Supplementary information

Sustainability of bio-based polyethylene: the influence of biomass sourcing and end-of-life

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Biogenic carbon calculations

The amount of biogenic CO_2 stored in 1 kg of bio-HDPE was calculated according to the following equation:

$$m_{BCstored} = \frac{m_{BC}}{m_{HDPE}} \cdot \frac{m_{CO_2}}{m_C} \cdot m_{polymer} = \frac{12.0096}{12.0096 + 2 \cdot 1.00784} \cdot \frac{12.0096 + 2 \cdot 15.99903}{12.0096} \cdot 1 = 3.14\ kg$$

In this equation, $m_{BCstored}$ is the atmospheric CO_2 stored in the polymer in kg. M_{BC} is the molecular weight of biogenic carbon in 1 repeating unit of the polymer. The molecular structure of polyethylene is $(CH_2)_n$, so it equals the molecular weight of one carbon atom in our case. m_{HDPE} is the molecular weight of one repeating unit of the polymer, m_{CO_2} is the molecular weight of one carbon dioxide molecule, and m_c is the atomic weight of carbon. Finally, $m_{polymer}$ is the mass for which the contained CO_2 is to be calculated, 1 kg in this case. The equation first calculates fraction of the weight of a polymer is biogenic carbon. Every kg polyethylene contains of 0.85 kg of carbon atoms. Next, the relation between CO_2 and atomic carbon is used to compute the weight of the corresponding CO_2, amounting to 3.14 kg for bio-HDPE.

Table S1: Lifecycle inventory of petrochemical-based HDPE scenarios.

Scenario	**amount**	**Activity**	**Adjustments**
Petro-RoW	1 kg	Polyethylene, high density, granulate [RoW]	
Petro-RER	1 kg	Polyethylene, high density, granulate [RER]	

Table S2: Lifecycle inventory of the ethylene conversion process.

Amount	**Activity**	**Location**
0.0672 kg	nitrogen, liquid	RoW or RER
0.00011 kg	zeolite, powder	RoW or RER
0.0266 kg	sodium bicarbonate	RoW or RER
2.57 kg	tap water	Specific country
0.0372 kg	nitrogen, liquid	RoW or RER
0.0035 kg	propylene	RoW or RER
0.47 kWh	electricity, medium voltage	Specific country
4.84 MJ	heat, district or industrial	Specific country

Table S3: Lifecycle inventory of bio-based HDPE scenario's. *Data from the Global Feed LCA database.

Scenario	Amount	Activity	Adjustments
SC-BR	18.57 kg	Sugarcane [BR]	
	2.084 kg	ethanol, without water, in 99.7% solution state, from fermentation [BR]	
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [BR]
	1 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [BR}
SC-CN	18.57 kg	Sugarcane [CN]*	
	2.084 kg	ethanol, without water, in 99.7% solution state, from fermentation [BR]	Adjusted energy to [CN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CN]
	1 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CN]
SC-CO	18.57 kg	Sugarcane [CO]	
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [BR]	Adjusted energy to [CO]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CO]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CO]
SC-IN	18.57 kg	Sugarcane [IN]	
	2.084 kg	ethanol, without water, in 99.7% solution state, from fermentation [BR]	Adjusted energy to [IN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [IN]
	1 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [IN]
SC-US	18.57 kg	Sugarcane [US]*	
	2.084 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [US]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [US]
	1 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [US]
M-BR	6.72 kg	maize grain [BR]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [BR]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [BR]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to Brazil
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to Brazil
M-CA-QC	6.72 kg	maize grain [CA-QC]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [CA-QC]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [CA-QC]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CA-QC]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CA-QC]

Table S3: continued.

Scenario	Amount	Activity	Adjustments
M-CN	6.72 kg	maize grain [CN]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [CN]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [CN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CN]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CN]
M-IN	6.72 kg	maize grain [IN]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [IN]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [IN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [IN]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [IN]
M-US	6.72 kg	maize grain [US]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [US]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [US]
M-ZA	6.72 kg	maize grain [ZA]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [ZA]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [ZA]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [ZA]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [ZA]
M-CH	6.72 kg	maize grain [CH]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [CH]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [CH]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [CH]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [CH]
M-DE	6.72 kg	maize grain [DE]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [DE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [DE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [DE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [DE]

Table S3: continued

Scenario	Amount	Activity	Adjustments
M-FR	6.72 kg	maize grain [FR]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [US]	Adjusted energy and tap water to [FR]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [US]	Adjusted energy to [FR]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [FR]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [FR]
SB-US	13.56 kg	sugar beet [US]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [US]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [US]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [US]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [US]
SB-CH	13.56 kg	sugar beet [CH]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [CH]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [CH]
SB-DE	13.56 kg	sugar beet [DE]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [DE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [DE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [DE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [DE]
SB-FR	13.56 kg	sugar beet [FR]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [FR]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [FR]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [FR]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [FR]
SB-SE	13.56 kg	sugar beet [SE]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [SE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [SE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [SE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [SE]

Table S3: continued

Scenario	Amount	Activity	Adjustments
P-CA-QC	29.63 kg	Potato [CA-QC]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [CA-QC]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [CA-QC]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CA-QC]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CA-QC]
P-CN	29.63 kg	Potato [CN]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [CN]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [CN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CN]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CN]
P-IN	29.63 kg	Potato [IN]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [IN]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [IN]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [IN]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [IN]
P-US	29.63 kg	Potato [US]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [US]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [US]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [US]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [US]
P-CH	29.63 kg	Potato [CH]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [CH]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [CH]

Table S3: continued

Scenario	Amount	Activity	Adjustments
P-DE	29.63 kg	Potato [DE]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [DE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [DE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [DE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [DE]
P-FR	29.63 kg	Potato [FR]*	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [FR]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [FR]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [FR]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [FR]
WO-CA-QC	7.93 kg	wood chips, wet, measured as dry mass [CA-QC]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [CA-QC]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [CA-QC]
	1.002 kg	Ethylene [RoW]	Adjusted energy and tap water to [CA-QC]
	1.0 kg	polyethylene, high density, granulate [RoW]	Adjusted energy to [CA-QC]
WO-CH	7.93 kg	wood chips, wet, measured as dry mass [CH]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [CH]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [CH]
WO-DE	7.93 kg	wood chips, wet, measured as dry mass [DE]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [DE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [DE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [DE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [DE]

Table S3: continued

Scenario	Amount	Activity	Adjustments
WO-SE	7.93 kg	wood chips, wet, measured as dry mass [SE]	
	2.08 kg	ethanol, without water, in 95% solution state, from fermentation [CH]	Adjusted energy and tap water to [SE]
	2.08 kg	ethanol, without water, in 99.7% solution state, from fermentation [CH]	Adjusted energy to [SE]
	1.002 kg	Ethylene [RER]	Adjusted energy and tap water to [SE]
	1.0 kg	polyethylene, high density, granulate [RER]	Adjusted energy to [SE]

Table S4: Overview of transport scenario 1.

Scenario	Transport 1	
SC-BR	Truck [BR]	1.86 t-km
SC-CN	Truck [CN]	1.86 t-km
SC-CO	Truck [CO]	1.86 t-km
SC-IN	Truck [IN]	1.86 t-km
SC-US	Truck [US]	1.86 t-km
M-BR	Truck [BR]	0.67 t-km
M-CA-QC	Truck [CA-QC]	0.67 t-km
M-CN	Truck [CN]	0.67 t-km
M-IN	Truck [IN]	0.67 t-km
M-US	Truck [US]	0.67 t-km
M-ZA	Truck [ZA]	0.67 t-km
M-CH	Truck [CH]	0.67 t-km
M-DE	Truck [DE]	0.67 t-km
M-FR	Truck [FR]	0.67 t-km
SB-US	Truck [US]	1.36 t-km
SB-CH	Truck [CH]	1.36 t-km
SB-DE	Truck [DE]	1.36 t-km
SB-FR	Truck [FR]	1.36 t-km
SB-SE	Truck [SE]	1.36 t-km
P-CA-QC	Truck [CA-QC]	2.96 t-km
P-CN	Truck [CN]	2.96 t-km
P-IN	Truck [IN]	2.96 t-km
P-US	Truck [US]	2.96 t-km
P-CH	Truck [CH]	2.96 t-km
P-DE	Truck [DE]	2.96 t-km
P-FR	Truck [FR]	2.96 t-km
P-SE	Truck [SE]	2.96 t-km
WO-CA-QC	Truck [CA-QC]	0.79 t-km
WO-CH	Truck [CH]	0.79 t-km
WO-DE	Truck [DE]	0.79 t-km
WO-SE	Truck [SE]	0.79 t-km

Table S5: Overview of transport scenarios 2 and 3.

Scenario	Transport				References
SC-BR	T2	Train	To ethylene plant	2.98 t-km	(Braskem, 2022; Google, n.d.; Wernet et al., 2016)
	T3	Train	To Porto Alegre [BR]	1.26 t-km	(Google, n.d.; Wernet et al., 2016)
	T3	Freight ship	Porto Alegre [BR] → Port of Antwerp [BE]	23.56 t-km	(Sea Distances, n.d.)
SC-CN	T2/T3	Train	Gianxi [CN] → Guangzhou [CN]	1.27 t-km	(Google, n.d.; Peng, 2023; M. Zhang & Govindaraju, 2018)
	T2	Freight ship	Guangzhou [CN] → Porto Alegre [BR]	40.83 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Guangzhou [CN] → Port of Antwerp [BE]	37.96 t-km	(Sea Distances, n.d.)
SC-CO	T2/T3	Truck	Rio Cauca [CO] → Covenas [CO]	1.24 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Covenas [CO] → Porto Alegre [BR]	19.04 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Covenas [CO] → Port of Antwerp [BE]	17.96 t-km	(Sea Distances, n.d.)
SC-IN	T2/T3	Train	Rattipur [IN] → Kandla port [IN]	2.78 t-km	(Google, n.d.; Indian Railways, n.d.; Wernet et al., 2016)
	T2	Freight ship	Kandla port [IN] → Porto Alegre [BR]	30.85 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Kandla port [IN] → Port of Antwerp [BE]	24.06 t-km	
SC-US	T2/T3	Truck	Lake Okeechobee [US] → Port of Palm Beach [US]	0.19 t-km	(Google, n.d.; U.S. Department of Transportation, 2022; United States Department of Agriculture, 2022; Wernet et al., 2016)
	T2	Freight ship	Port of Palm Beach [US] → Porto Alegre [BR]	20.66 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port of Palm Beach [US] → Port of Antwerp [BE]	15.63 t-km	(Sea Distances, n.d.)
M-BR	T2	Train	To ethylene plant	3.79 t-km	(Braskem, 2022; Google, n.d.; Wernet et al., 2016)
	T3	Train	To Porto Alegre [BR]	3.79 t-km	
	T3	Freight ship	Porto Alegre [BR] → Port of Antwerp [BE]	23.56 t-km	(Sea Distances, n.d.)
M-CA-QC	T2/T3	Train	Ottowa [CA] → Quebec Port [CA]	0.93 t-km	(Aberdeen Carolina & Western Railway Company, n.d.-a; Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Quebec Port [CA] → Porto Alegre [BR]	23.39 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Quebec Port [CA] → Port of Antwerp [BE]	12.18 t-km	(Sea Distances, n.d.)

Table S5: continued.

M-CN	T2/T3	Train	Hebei [CN] → Tianjin port [CN]	0.77 t-km	(Google, n.d.; Peng, 2023; Y. Zhang et al., 2019)
	T2	Freight ship	Tianjin port [CN] → Porto Alegre [BR]	45.55 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Tianjin port [CN] → Port of Antwerp [BE]	42.67 t-km	(Sea Distances, n.d.)
M-IN	T2/T3	Train	Rattipur [IN] → Kandla port [IN]	2.78 t-km	(Google, n.d.; Indian Railways, n.d.; Wernet et al., 2016)
	T2	Freight ship	Kandla port [IN] → Porto Alegre [BR]	31.99 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Kandla port [IN] → Port of Antwerp [BE]	24.06 t-km	(Sea Distances, n.d.)
M-US	T2/T3	Train	Iowa [US] → Chicago port [US]	1.04 t-km	(Aberdeen Carolina & Western Railway Company, n.d.-b; Google, n.d.; United States Department of Agriculture, n.d.)
	T2	Freight ship	Chicago port [US] → Porto Alegre [BR]	28.08 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Chicago port [US] → Port of Antwerp [BE]	16.87 t-km	(Sea Distances, n.d.)
M-ZA	T2/T3	Truck	Farm to Cape Town port (estimate) [ZA]	0.21 t-km	(Google, n.d.)
	T2	Freight ship	Cape Town port [ZA] → Porto Alergre [BR]	14.03 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Cape Town port [ZA] → Port of Antwerp [BE]	23.80 t-km	(Sea Distances, n.d.)
M-CH	T2/T3	Train	Bern [CH] → Le Havre [FR]	1.59 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	La Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
M-DE	T2/T3	Train	Central Germany [DE] → Port of Hamburg [DE]	1.88 t-km	(Google, n.d.)
	T2	Freight ship	Port of Hamburg [DE] → Porto Alegre [BR]	24.52 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port of Hamburg [DE] → Port of Antwerp [BE]	1.56 t-km	(Sea Distances, n.d.)
M-FR	T2/T3	Train	Central France [FR] → Le Havre [FR]	1.09 t-km	(Google, n.d.)
	T2	Freight ship	Le Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
SB-US	T2/T3	Train	Minesota [US] → Port Duluth [US]	0.51 t-km	(Aberdeen Carolina & Western Railway Company, n.d.-b; Google, n.d.; United States Department of Agriculture, 2022)
	T2	Freight ship	Port Duluth [US] → Porto Alegre [BR]	28.40 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port Duluth [US] → Port of Antwerp [BE]	17.19 t-km	(Sea Distances, n.d.)

Table S5: continued.

SB-CH	T2/T3	Train	Bern [CH] → Le Havre [FR]	1.59 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	La Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
SB-DE	T2/T3	Train	Central Germany [DE] → Port of Hamburg [DE]	1.88 t-km	(Google, n.d.)
	T2	Freight ship	Port of Hamburg [DE] → Porto Alegre [BR]	24.52 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port of Hamburg [DE] → Port of Antwerp [BE]	1.56 t-km	(Sea Distances, n.d.)
SB-FR	T2/T3	Train	Central France [FR] → Le Havre [FR]	1.09 t-km	(Google, n.d.)
	T2	Freight ship	Le Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
SB-SE	T2/T3	Truck	Southern Sweden → Malmo Port [SE] (estimate)	0.10 t-km	(Google, n.d.)
	T2	Freight ship	Malmo Port [SE] → Porto Alegre [BR]	25.70 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Malmo Port [SE] → Port of Antwerp [BE]	2.74 t-km	(Sea Distances, n.d.)
P-CA-QC	T2/T3	Train	Ottowa [CA] → Quebec Port [CA]	0.93 t-km	(Aberdeen Carolina & Western Railway Company, n.d.-a; Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Quebec Port [CA] → Porto Alegre [BR]	23.39 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Quebec Port [CA] → Port of Antwerp [BE]	12.18 t-km	(Sea Distances, n.d.)
P-CN	T2/T3	Train	Hebei [CN] → Tianjin port [CN]	0.77 t-km	(Google, n.d.; Peng, 2023; Y. Zhang et al., 2019)
	T2	Freight ship	Tianjin port [CN] → Porto Alegre [BR]	45.55 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Tianjin port [CN] → Port of Antwerp [BE]	42.67 t-km	(Sea Distances, n.d.)
P-IN	T2/T3	Train	Rattipur [IN] → Kandla port [IN]	2.78 t-km	(Google, n.d.; Indian Railways, n.d.; Wernet et al., 2016)
	T2	Freight ship	Kandla port [IN] → Porto Alegre [BR]	31.99 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Kandla port [IN] → Port of Antwerp [BE]	24.06 t-km	(Sea Distances, n.d.)
P-US	T2/T3	Train	Idaho [US] → Coos Bay Port [US]	2.55 t-km	(Google, n.d.; Statista, n.d.)
	T2	Freight ship	Coos Bay Port [US] → Porto Alegre [BR]	31.76 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Coos Bay port [US] → Port of Antwerp [BE]	32.68 t-km	(Sea Distances, n.d.)
P-CH	T2/T3	Train	Bern [CH] → Le Havre [FR]	1.59 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	La Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)

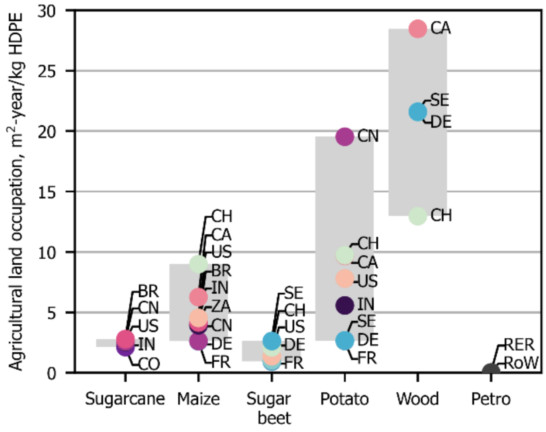
Table S5: continued.

P-DE	T2/T3	Train	Central Germany [DE] → Port of Hamburg [DE]	1.88 t-km	(Google, n.d.)
	T2	Freight ship	Port of Hamburg [DE] → Porto Alegre [BR]	24.52 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port of Hamburg [DE] → Port of Antwerp [BE]	1.56 t-km	(Sea Distances, n.d.)
P-FR	T2/T3	Train	Central France [FR] → Le Havre [FR]	1.09 t-km	(Google, n.d.)
	T2	Freight ship	Le Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
P-SE	T2/T3	Truck	Southern Sweden → Malmo Port [SE] (estimate)	0.10 t-km	(Google, n.d.)
	T2	Freight ship	Malmo Port [SE] → Porto Alegre [BR]	25.70 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Malmo port [SE] → Port of Antwerp [BE]	2.72 t-km	(Sea Distances, n.d.)
WO-CA-QC	T2/T3	Train	Ottowa [CA] → Quebec Port [CA]	0.93 t-km	(Aberdeen Carolina & Western Railway Company, n.d.-a; Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Quebec Port [CA] → Porto Alegre [BR]	23.39 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Quebec port [CA] → Port of Antwerp [BE]	12.18 t-km	(Sea Distances, n.d.)
WO-CH	T2/T3	Train	Bern [CH] → Le Havre [FR]	1.59 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	La Havre [FR] → Porto Alegre [BR]	22.75 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Le Havre [FR] → Port of Antwerp [BE]	0.97 t-km	(Sea Distances, n.d.)
WO-DE	T2/T3	Train	Central Germany [DE] → Port of Hamburg [DE]	1.88 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Port of Hamburg [DE] → Porto Alegre [BR]	24.52 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Port of Hamburg [DE] → Port of Antwerp [BE]	1.56 t-km	(Sea Distances, n.d.)
WO-SE	T2/T3	Truck	Southern Sweden → Malmo Port [SE] (estimate)	0.10 t-km	(Google, n.d.; Wernet et al., 2016)
	T2	Freight ship	Malmo Port [SE] → Porto Alegre [BR]	25.70 t-km	(Sea Distances, n.d.)
	T3	Freight ship	Malmo Port[SE] → Port of Antwerp [BE]	2.72 t-km	(Sea Distances, n.d.)

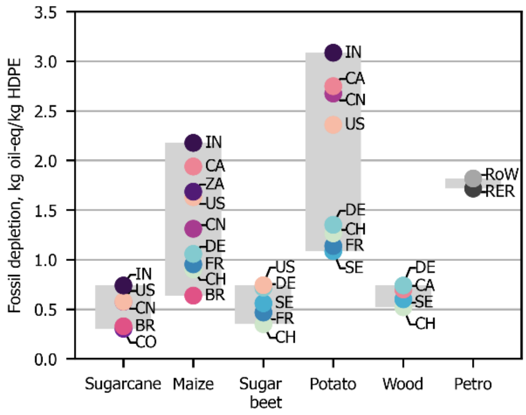
Truck	T2	Porto Alegre [BR] → Ethylene factory [BR]	0.10 t-km	(Braskem, 2022; Google, n.d.)
Train	T2	Ethylene factory [BR] → polyethylene factory [BR]	1.21 t-km	(Braskem, 2022; Google, n.d.)
Truck	T3	Port of Antwerp [BE] → Factory [BE]	0.02 t-km	(Google, n.d.)

Table S6: Overview of land-use change emissions results.

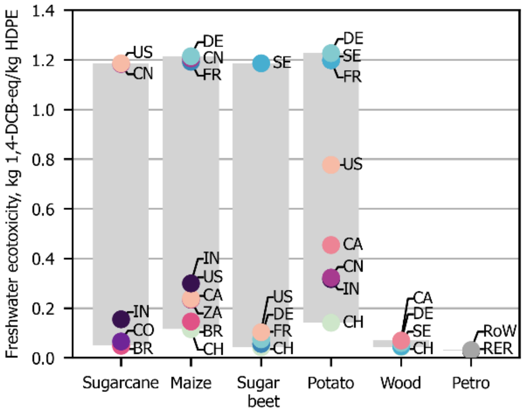
Scenario	Total emissions	Total LUC emissions	Percentage LUC emissions	Percentage LUC emissions with biogenic carbon
SC-BR	1.64	9.74E-04	0.06%	0.07%
SC-CN	3.02	3.06E-04	0.01%	0.26%
SC-CO	1.11	4.16E-05	0.00%	0.00%
SC-IN	2.62	6.62E-05	0.00%	0.01%
SC-US	2.74	1.90E-04	0.01%	0.05%
M-BR	5.67	8.23E-04	0.01%	0.03%
M-CA-QC	7.22	1.56E-04	0.00%	0.00%
M-CN	5.18	8.11E-02	1.57%	3.98%
M-IN	8.39	1.72E-01	2.05%	3.27%
M-US	5.79	2.06E-04	0.00%	0.01%
M-ZA	6.46	7.56E-04	0.01%	0.02%
M-CH	3.73	8.74E-05	0.00%	0.01%
M-DE	3.91	1.54E-02	0.39%	2.00%
M-FR	3.40	3.95E-04	0.01%	0.15%
SB-US	2.65	8.63E-05	0.00%	0.02%
SB-CH	1.32	2.90E-05	0.00%	0.00%
SB-DE	2.48	6.82E-05	0.00%	0.01%
SB-FR	1.59	4.17E-05	0.00%	0.00%
SB-SE	2.47	1.70E-04	0.01%	0.03%
P-CA-QC	10.70	3.07E-03	0.03%	0.04%
P-CN	12.15	5.72E-04	0.00%	0.01%
P-IN	12.74	8.54E-01	6.70%	8.89%
P-US	7.95	5.17E-04	0.01%	0.01%
P-CH	4.71	1.89E-04	0.00%	0.01%
P-DE	4.66	1.40E-03	0.03%	0.09%
P-FR	5.29	2.13E-01	4.03%	9.91%
P-SE	3.63	3.75E-03	0.10%	0.76%
WO-CA-QC	2.31	7.49E-05	0.00%	0.01%
WO-CH	1.66	4.21E-04	0.03%	0.03%
WO-DE	2.33	4.98E-04	0.02%	0.06%
WO-SE	1.85	1.99E-04	0.01%	0.02%



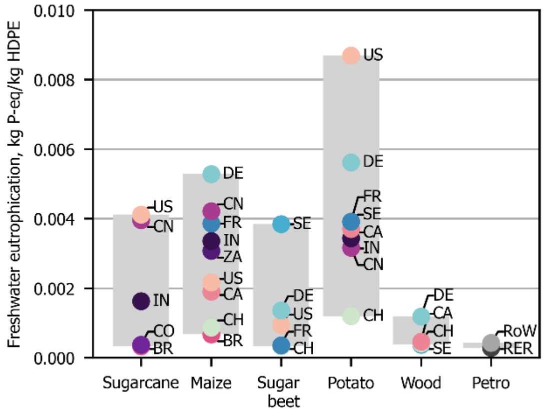
(a) Agricultural land occupation.



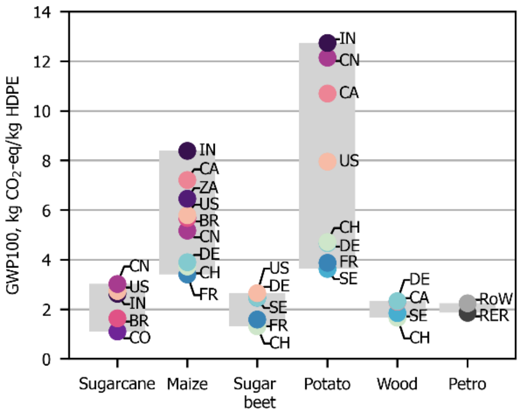
(b) Fossil depletion.



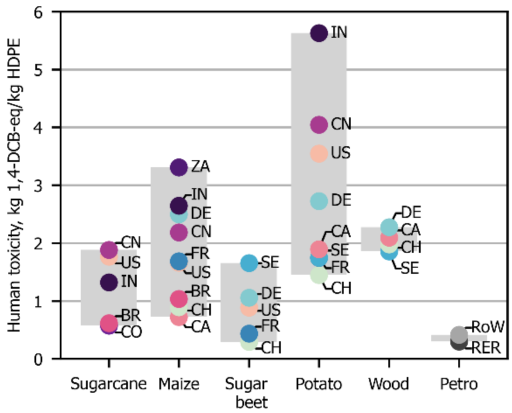
(c) Freshwater ecotoxicity.



(d) Freshwater eutrophication.



(e) Global warming potential (GWP100).



(f) Human toxicity.

Legend

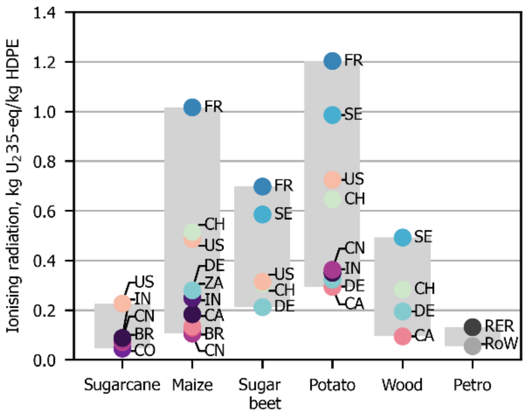
Bio-based (in order of GWP100 of electricity mix, high to low):

India (IN) | China (CN) | United states (US) | Sweden (SE)
South Africa (ZA) | Brazil (BR) | Switzerland (CH) | France (FR)
Colombia (CO) | Canada-Quebec (CA-QC) | Germany (DE)

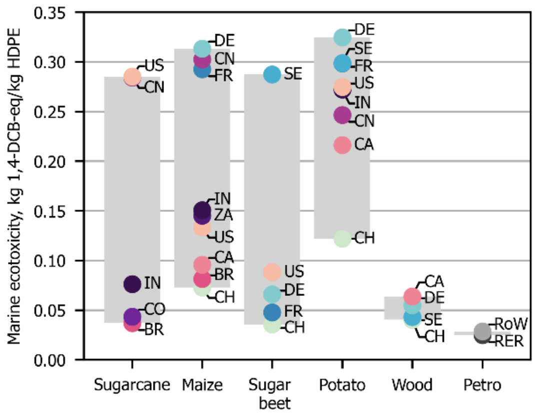
Petrochemical-based:

Europe (RER) | Outside of Europe (RoW)

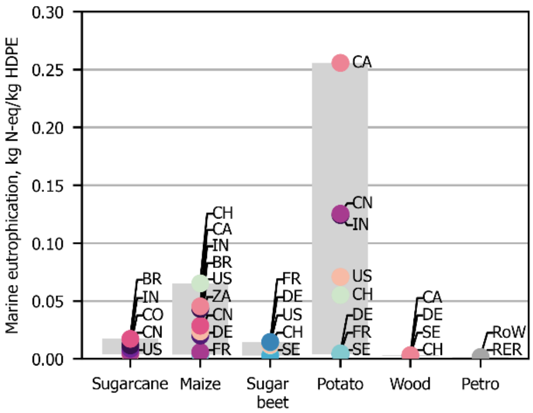
Figure S1: Comparison of the environmental impact of petro-HDPE and bio-HDPE from various resources according to the ReCiPe impact categories.



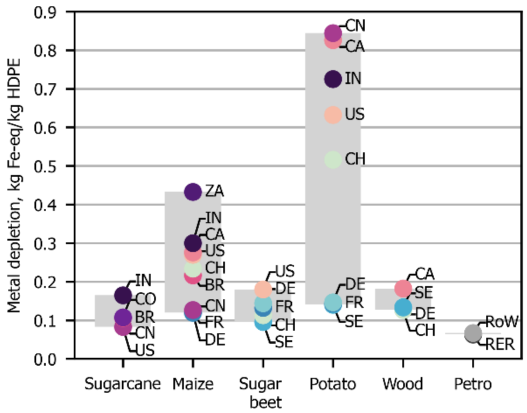
(g) **Ionising radiation.**



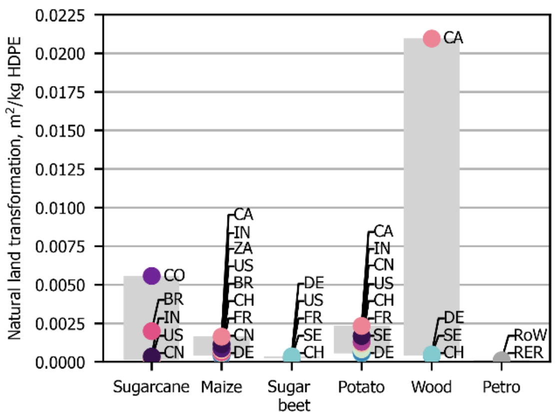
(h) **Marine ecotoxicity.**



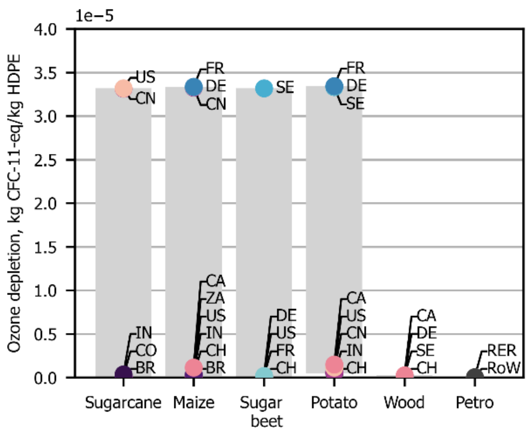
(i) **Marine eutrophication.**



(j) **Metal depletion.**



(k) **Natural land transformation.**



(l) **Ozone depletion.**

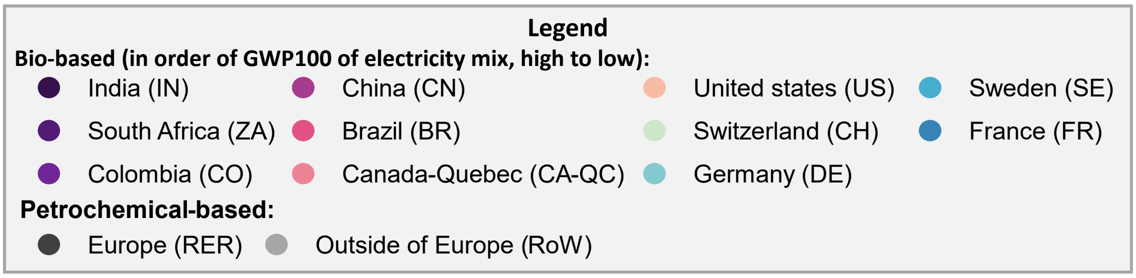
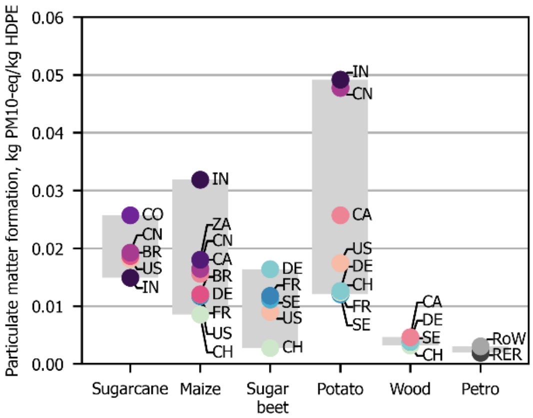
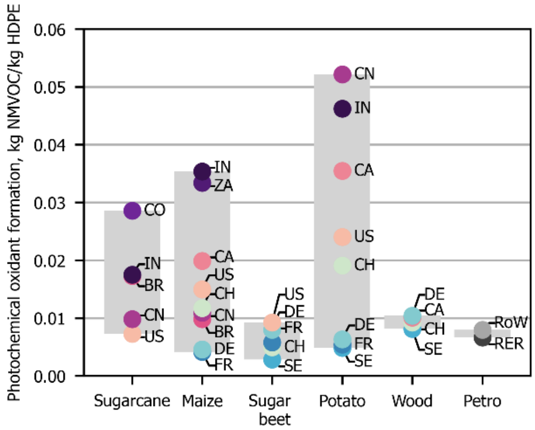


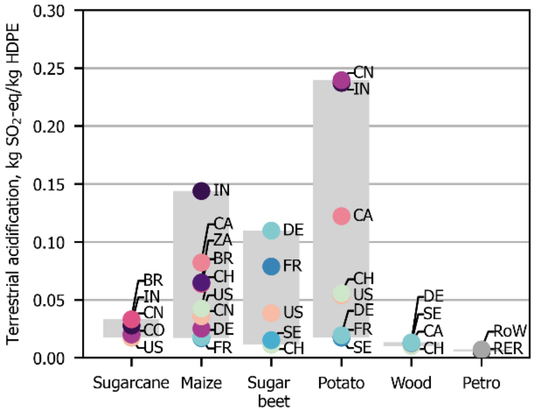
Figure S1: Continued.



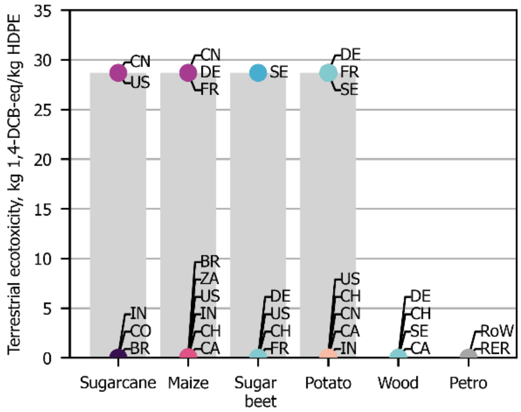
(m) Particulate matter formation.



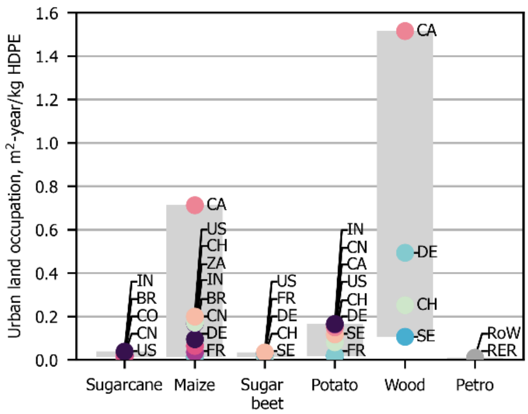
(n) Photochemical oxidant formation.



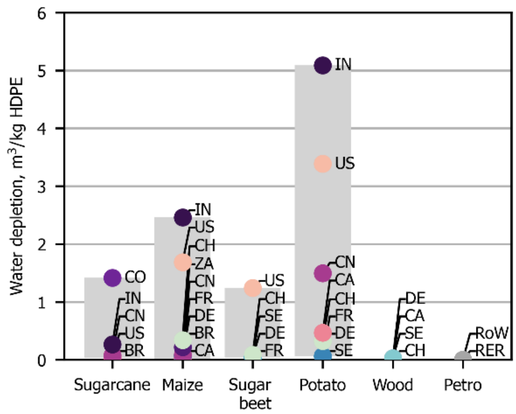
(o) Terrestrial acidification.



(p) Terrestrial ecotoxicity.



(q) Urban land occupation.



(r) Water depletion.

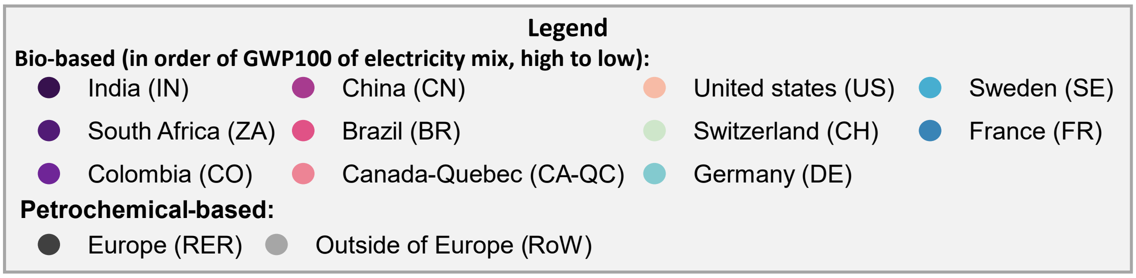
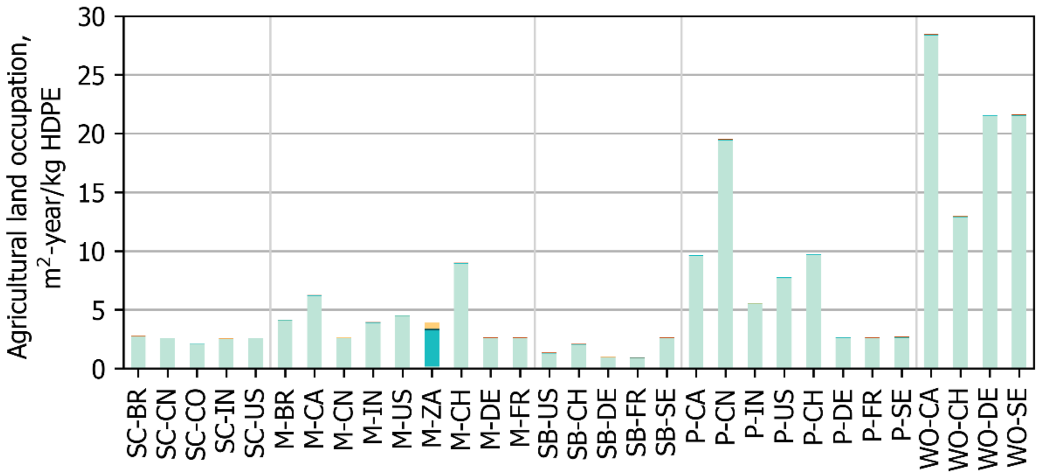
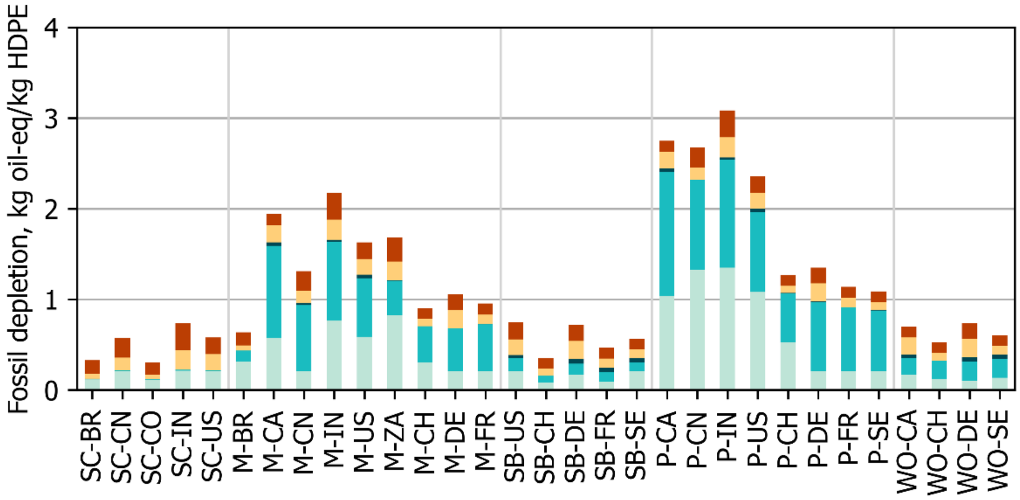


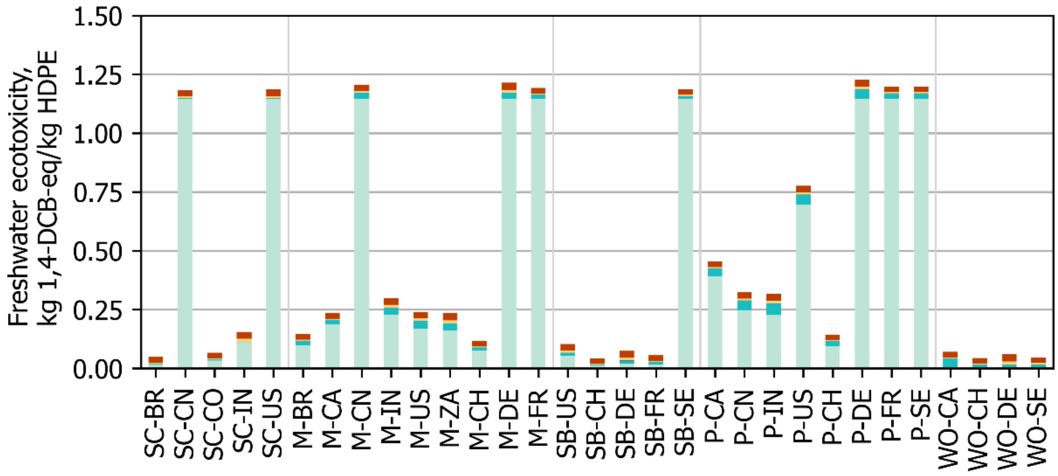
Figure S1: Continued.



(a) Agricultural land occupation.



(b) Fossil depletion.



(c) Freshwater ecotoxicity.

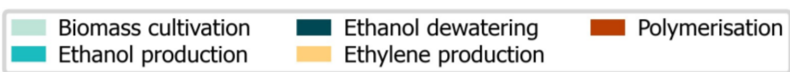
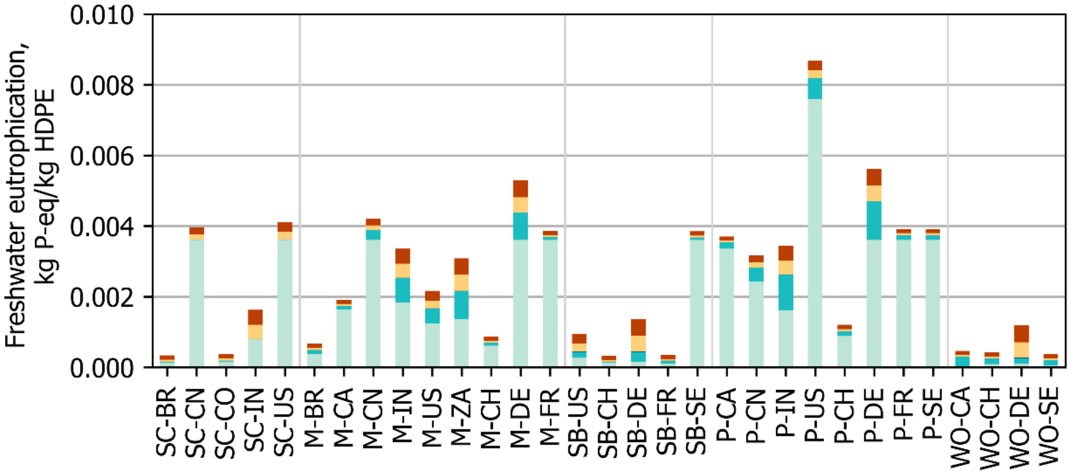
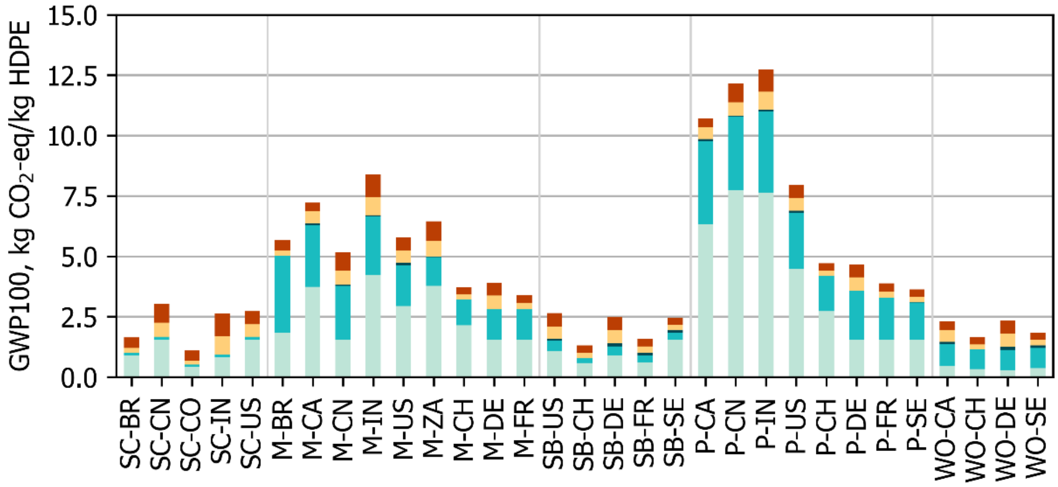


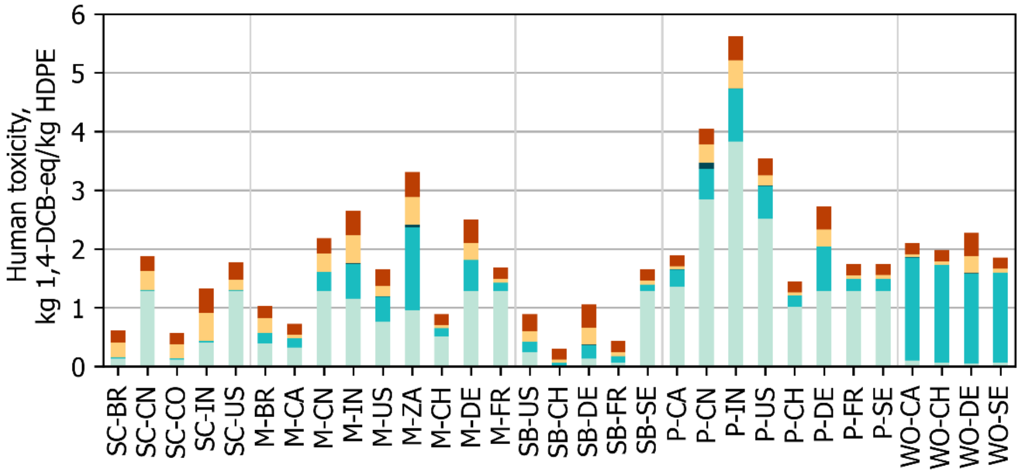
Figure S2: Contribution of production stages to the environmental impact of bio-HDPE.



(d) Freshwater eutrophication.



(e) Global warming potential (GWP100).



(f) Human toxicity.

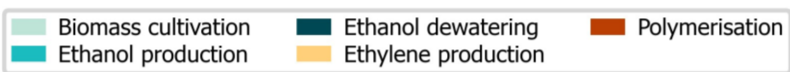
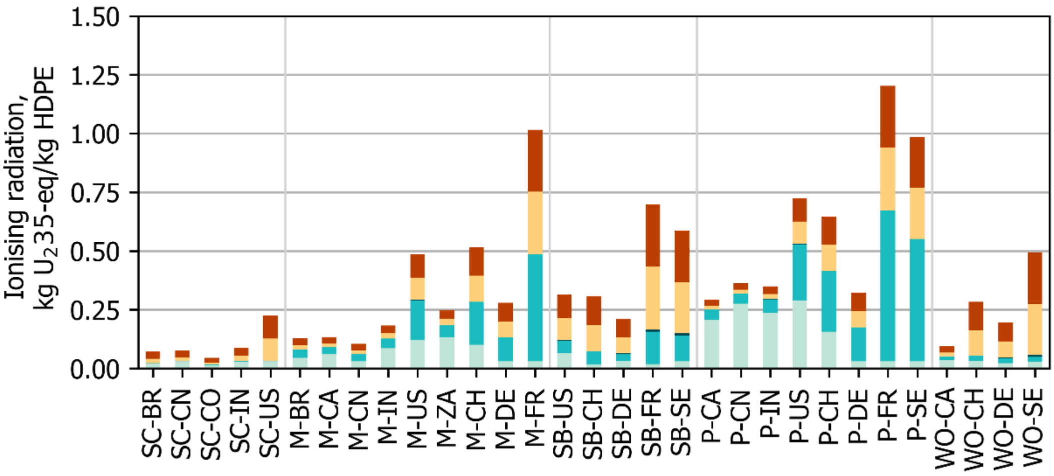
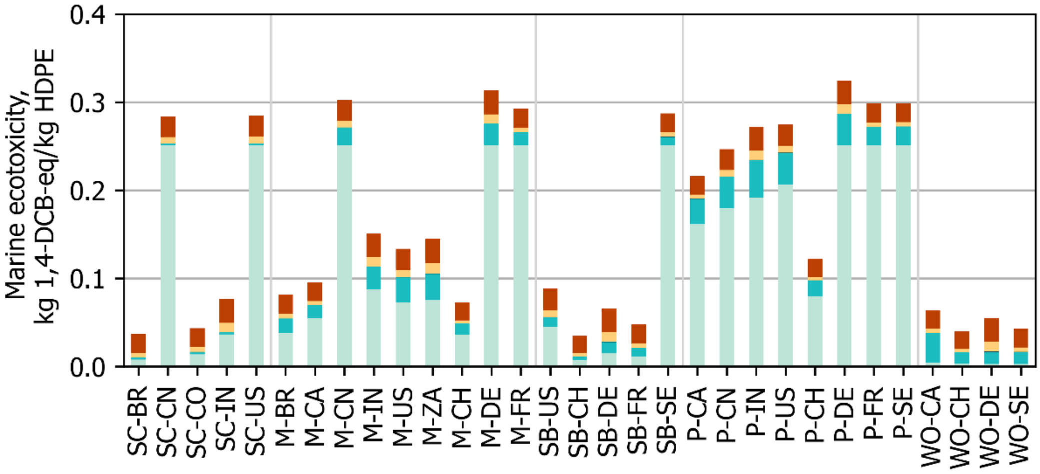


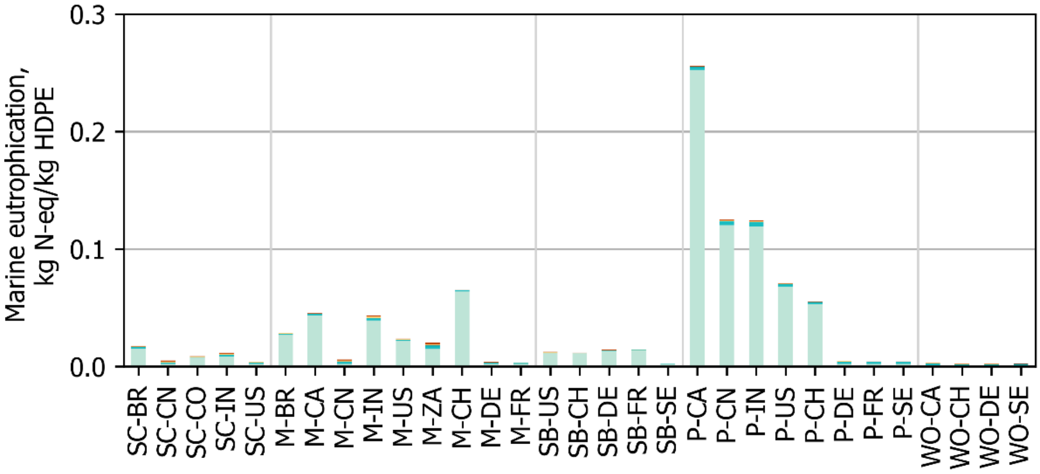
Figure S2: Continued.



(g) Ionising radiation.



(h) Marine ecotoxicity.



(i) Marine eutrophication.

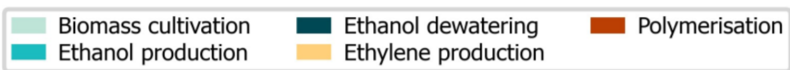
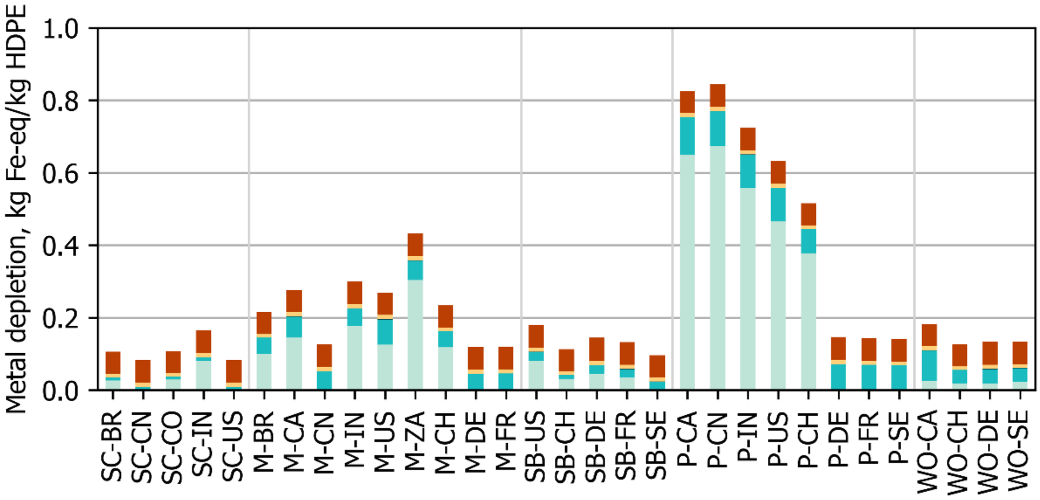
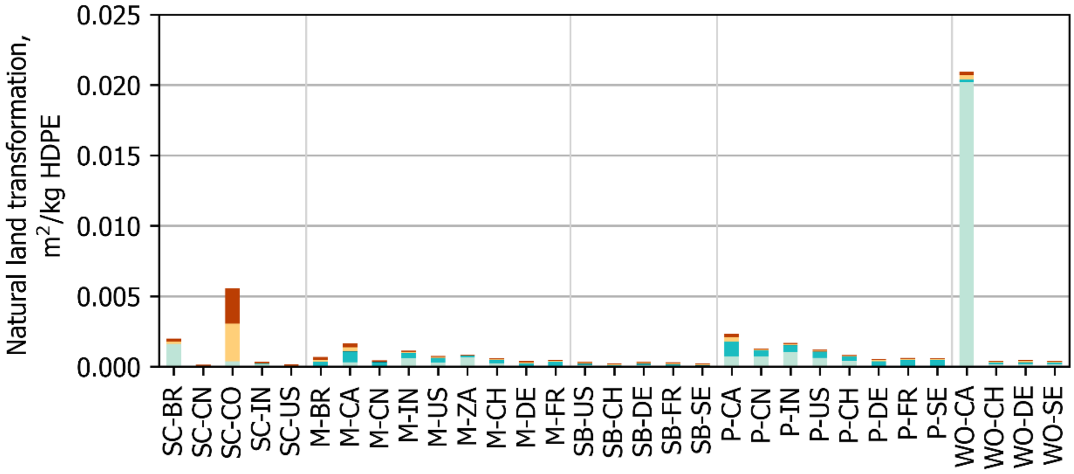


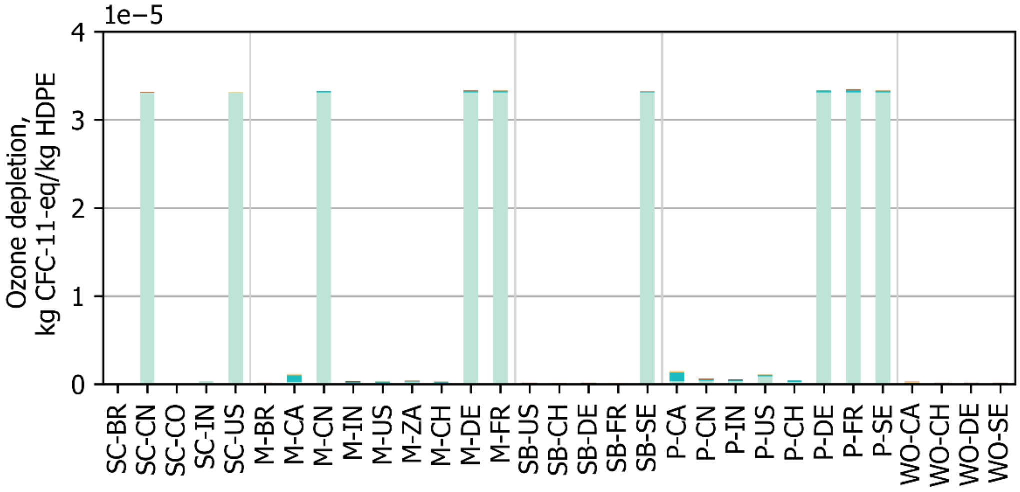
Figure S2: Continued.



(j) Metal depletion.



(k) Natural land transformation.



(l) Ozone depletion.

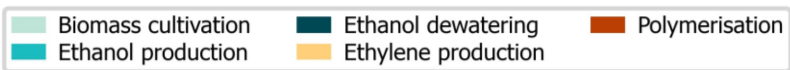
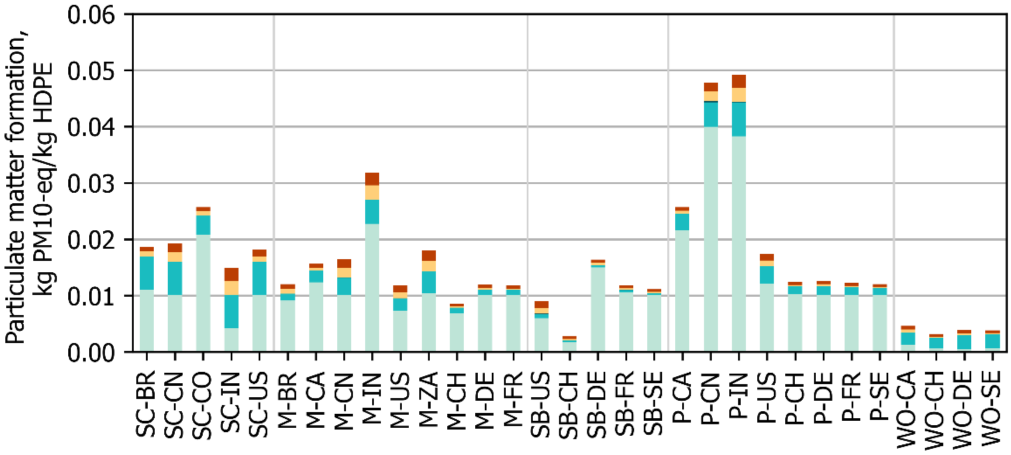
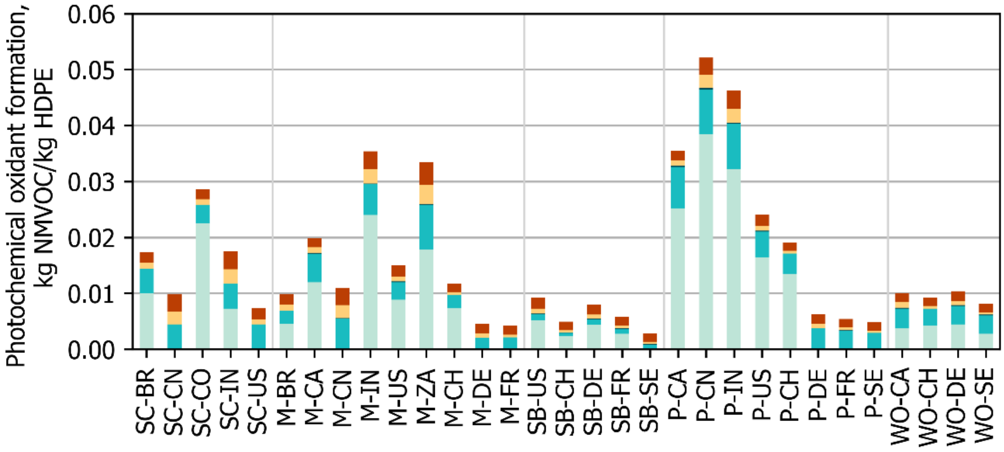


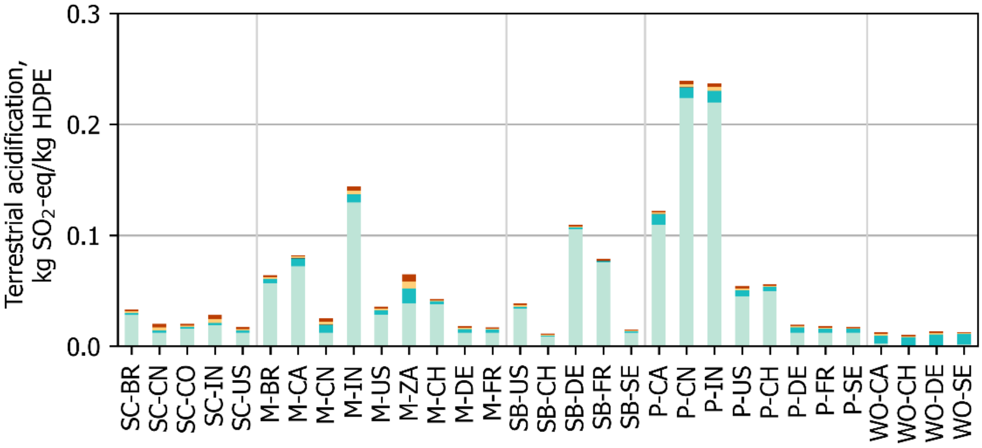
Figure S2: Continued.



(m) Particulate matter formation.



(n) Photochemical oxidant formation.



(o) Terrestrial acidification.

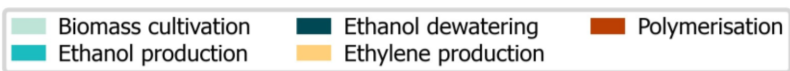
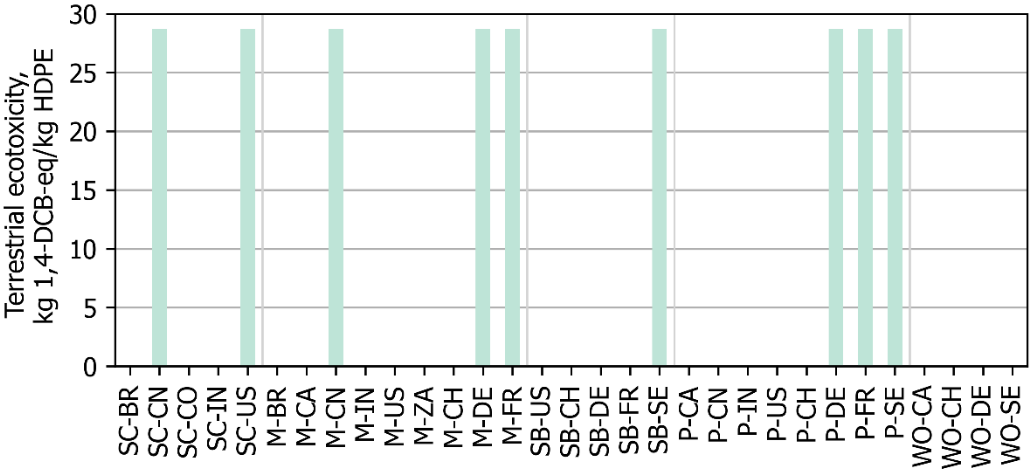
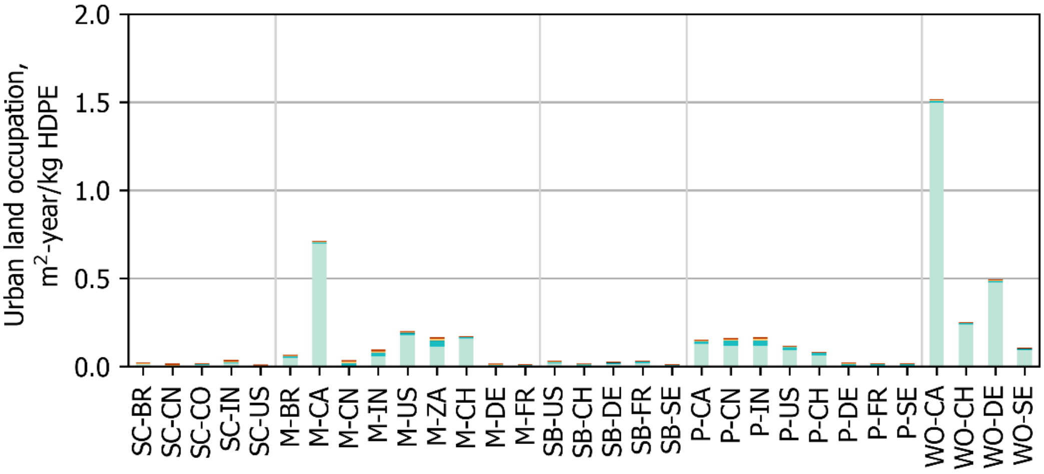


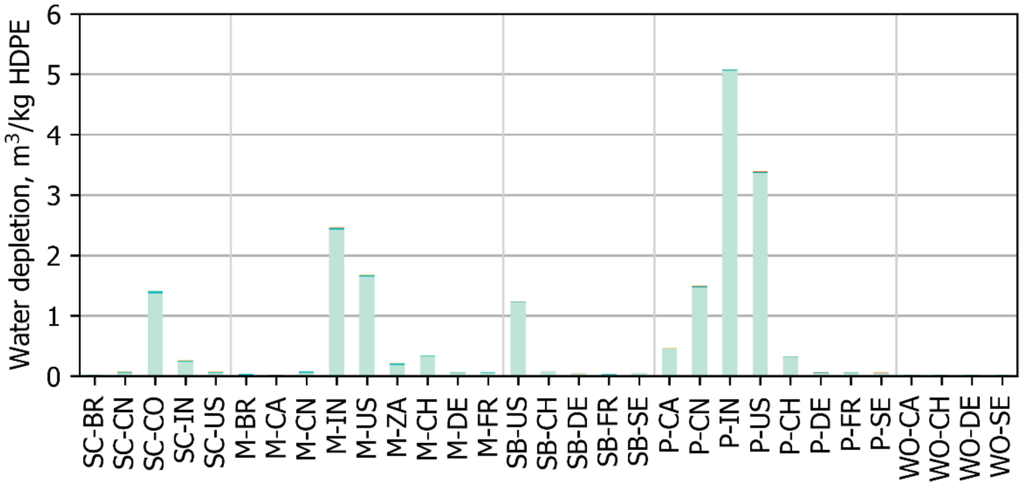
Figure S2: Continued.



(p) Terrestrial ecotoxicity.



(q) Urban land occupation.



(r) Water depletion.

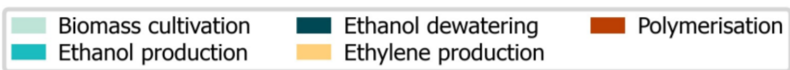
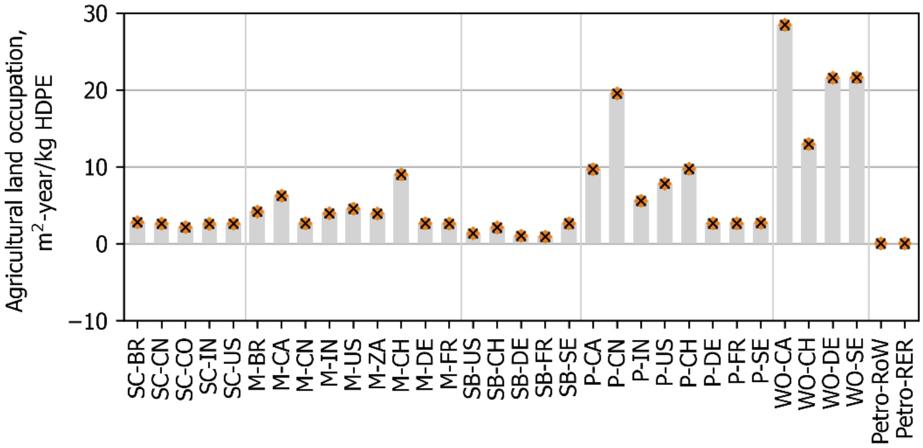
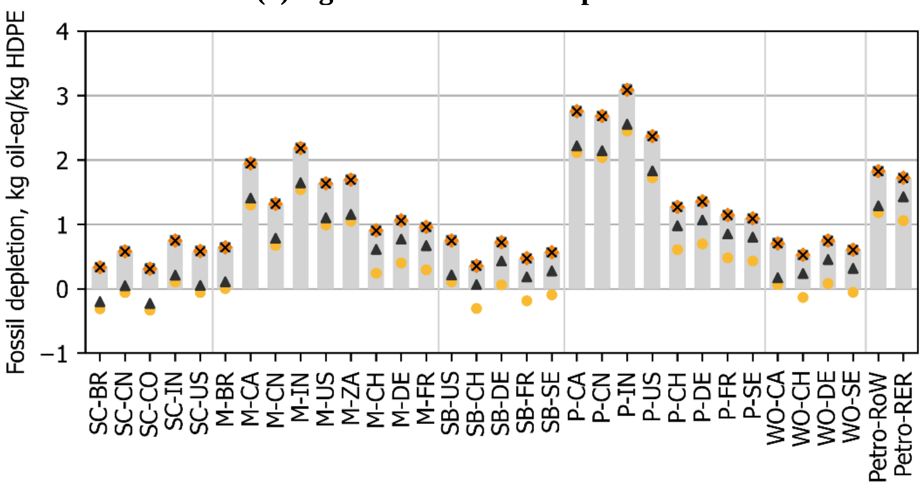


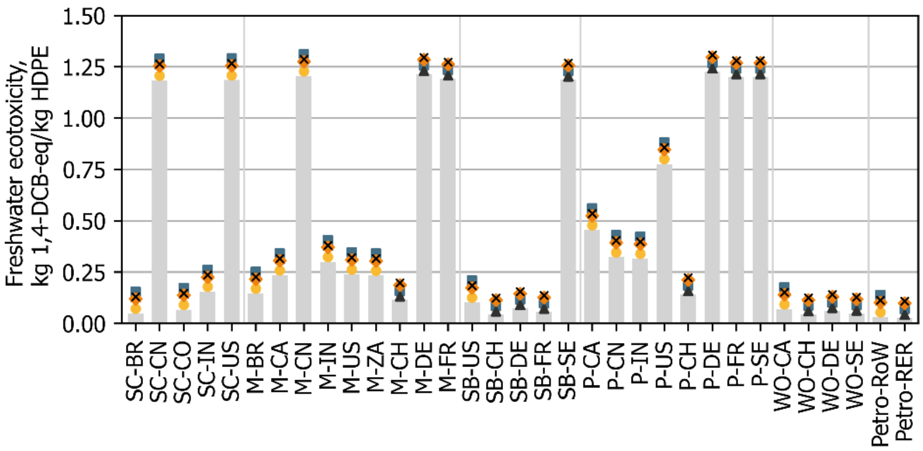
Figure S2: Continued.



(a) Agricultural land occupation.

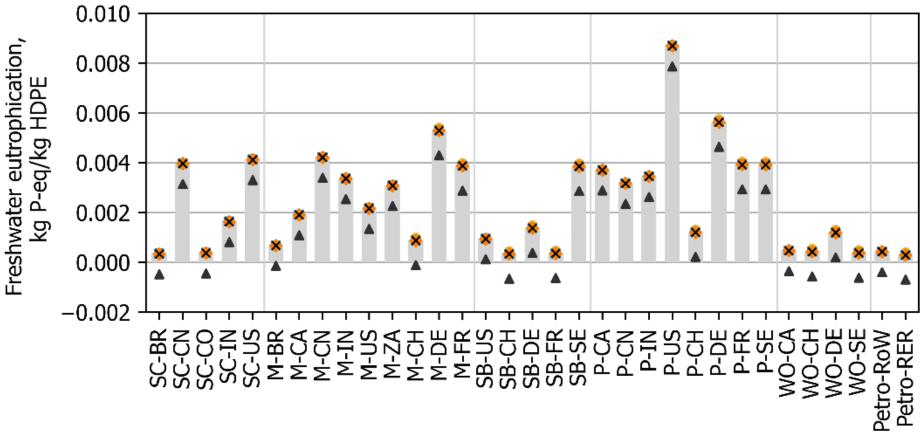


(b) Fossil depletion.

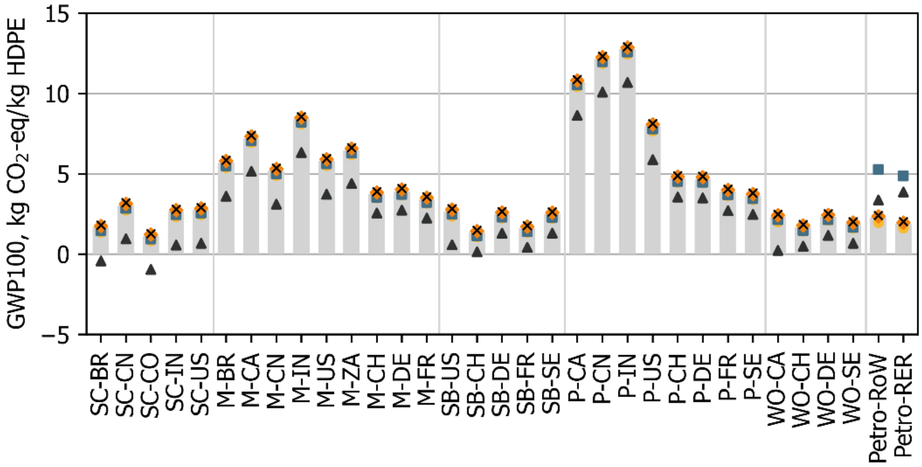


(c) Freshwater ecotoxicity.

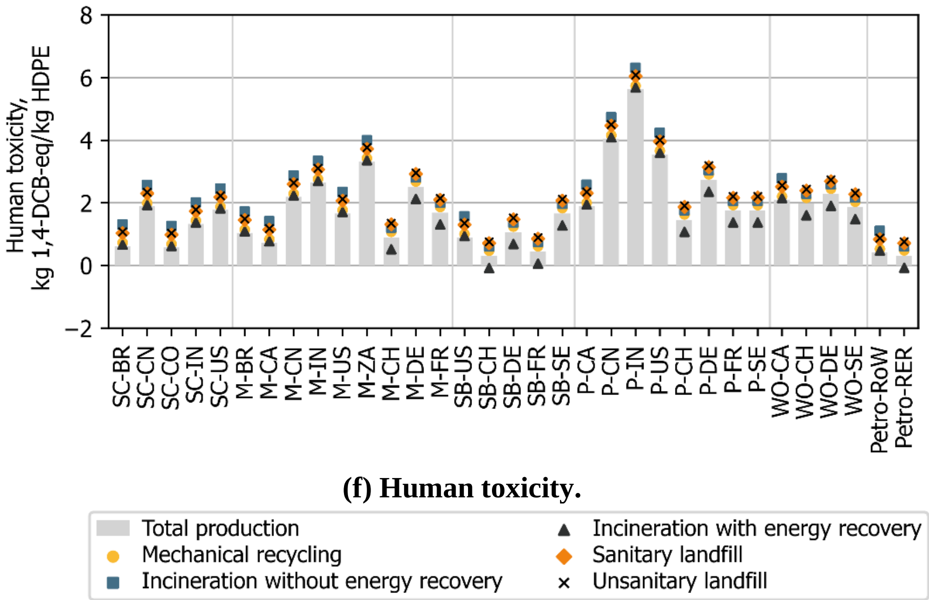
Figure S3: Comparison of the environmental impact of three end-of-life treatment options for bio-HDPE and petro-HDPE.



(d) Freshwater eutrophication.

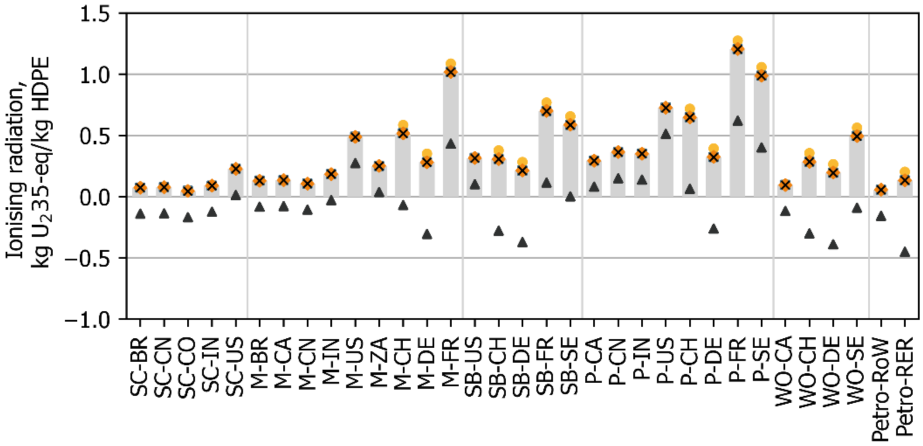


(e) Global warming potential (GWP100).

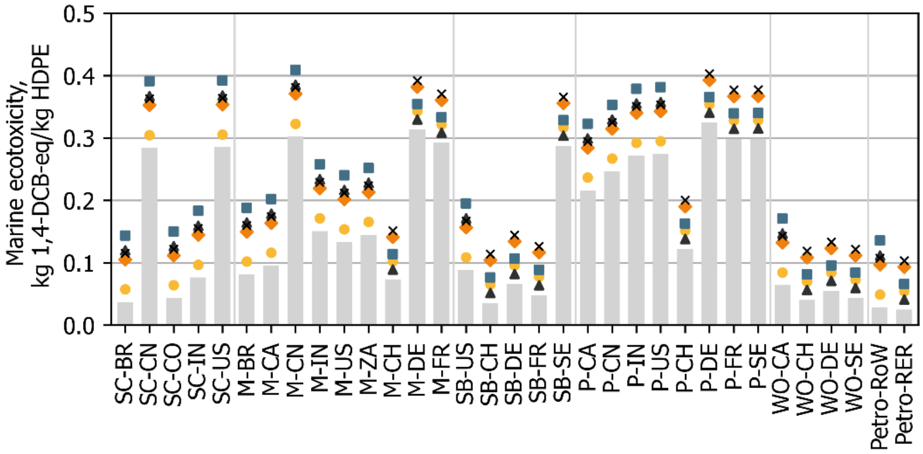


(f) Human toxicity.

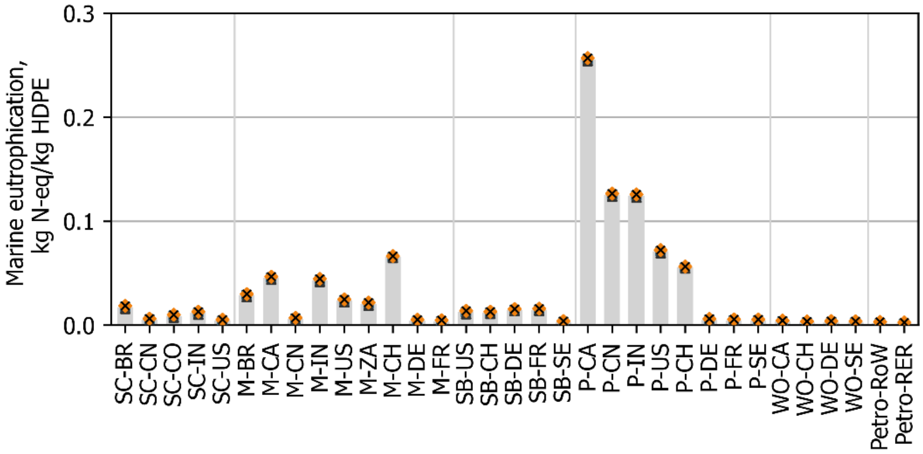
Figure S3: Continued.



(g) Ionising radiation.

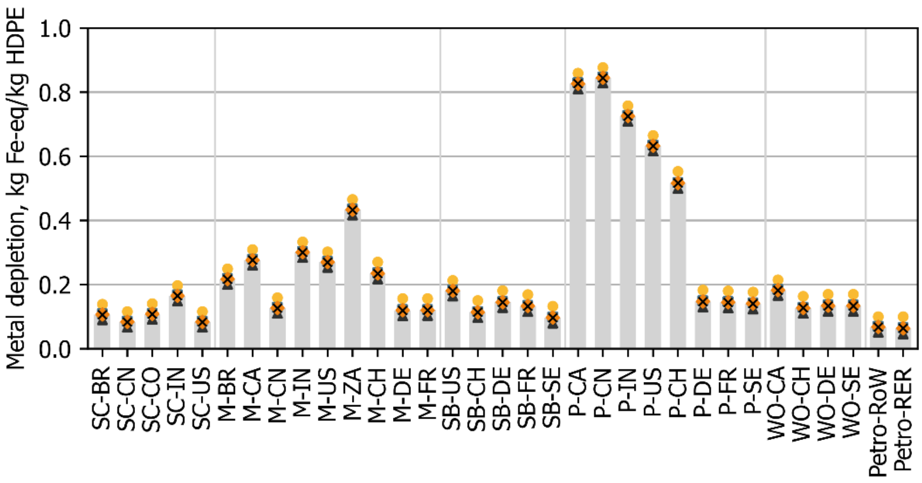


(h) Marine ecotoxicity.

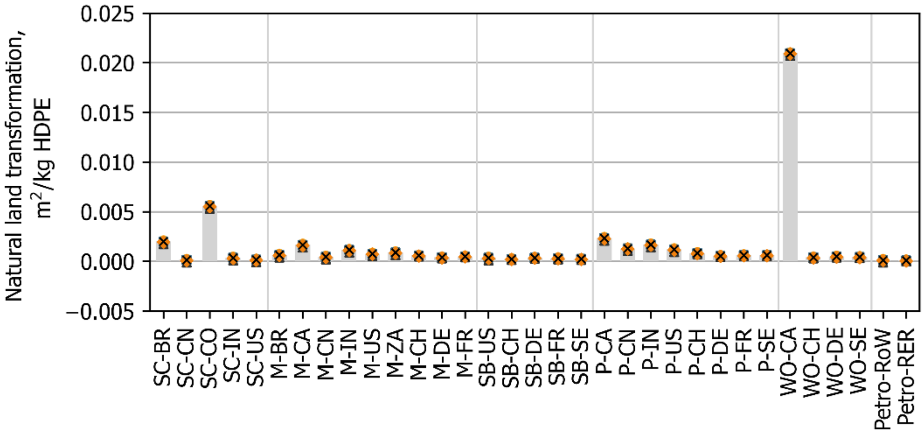


(i) Marine eutrophication.

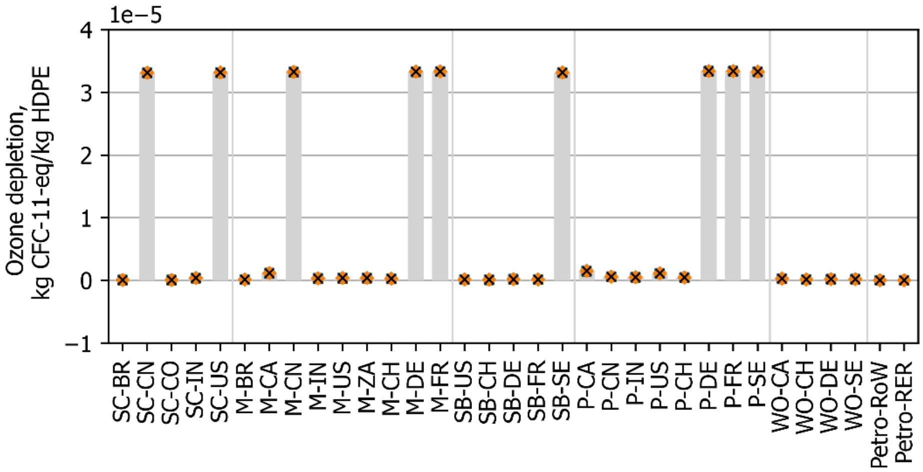
Figure S3: Continued.



(j) Metal depletion.



(k) Natural land transformation.



(l) Ozone depletion.

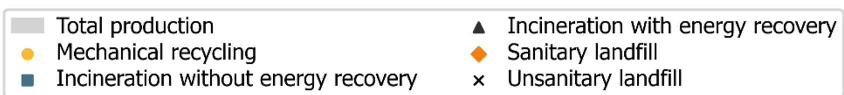
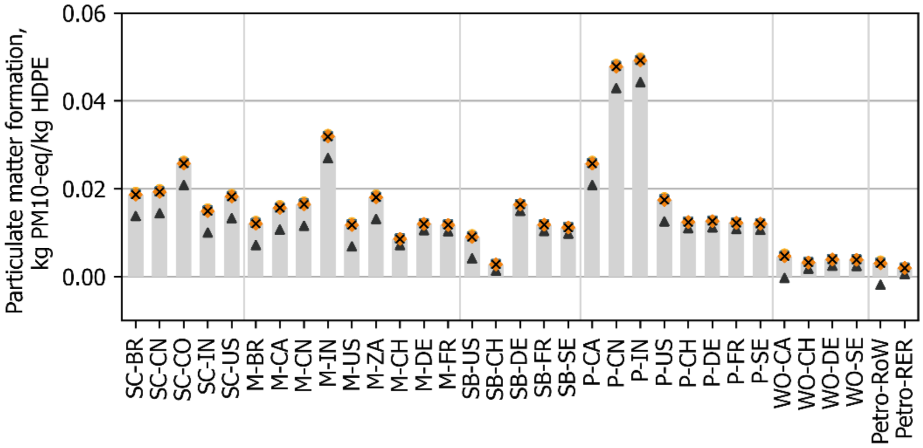
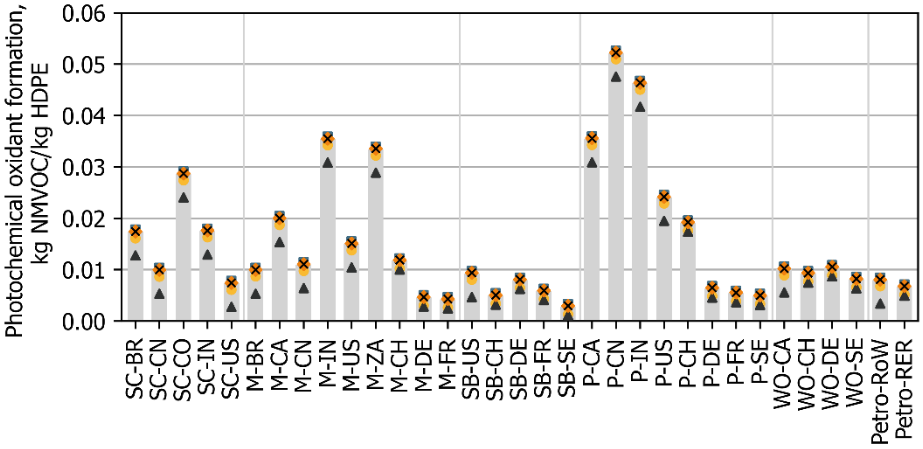


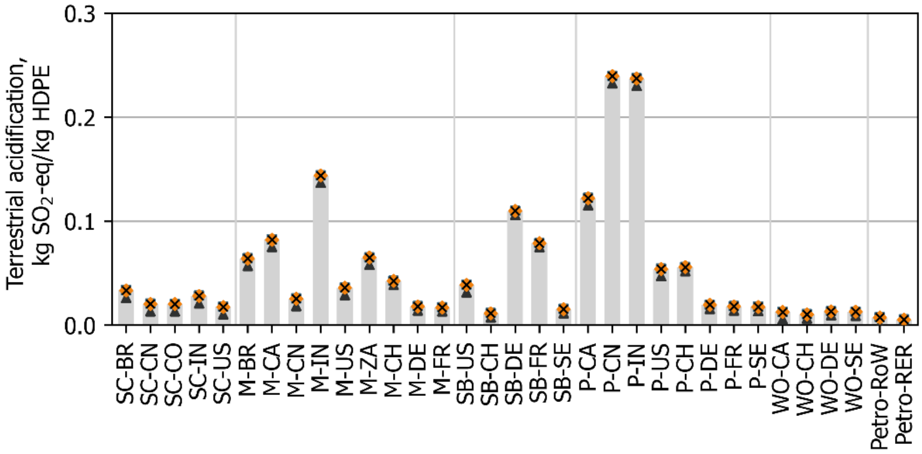
Figure S3: Continued.



(m) Particulate matter formation.

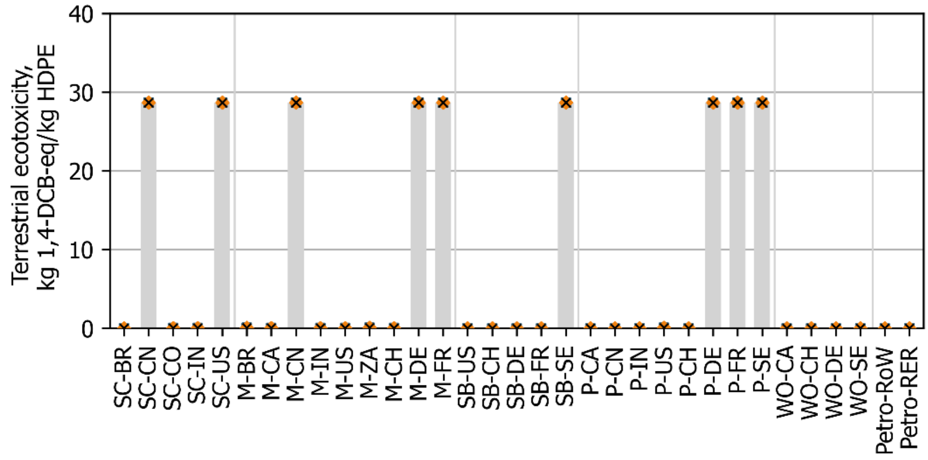


(n) Photochemical oxidant formation.

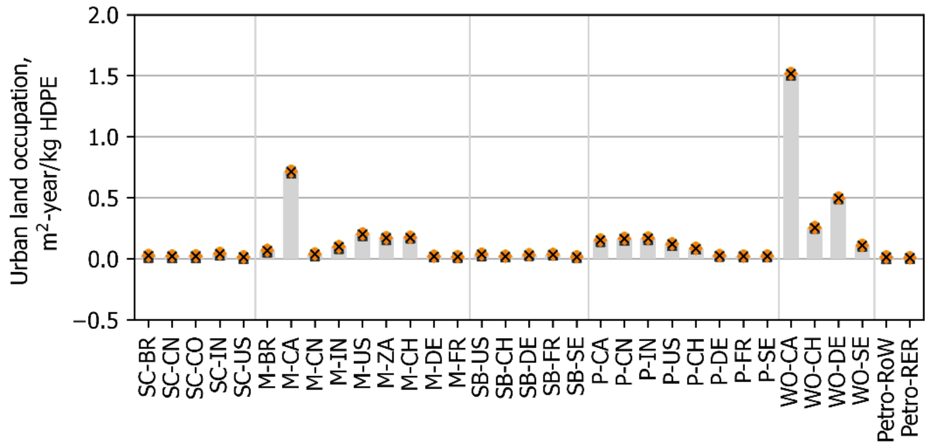


(o) Terrestrial acidification.

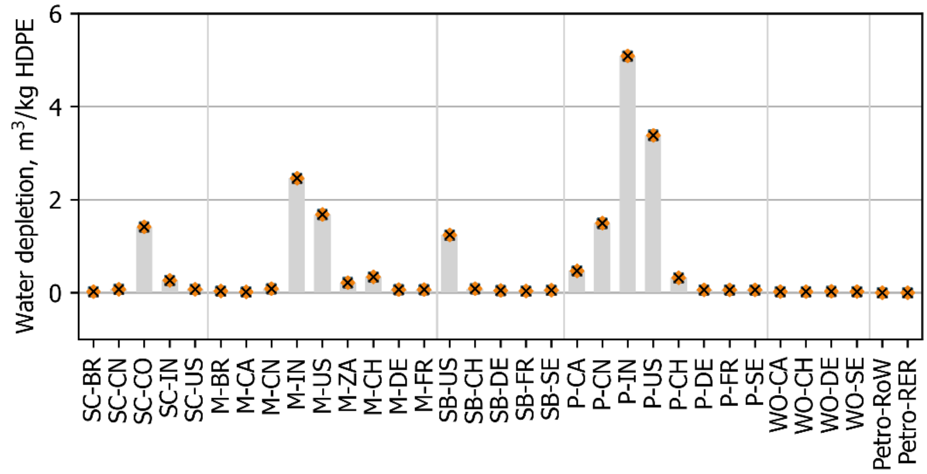
Figure S3: Continued.



(p) Terrestrial ecotoxicity.

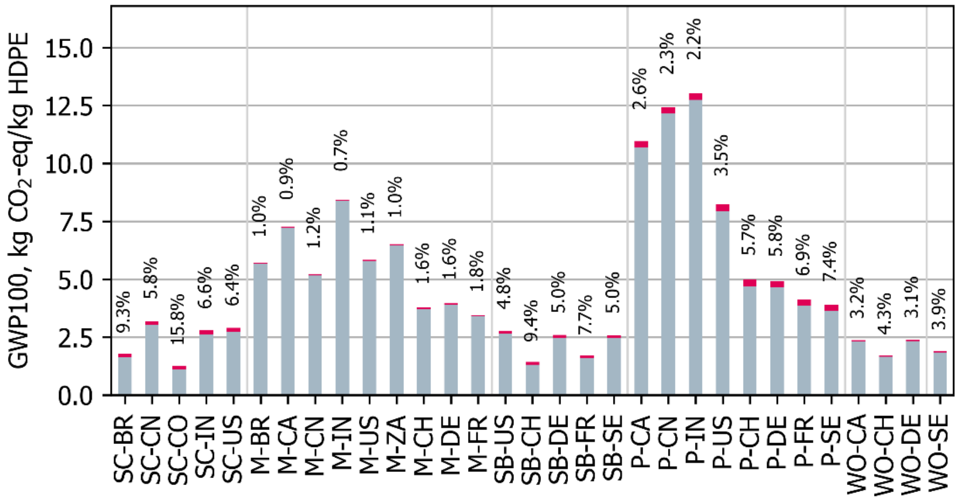


(q) Urban land occupation.

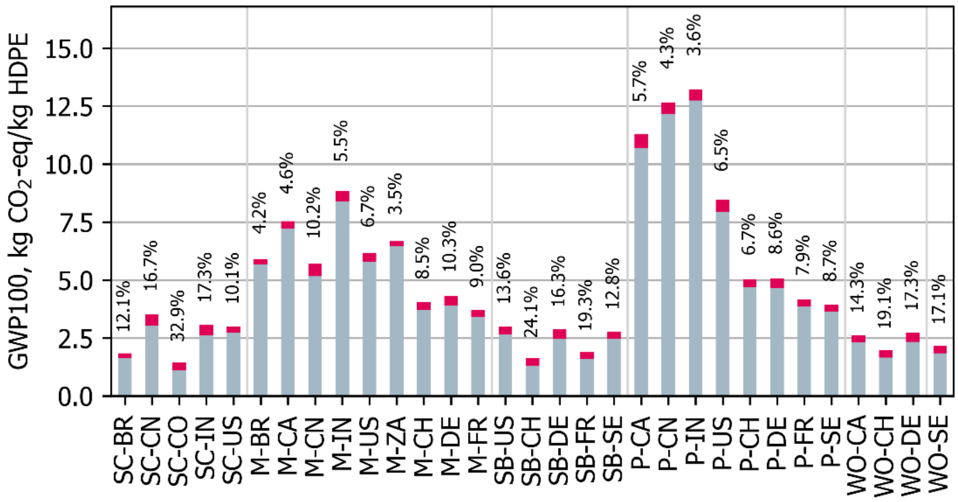


(r) Water depletion.

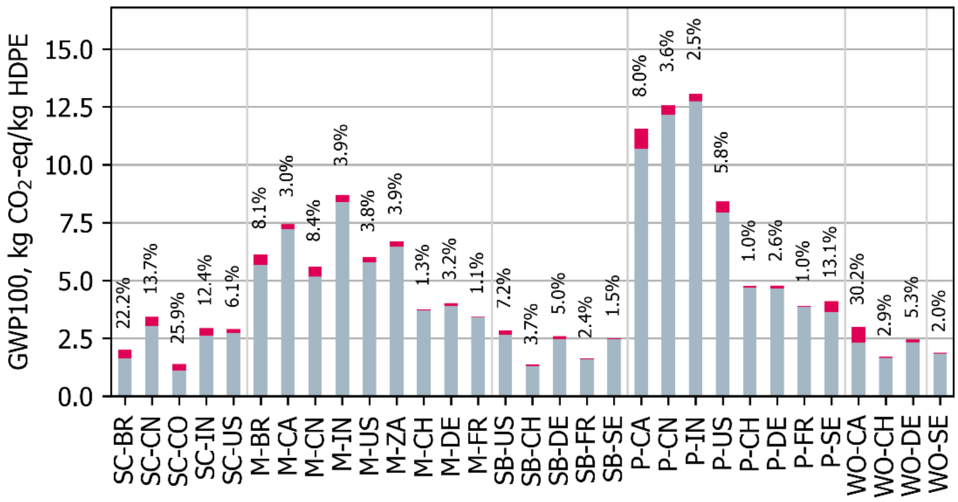
Figure S3: Continued.



(a) GWP100 due to transport scenario 1: 100 km transport of biomass to ethanol plant by truck.



(b) GWP100 due to transport scenario 2: ethanol transport from cultivation location to Brazil.



(c) GWP100 due to transport scenario 3: ethanol transport from cultivation location to Belgium.

Total production
Total transport

Figure S4: GWP100 results for the transport scenarios.

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