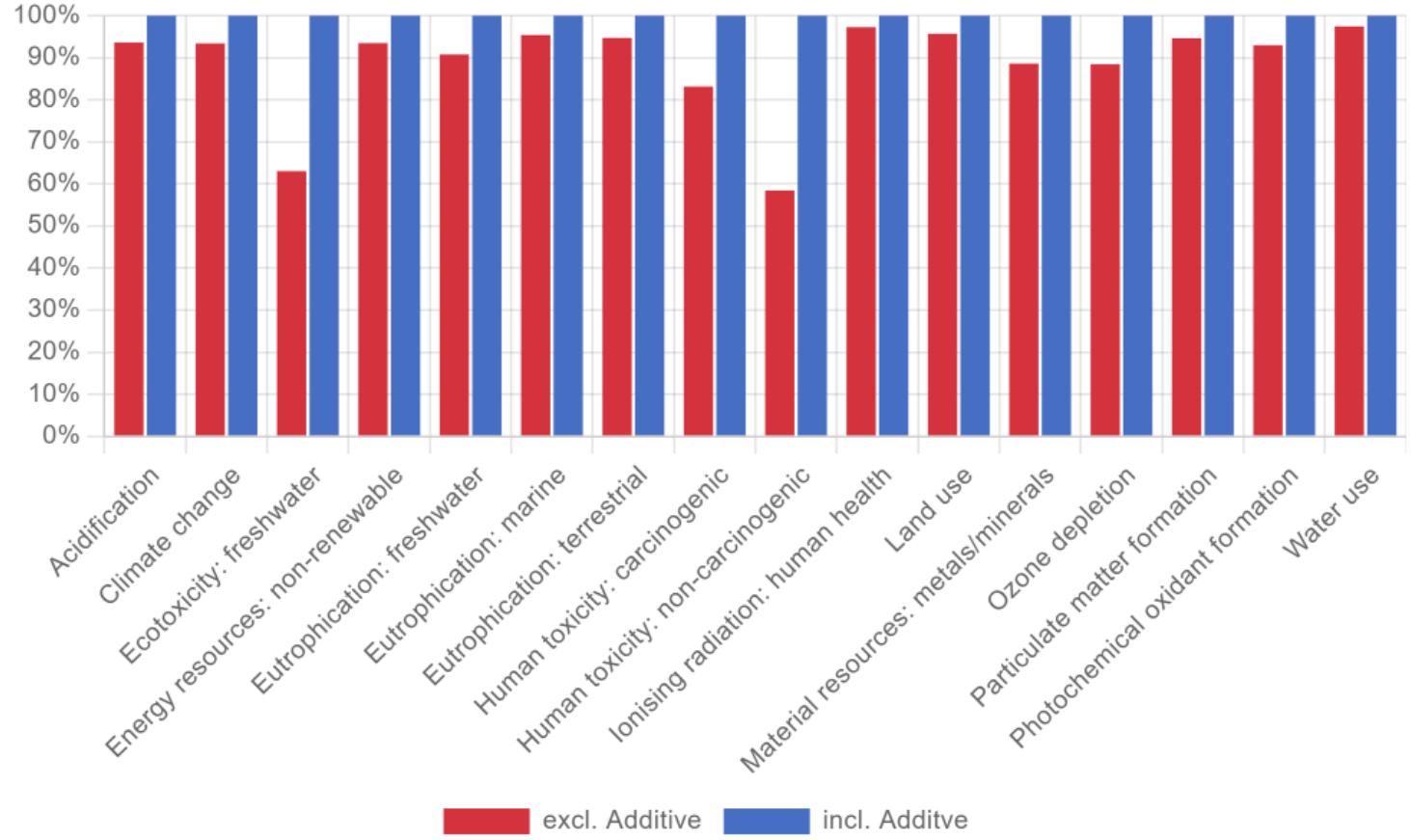
PRIMUS, case study on rHIPS for fridge

A hidden environmental-burden **hotspot of the system is the production of the antioxidant**. **Only 2% is used** to make the formulation to make the plastic part, however the model suggests that it can have very high contributions, i.e. **around 40% of contribution to Ecotoxicity (freshwater) and Human Toxicity**.



"Additive (2w%) holds significant contribution"

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How to fill the data gap for the organic antioxidant?

<ecoinvent v3.11

> chemical, organic

Flow	Category	Amount	Unit
urea	C:Manufacturing...	0.05015	kg
acetic acid, wi...	C:Manufacturing...	0.05000	kg
methyl t-butyl...	C:Manufacturing...	0.05000	kg
styrene	C:Manufacturing...	0.05000	kg
vinyl acetate	C:Manufacturing...	0.05000	kg
ethylene glycol	C:Manufacturing...	0.04715	kg
ethylene	C:Manufacturing...	0.04569	kg
propylene	C:Manufacturing...	0.04561	kg
ethylene dichl...	C:Manufacturing...	0.04438	kg
xylene, mixed	C:Manufacturing...	0.04421	kg

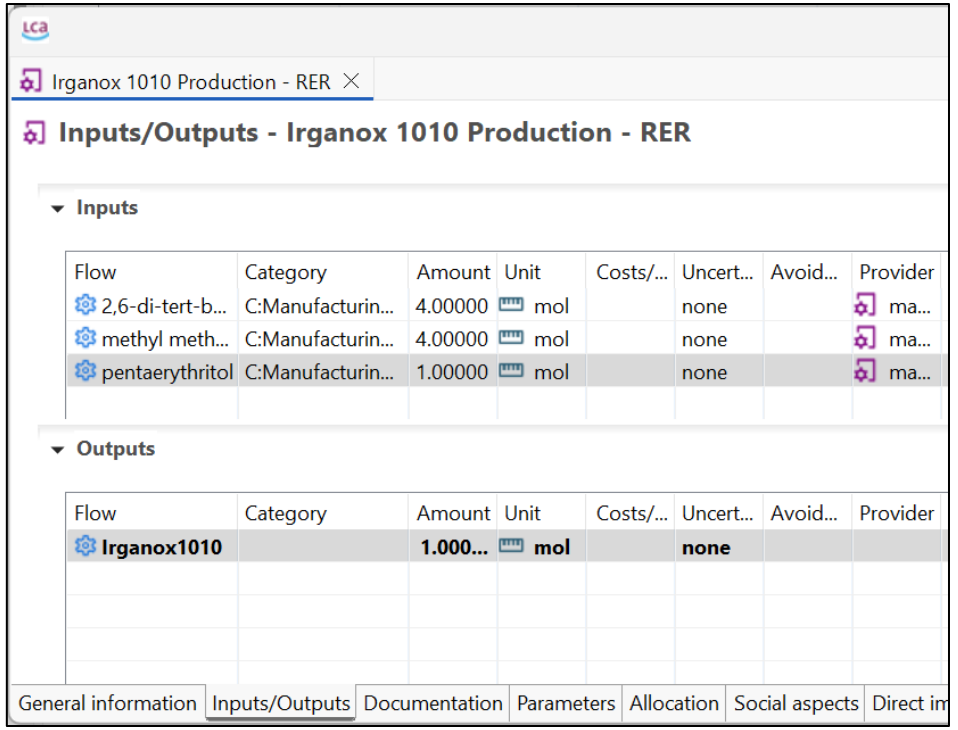
>ecoinvent v3.11

- chemical, organic, alcohols
- chemical, organic, aromatics
- chemical, organic, carboxylic acids
- chemical, organic, esters
- chemical, organic, unspecified

Selecting the right proxy is an art itself!

With ecoinvent v3.12 molality of >9000 chemicals:

- Production details from Ullmann or public sources
- Create a process with the flow and „mol“
- Add inputs in stochiometric fashion (CAS search)



- This can be adapted to yield and energy demand but also direct emissions (mol)

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Plastic Functional Units

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Additives often alter the technical performance!

Plastic Functional Units

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JRC, SSbD case study (2023)	PVC gasket with different additives	To provide an airtight seal between one glass jar and its metal cap, able to last for the whole shelf-life of the food content of the jar, and which is suitable for the contact with oily food	Cradle-to-grave	1 kg of PVC	Yes (stochiometric), Production	Yes, same performance
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Additives are incorporated into plastic materials to modify and enhance specific properties such as durability, processability, stability, and functionality during use. → How to quantity?

JRC, plastic case study (2022), bottle case study

- "According to the suggestions of a relevant stakeholder, the improved barrier and mechanical properties of PEF should approximately allow for an overall 20% reduction in material usage"

Material	Bottle mass (g)	Reference flow (kg/FU)
PET	24	48
HDPE	26.5	53
PEF	24 x 80%	38.4

The amount of polymer required to fulfil the function of the bottle was **calculated based on the gas permeability values** [...]. These calculations resulted in bottle masses of 13 g for PEF and 24 g for the reference PET bottle. Bottle masses were confirmed as being appropriate under the assumptions used by industry experts - PEF – A Sustainable Packaging Material for Bottles – **Nova Institute 2022**

How is better performance even taken into account using LCA methods?

→ Here, the FU was „ensuring a minimum of 12 weeks CO_2 shelf life"

→ However, barrier properties of PEF, which are ~10x better for O_2 , ~15x better for CO_2, and ~2.5x better for water than PET

Defining Functional Units in Comparative Scenarios

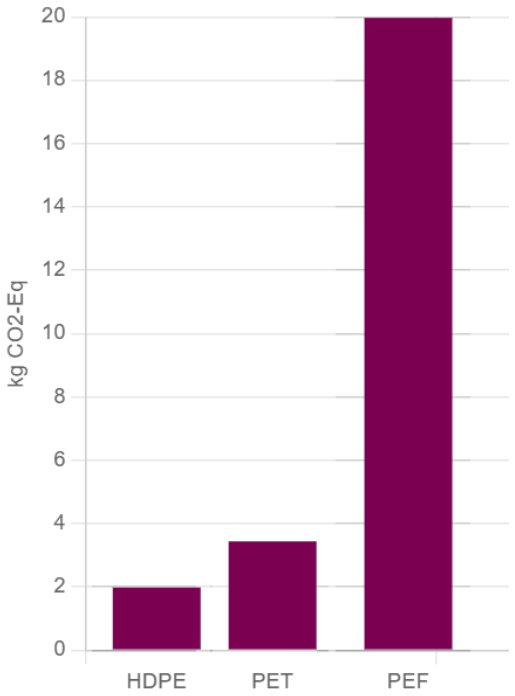
	Reference flow functional unit	Property functional unit	Performance functional unit
Description	Represents a certain amount of material	Represents the main relevant properties of the material for a certain application area	Represents the performance of the material in a specific end product
Typical goal	Generic comparison of environmental impacts of materials, e.g., for ecodesign purposes	Comparison of environmental impacts of materials based on relevant properties for an application area	Comparison of the environmental impacts of materials in specific end products
Typical example	1 kg material	1 kg material with certain properties	1 end product with a certain performance
Procedure for functional unit construction	Equal to the LCA reference flow	Relevant properties are combined in some way	Performance data is estimated from, e.g., experiments

Furberg et al., *J. Ind. Ecol.* 2022; 26:718–730.

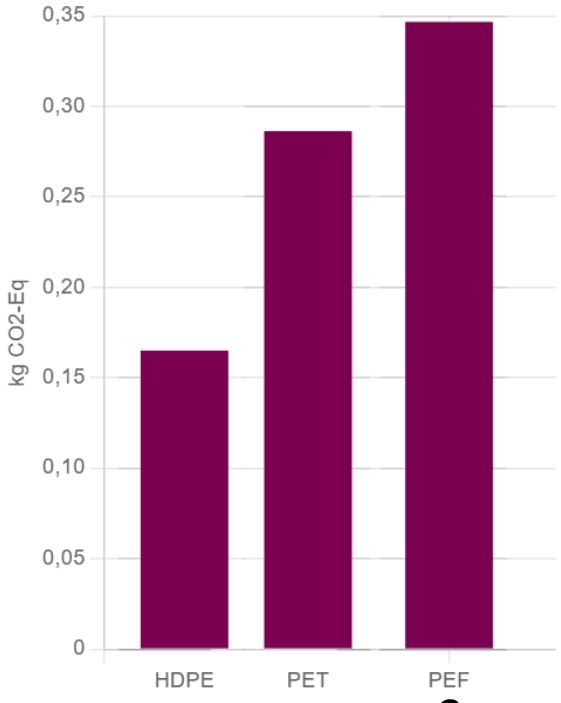
Defining Functional Units in Comparative Scenarios

~10x better for O2 , ~15x better for CO2, and ~2.5x better for water than PET

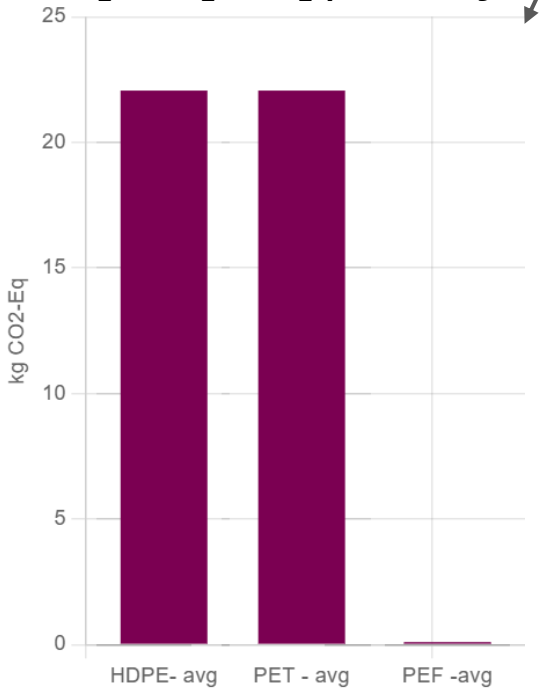
per kg of material (cradle-to-gate)



per property-scaled kg (weeks of storage adj.)

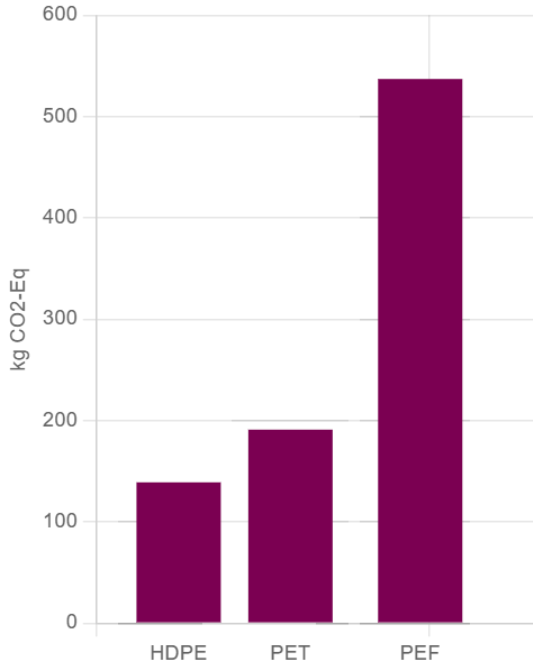


per property-scaled kg ($H_2O/O_2/CO_2$ perf. adj.)



Very subjective!

per 1000 litres of beverage delivered



Using property-based functional unit can be misleading

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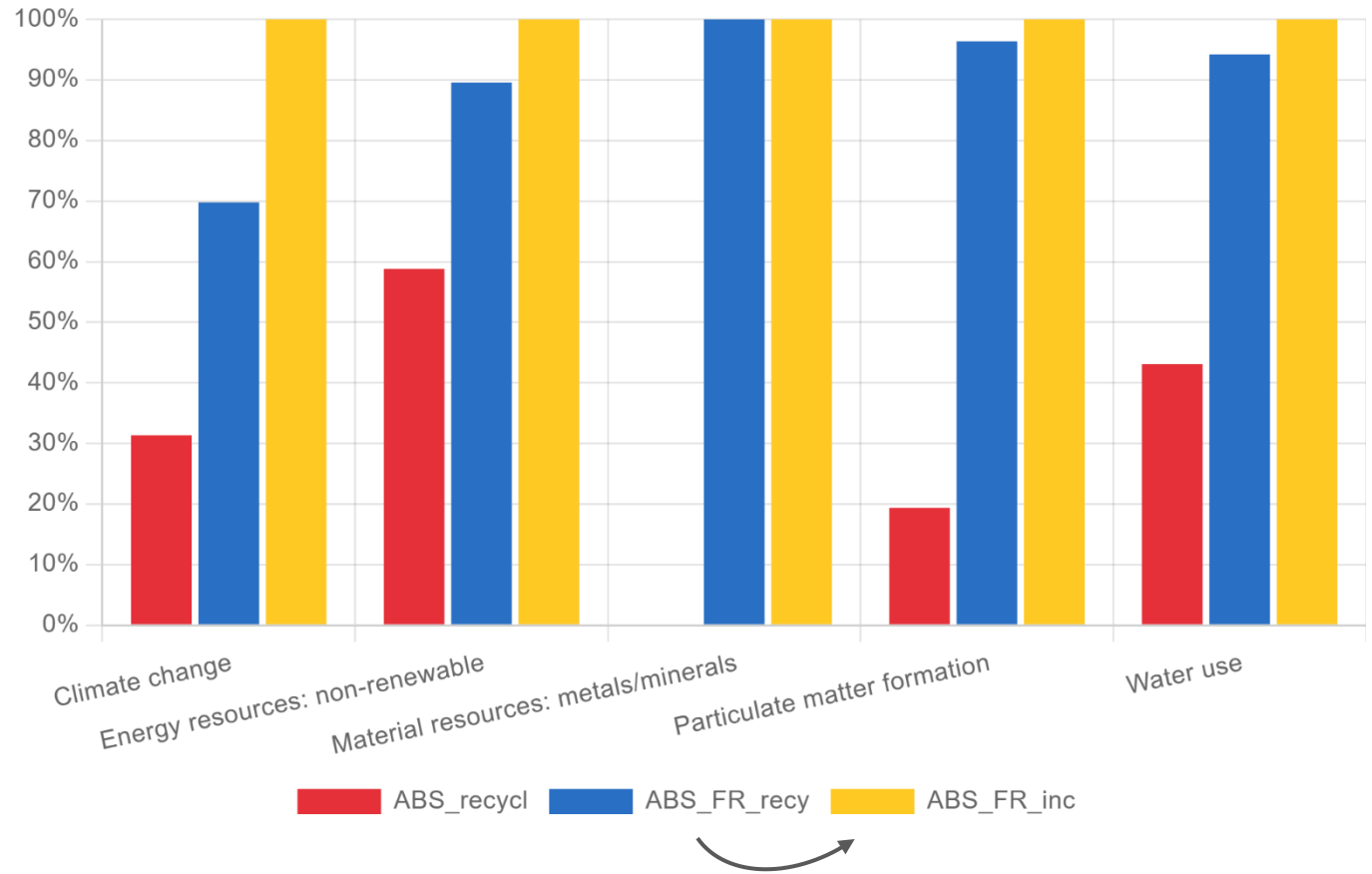
Systems level thinking

- However, we have also system related dimensions: If we add an additive to a material, its EoL pathway might differ (FR is DecaBDE and Sb_2O_3)!



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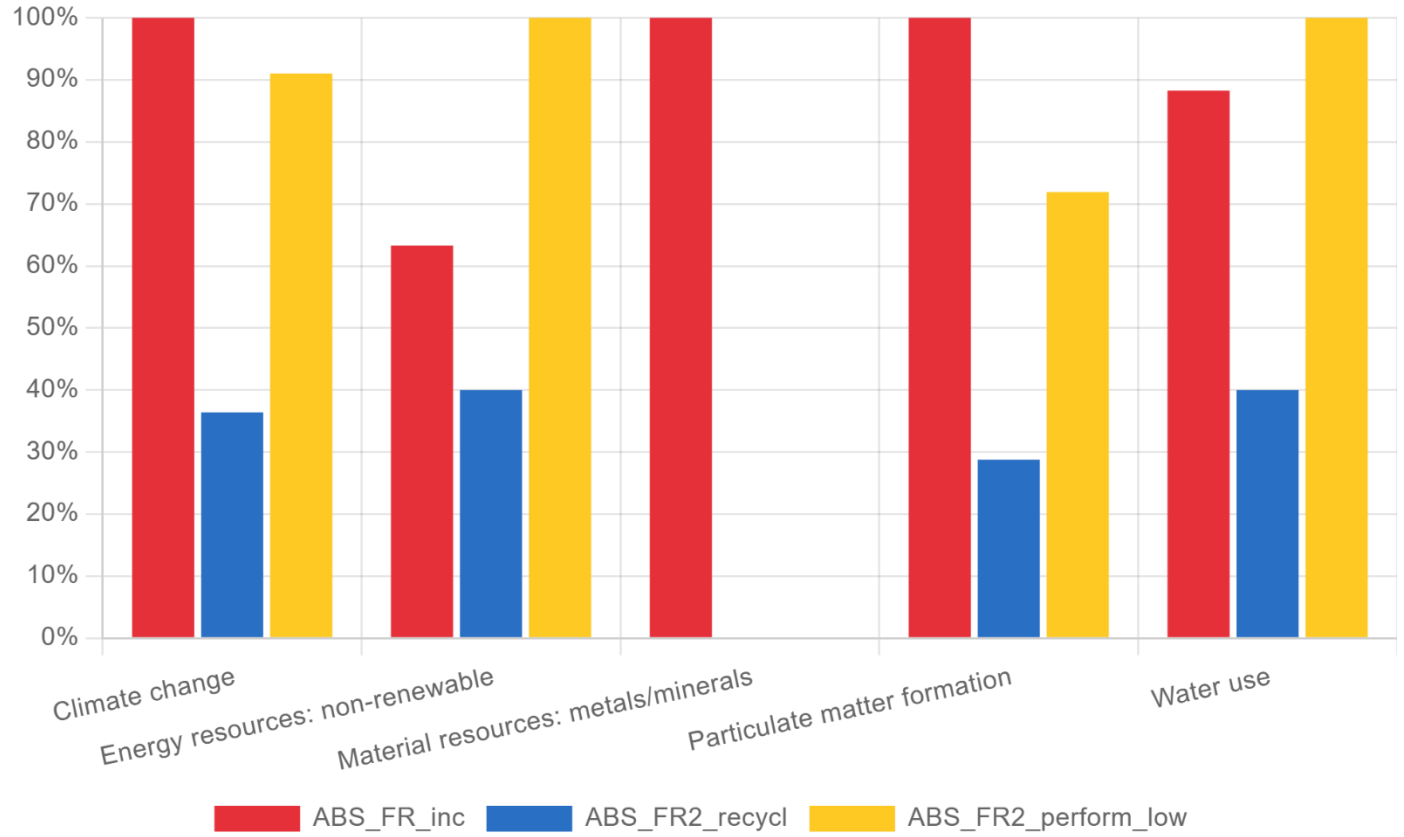
Systems level thinking

- However, we have also system related dimensions: If we add an additive to a material, its EoL pathway might differ (FR is DecaBDE and Sb_2O_3; FR2: $Al(OH)_3$; with 2.5 worse performance)



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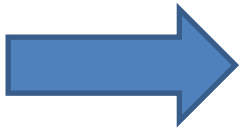
Conclusion

- Please consider **implementation of additives** in your products life cycle
  - It can have strong implications to environmental impacts besides small mass
  - openLCA supports implementation of stochiometric pathways
  - The whole product's life cycle can be effected by it (system thinking)
  - Also the performance **might be improved and can influence impacts**:

  Reference flow functional unit | Property functional unit | Performance functional unit

- **Do not limit the scope to the production of additives**:
  - Integrate it in the **Use phase** (see performance but also direct emissions)
  - Investigated if the **EoL** if changed with present additives (recyclability)



Visit Max presentation on how additives can change EoL pathway!

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Thank you!

Picture: Julia Cilleruelo Palomero

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