PRIMUS

Increasing transparency for inventory data of plastic production by modeling the olefin supply chain

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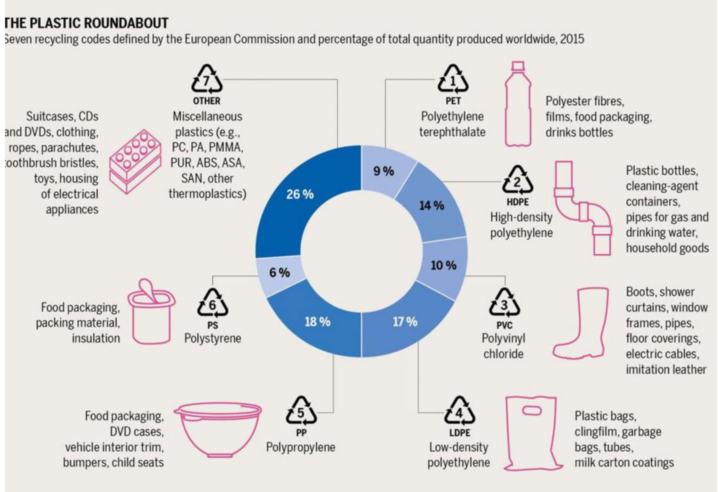
Plastic

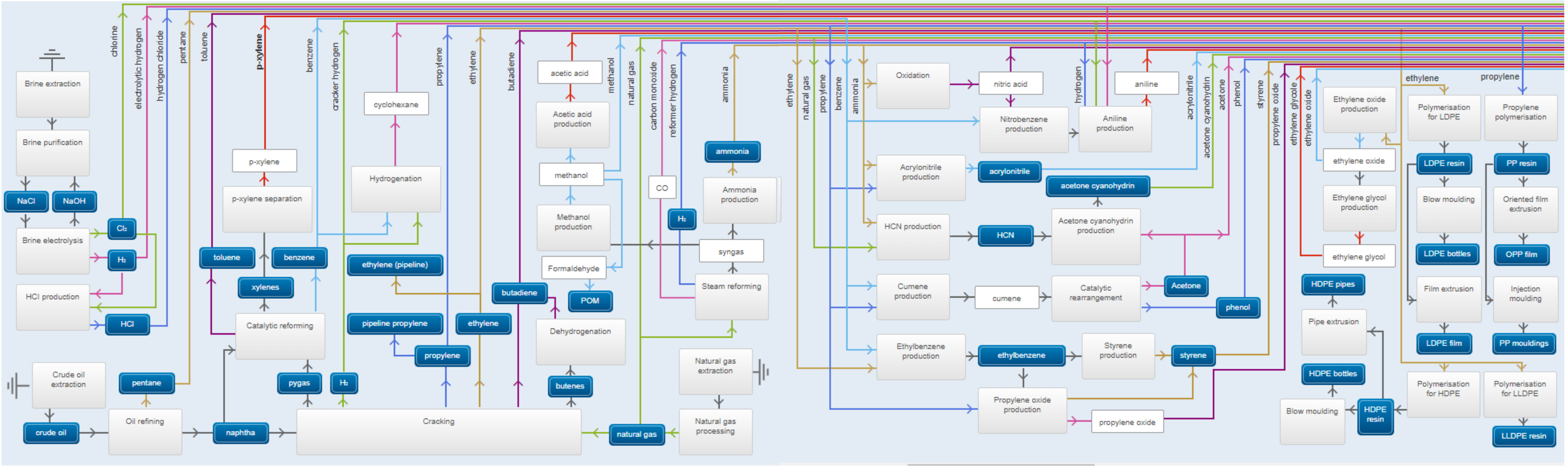
- Plastic is an important and ubiquitous material in our society
- In Europe over 57.2 million t/a of plastics are produced
- By 2050, plastic production is projected to triple
  - contributing to 15% of global greenhouse gas emissions
  - 99%+ of plastic is sourced from fossil fuels currently
- Performing Life Cycle Assessments (LCAs) of plastic products is crucial for understanding their environmental impacts
- Lack on latest and transparent LCI data for plastic precursors hinders accurate impact assessments
- LCI data is often aggregated (CarbonMinds, GaBi, EF 3.1 database)
- **A higher degree of transparency concerning the production of plastic and attributed environmental impacts is needed**



Heinrich-Böll Stiftung and Bardow et al. *Nature* 2022, 612, 214.

Modeling plastic, current approach:

The base for most LCI data, EcoProfiles by Plastics Europe:



- EcoProfiles can represent up to 100% of the producing industry in Europe (based on prod. capacity)
- Yet, processes are aggregated preventing transparency in the supply chain
- Ecoinvent, GaBi, Environmental Footprint database etc. use those EcoProfiles for their datasets

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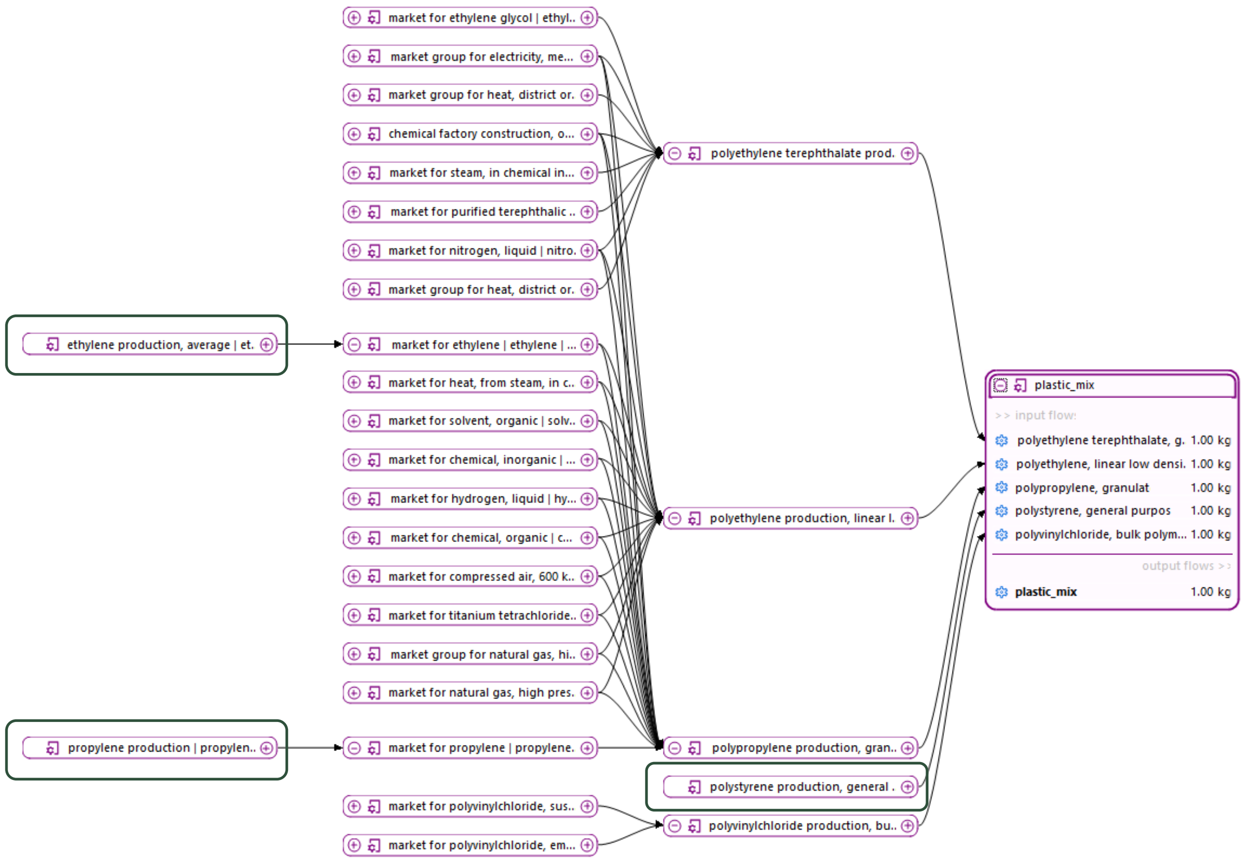
Modeling plastic, current approach in ecoinvent 3.9.1:

Plastic datasets in ei 3.9.1 are based on EcoProfiles by PlasticsEurope:

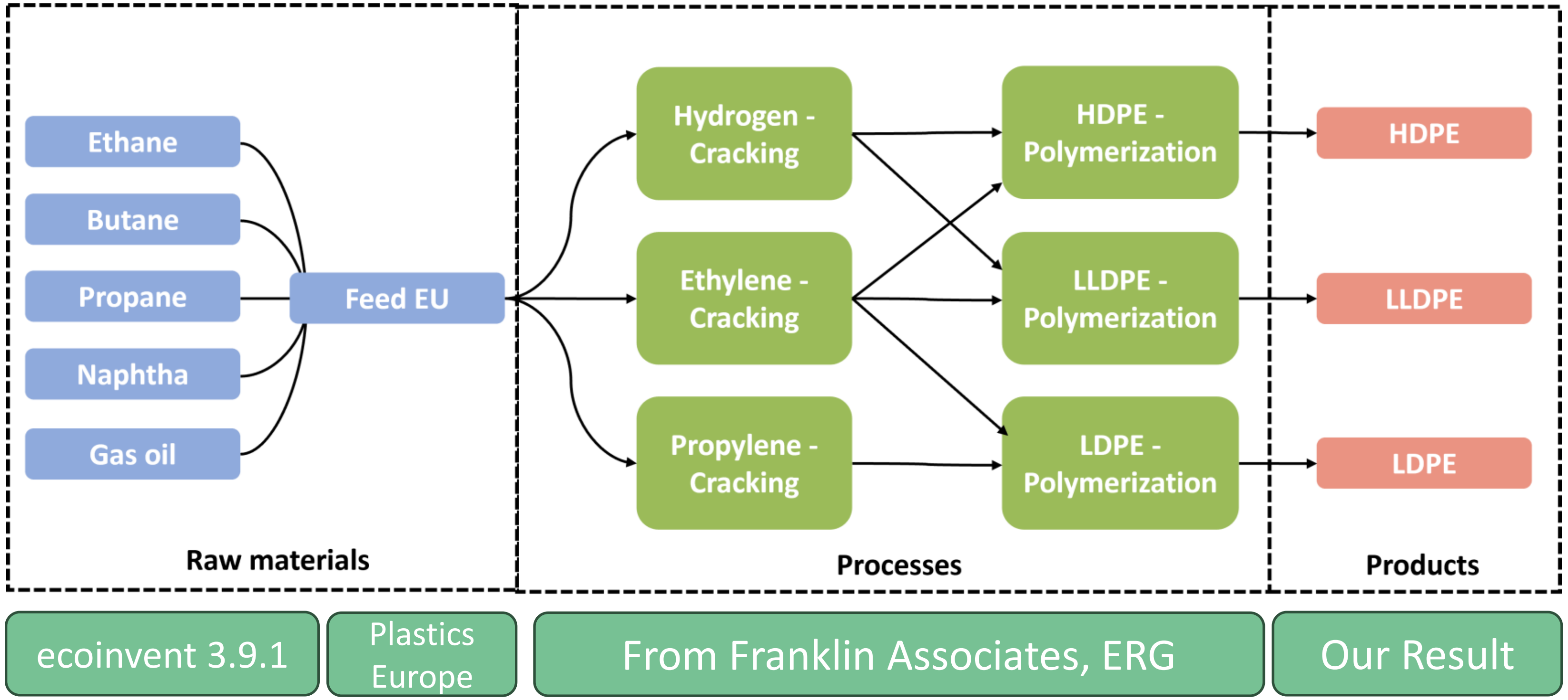


- The chemical supply chain is cut-off at the ethylene, propylene level
- This comprises strongly any further analysis of hot spots!
- Even PlasticsEurope states:

  Current Polyolefins eco-profiles datasets keep a good production process representativeness but need now to be aligned **with main LCI databases regarding Oil and Gas datasets**, inducing an increase of the Carbon Footprint of polymers.

ecoinvent 3.9.1, cut-off in openLCA 2.1

Modeling plastic, our approach:

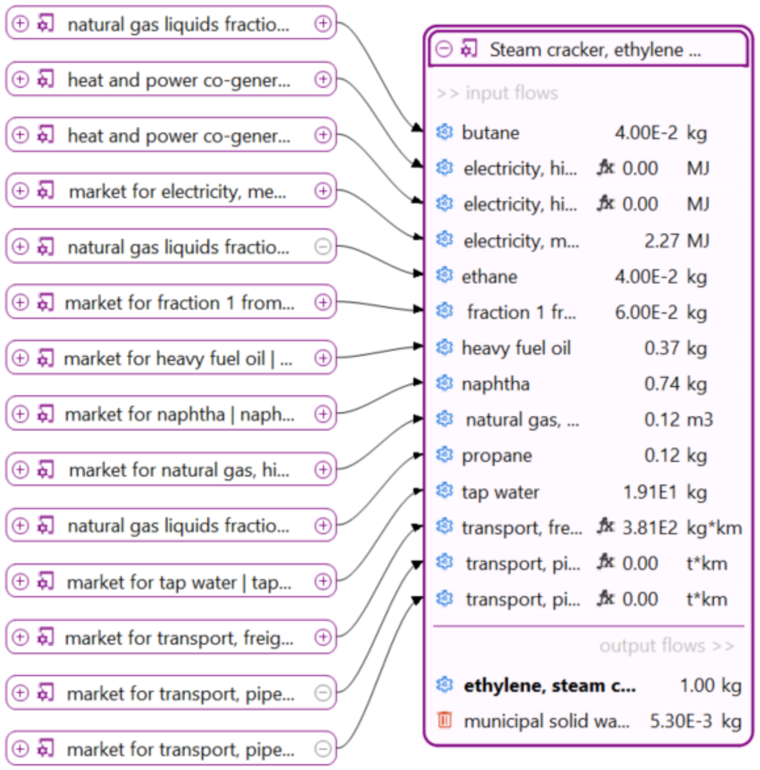


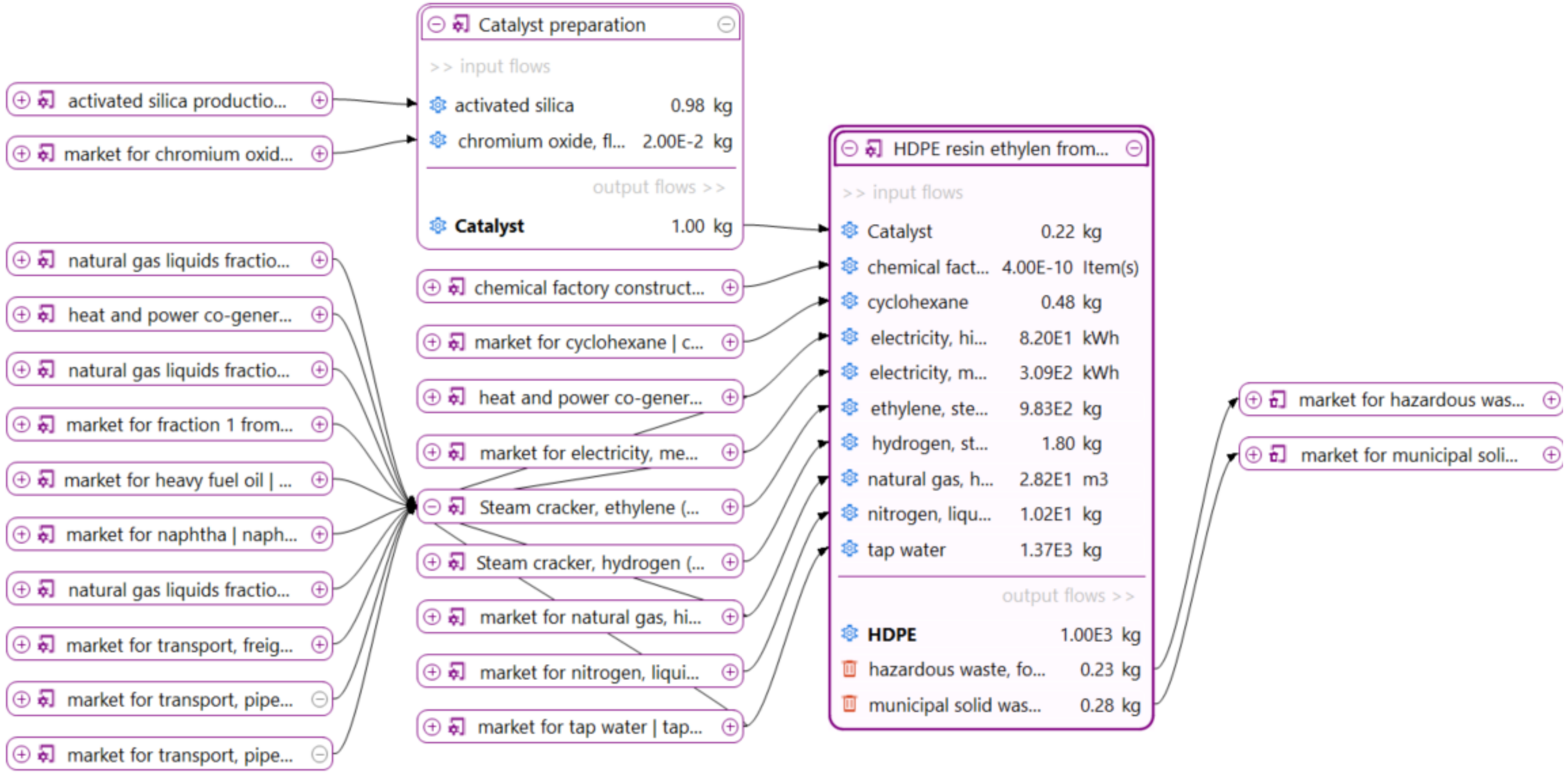
The inputs from Franklin Associates were adapted to EU feed (naphtha-rich)

Modeling plastic, our approach:

Ethylene

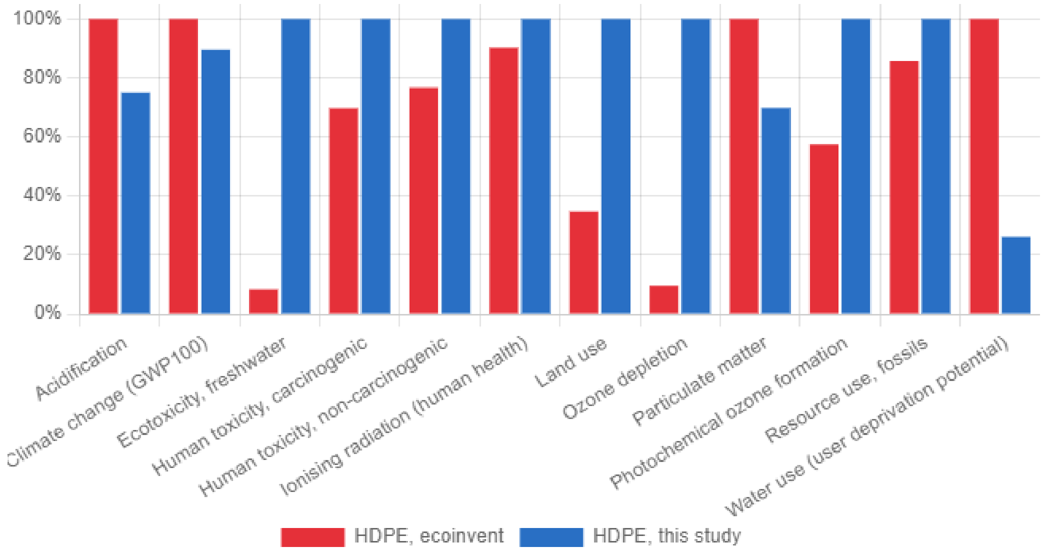
HDPE





Modeling plastic, our results:

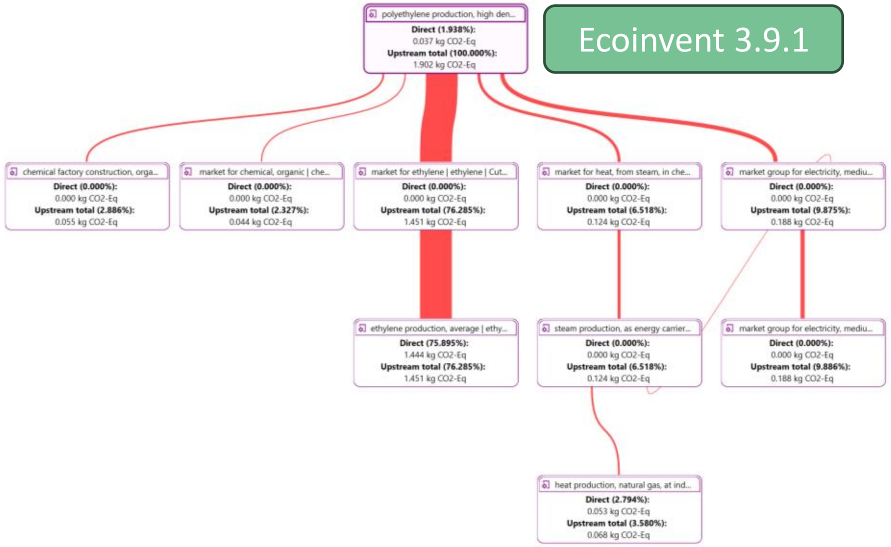
Impact categories	HDPE, this study	HDPE, ei 3.9.1	Unit	Diff.
Acidification	4.51E-03	6.01E-03	mol H+-Eq	-25%
Climate change (GWP100)	1.70	1.90	kg CO2-Eq	-10%
Ecotoxicity, freshwater	**27.83**	**2.33**	**CTUe**	**1094%**
Human toxicity, carcinogenic	6.54E-10	4.56E-10	CTUh	43%
Human toxicity, non-carcinogenic	1.33E-08	1.02E-08	CTUh	30%
Ozone depletion	**1.32E-07**	**1.28E-08**	**kg CFC-11-Eq**	**935%**
Particulate matter	4.85E-08	6.95E-08	disease incidence	-30%
Photochemical ozone formation	1.13E-02	6.49E-03	kg NMVOC-Eq	74%
Resource use, fossils	83.65	71.66	MJ	17%
Water use	0.222	0.850	m3 world eq.	-73%

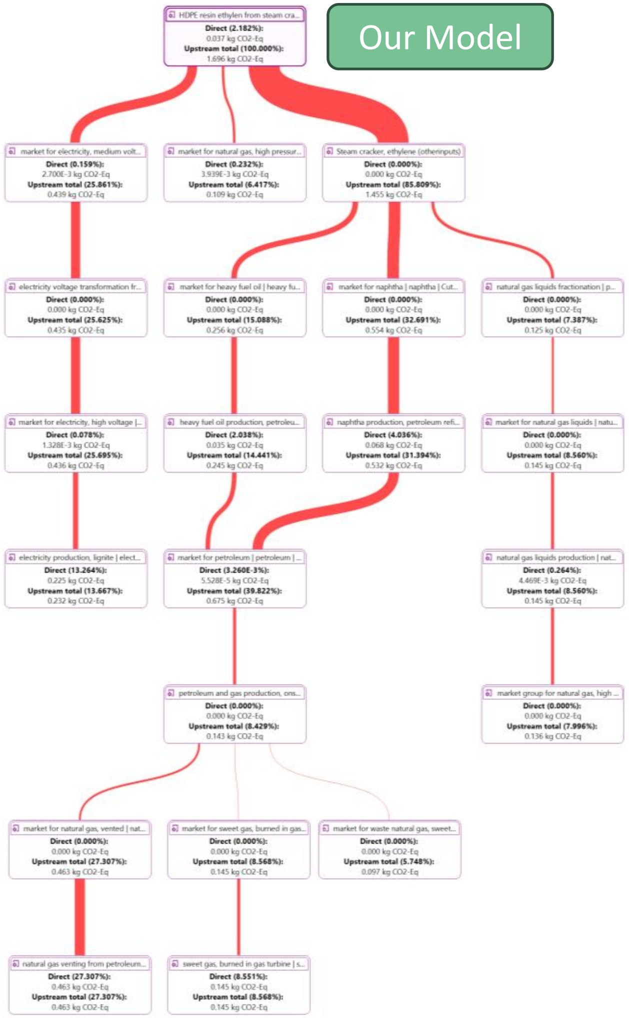


- Comparable impacts vis-à-vis the aggregated data (Global warming potential, Resource use, fossils) ✓
- Ecotox. values are higher than in the ecoinvent (1094%) due to crude oil extraction (Cl^-, Sr^{2+} release)
- ODP is highly increased (935%) due to CO_2 and CH_4 release during raw material extraction (crude oil)

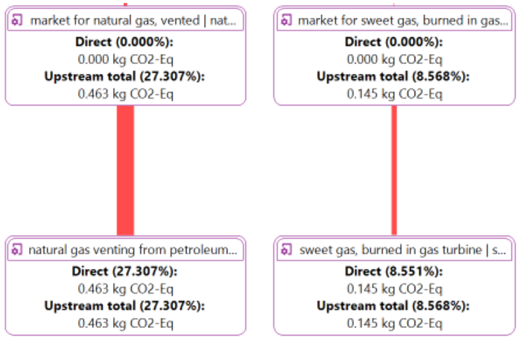
ecoinvent 3.9.1, cut-off in openLCA 2.1, LCIA EF 3.1, selected impact categories

Modeling plastic, details: GWP





- Our model provides detailed information about emissions besides holding similar overall values
- The hot spots of 'Scope 3' emissions can be located



ecoinvent 3.9.1, cut-off in openLCA 2.1, LCIA EF 3.1, selected impact categories

Wow, talk about a plot twist!

Chemicals

The Chemicals sector is updated to improve the data representation for essential chemical precursors and their derivatives, such as short-chain alkenes (ethylene, propylene, butene, and butadiene), monocyclic aromatics (benzene, toluene, and xylenes [p-, o-, mixed]), ethylene oxide, and ethylene glycol. Industry data for European conditions was provided by Plastics Europe. Additional key updates comprise of technological and geographical coverage expansion for ethylene, propylene, hydrogen, and methanol. Specifically, ecoinvent v3.10 introduces data for China, United States, and Europe.

Recent development: Ecoinvent 3.10

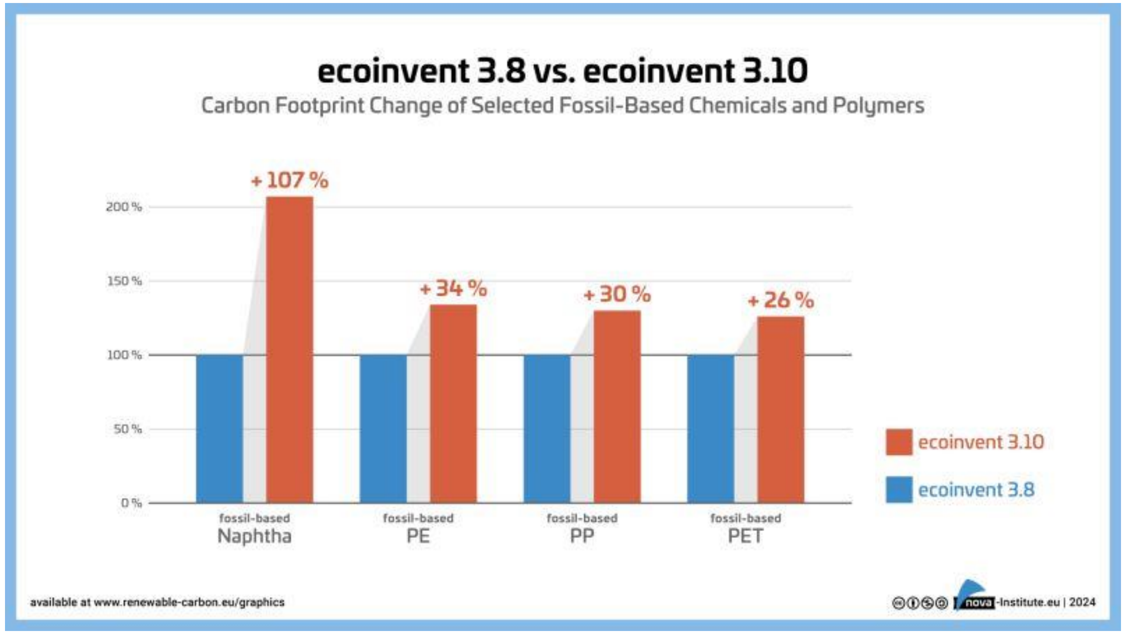
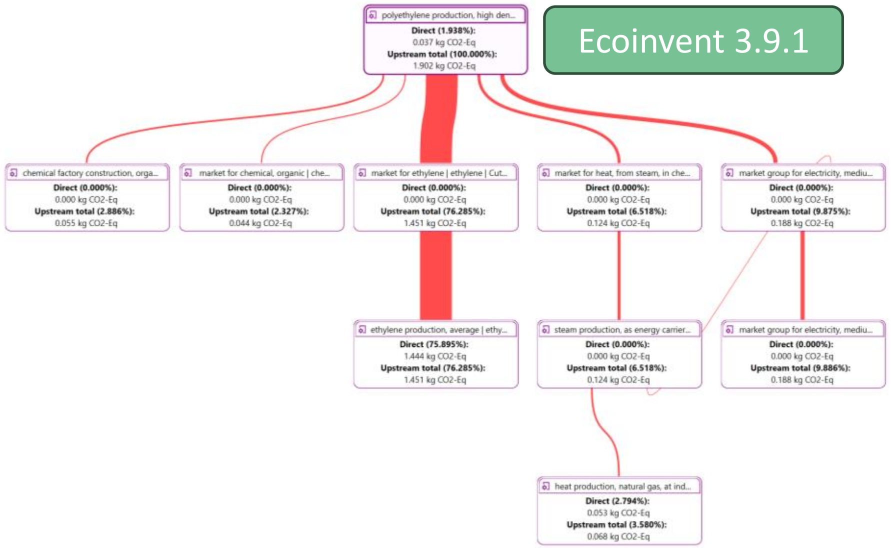
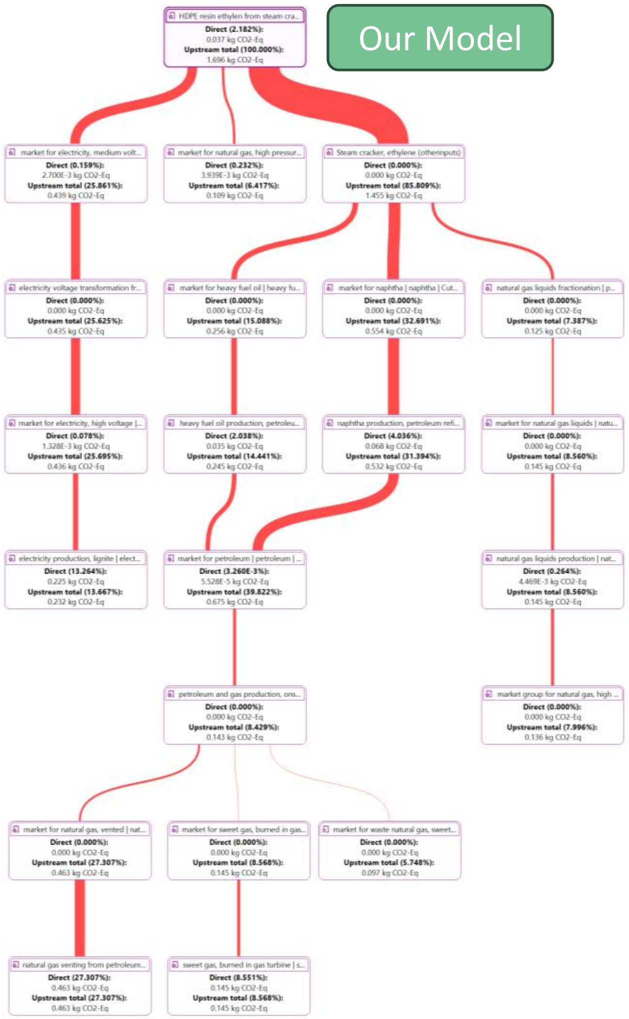


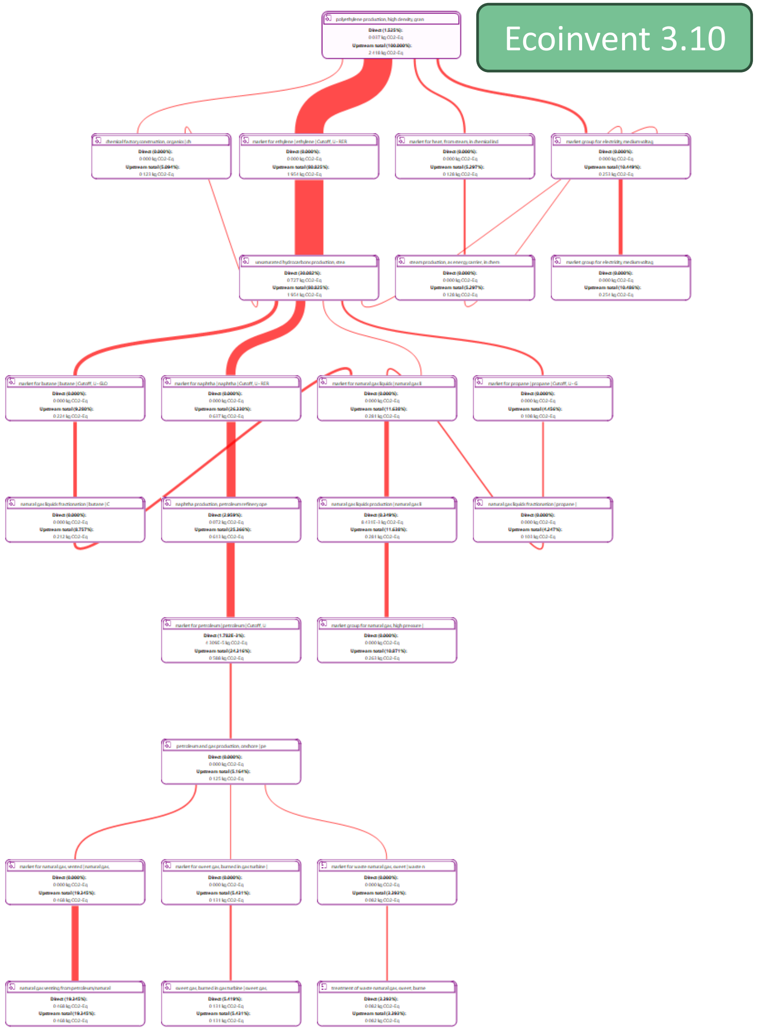
Table 30. Comparison of relative change in scores (EF 3.1) between version 3.9.1 and 3.10 (system model: allocation, cut-off) for the market for ethylene and propylene for RER (and RoW is provided in the parenthesis).

LCIA impact category – EF 3.1	Ethylene	Propylene
acidification-accumulated exceedance (AE)	14% (82%)	11% (90%)
climate change-global warming potential (GWP100)	35% (56%)	31% (99%)
ecotoxicity: freshwater; comparative toxic unit for ecosystems (CTUe)	2572% (9353%)	2506% (14182%)
energy resources: non-renewable; abiotic depletion potential (ADP): fossil fuels	6% (9%)	4% (17%)
eutrophication: freshwater; fraction of nutrients reaching freshwater end compartment (P)	2104% (3967%)	1961% (4798%)
eutrophication: marine; fraction of nutrients reaching marine end compartment (N)	25% (85%)	31% (110%)
eutrophication: terrestrial; accumulated exceedance (AE)	20% (79%)	26% (101%)
human toxicity: carcinogenic; comparative toxic unit for human (CTUh)	11719% (12917%)	10891% (11221%)
human toxicity: non-carcinogenic; comparative toxic unit for human (CTUh)	943% (876%)	890% (1207%)
ionising radiation: human health; human exposure efficiency relative to u235	53174% (59955%)	51204% (81179%)
land use; soil quality index	36346% (45207%)	34442% (45480%)
material resources: metals/minerals; abiotic depletion potential (ADP): elements (ultimate reserves)	31522% (38511%)	41489% (43954%)
ozone depletion; ozone depletion potential (ODP)	27872% (21880%)	27291% (22470%)
particulate matter formation; impact on human health	-22% (63%)	-25% (122%)
photochemical oxidant formation: human health; tropospheric ozone concentration increase	132% (149%)	137% (153%)
water use-user deprivation potential (deprivation-weighted water consumption)	-44% (-12%)	-44% (46%)

Modeling plastic, details: GWP



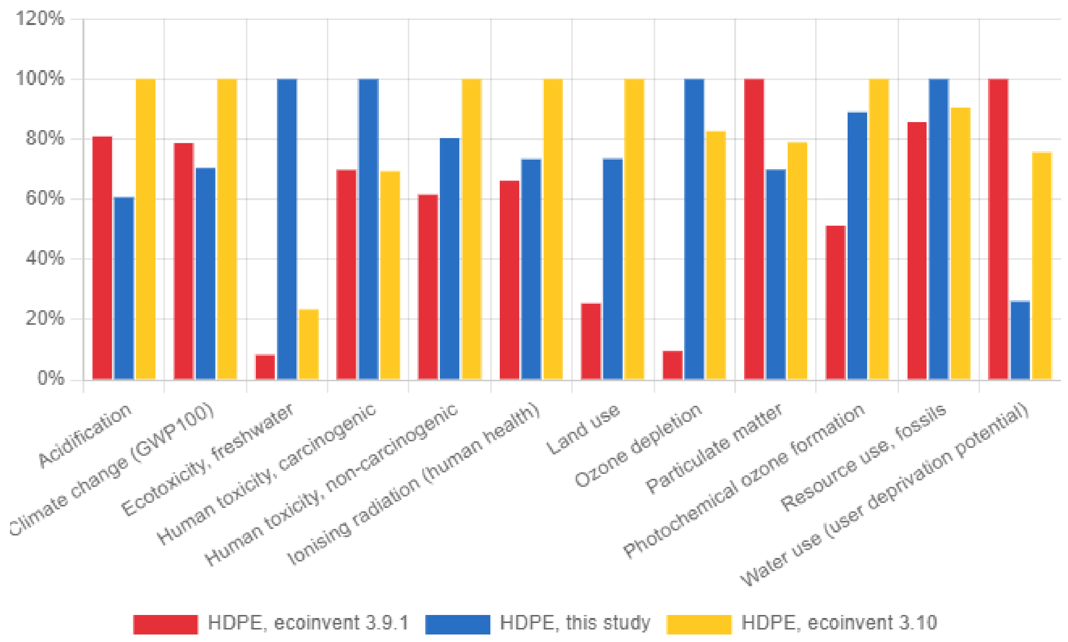




ecoinvent 3.10, cut-off in openLCA 2.1, LCIA EF 3.1, selected impact categories

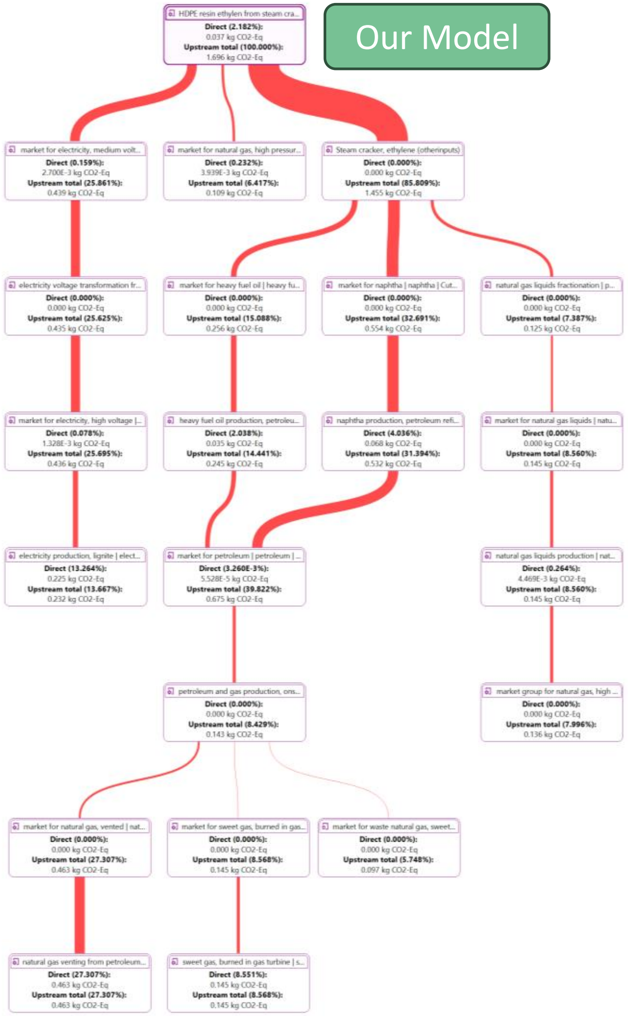
With ecoinvent 3.10

Impact categories	Differ. Study vs. ei 3.9.1	HDPE, ei 3.9.1	HDPE, this study	HDPE, ei 3.10	Differ. Study vs. ei 3.10	Unit
Acidification	-25%	0.00601	0.00451	0.00743	-39%	mol H+-Eq
Climate change (GWP100)	-10%	1.90245	1.70345	2.41752	-30%	kg CO2-Eq
Ecotoxicity, freshwater	1094%	2.32923	27.82664	6.53875	326%	CTUe
Human toxicity, carcinogenic	43%	4.56E-10	6.54E-10	4.53E-10	44%	CTUh
Human toxicity, non-carcinogenic	30%	1.02E-08	1.33E-08	1.66E-08	-20%	CTUh
Ozone depletion	935%	0.12847	0.14234	0.19391	21%	kg CFC-11-Eq
Particulate matter	-30%	1.73497	5.00155	6.80458	-12%	disease incidence
Photochemical ozone formation	74%	1.13E-02	6.49E-03	1.32E-02	-11%	kg NMVOC-Eq
Resource use, fossils	17%	71.66	83.65	75.70	11%	MJ
Water use	-73%	0.00649	0.01128	0.64350	-65%	m3 world eq.



Conclusion

- Most LCI data sets of (petro)chemicals is based on EcoProfiles
- Various databases like CarbonMinds, GaBi and ecoinvent 3.9.1 provide mostly system process lacking on transparency and Scope 3 identification
- Our modeling approach connected ethylene/propylene production with the ecoinvent 3.9.1 database
- Results of our model:
  - Similar impacts to the aggregated datasets from eocinenvt 3.9.1
  - The **largest contributor to GWP is 'natural gas venting' (27%)**
  - ODP and ecotox. are is highly increased for the emissions occurring during raw material extraction (crude oil, gas)
- Ecoinvent 3.10 integrated unit process for the olefin supply chain!
  - **GWP 'steam cracking' (30%) and 'natural gas venting' (18%)** ✓



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