Documentation of changes implemented in the ecoinvent database v3.9 (2022.10.13)

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1 Introduction to the new version: highlights

The v3.9 introduces several large updates to the ecoinvent database, some of them with a big influence in the results. The following chapters of this report will give you the details of all updates and additions made since the v3.8 (released in September 2021), this chapter aims at giving you a fast summary.

For a full comparison, at the exchange level, between the versions of the database, the Change Report Annex can be downloaded as an excel file from the “Files” section of the ecoQuery by license holders only. This file lists all activities highlighting its changes, it also aligns the 2 versions of the activities, at the flow level, to allow change tracking.

Correspondence files for each system model, as well as for the Undefined database are provided together with this report; they can be checked for equivalences in case of deletion or disaggregation of activities.

More information about the technical background of the sectors can be found in the dedicated sectorial pages, on the ecoinvent website.

1.1 Content Updates

The following sectors have been updated for v3.9:

Crude oil and natural gas extraction and supply: the extraction and supply of oil and gas at a lobal scale have been updated, covering 90% and 80% of the global supply respectively. Special attention has been paid to gas flaring and methane fugitive emissions. See chapter 6 for detailed information.

Waste: the wastewater sector has been fully restructured for v3.9 (see chapter 10), with a disaggregation of the treatment in the subsequent treatment chains for generated by-products.

Energy: this sector benefits from the regular update of market mixes in the attributional system models to the most recent available year, and also from the introduction of residual mixes for Europe (chapter 7).

Building and construction: the cement and concrete supply chains in the database have been remodelled, renamed and harmonized. Check chapter 4 to get all the mapping and replacement suggestions.

Chemical: the chemical sector (chapter 5) integrates 38 new chemicals and updates several key processes.

Agriculture: this sector increases the coverage of Canadian products with new pulse crops (chapter 3.1), and of Brazilian products with the introduction of more regionalised activities and agricultural practices (chapter 3.2).

Pulp, paper and cardboard: several updates in this sector bring most recent available data to the database (chapter 8).

The metal sector adds several scarce metal supply chains (chapter 8), and a new Lithium Iron Phosphate battery is added to the battery sector (chapter 11.2).

As a consequence of the update, the database scores change in the v3.9 compared to those of v3.8, with more radical changes identified in some sectors and with some indicators. This report contains detailed analysis of the results and the drivers of the change in dedicated chapters (see chapters 5, 6).

As we have done several changes to our methods, and mapping to elementary exchanges (see sections 2.1 and 2.5), we have used for comparison methods that showed stability between v3.8 and v3.9, to isolate the changes in results due to method updates to those changes due to data updates. We have used the following methods for comparison: CML v4.8 2016, Cumulative Energy Demand (CED), Cumulative Exergy Demand (CExD), Ecosystem Damage Potential, Ecological Footprint, EF v3.0 and IPCC 2013.

In general (in “allocation, recycled content, cut-off”), for most of the indicators studied, the results changed less than 10% (increase or decrease) for 50-90% of the database. Exceptions to that are the ozone depletion indicators, (show big decreases in results affecting to in some cases 30% of the datasets in v3.9),the metal indicators (show more modest decrease in scores, affecting up to 20% of the database),or some indicators of CED and CExD methods (they show decreases or increases in scores when v3.8 and v3.9 are compared, affecting between 10-20% of the database). Those changes in results are driven mostly by the petroleum and oil update (read more in chapter 6.6), but also relate to the updates in electricity and transmission infrastructures or some chemicals updates.

1.2 Other updates

Some improvements are done to the “allocation at the point of substitution” and “allocation, cut-off, EN15804” system models, to improve usability and result interpretation, read more in chapter 0 and 0.

The ecoinvent association has been heavily working on improving mapping between formats and databases, in the framework of the GLAD initiative[1]. The v3.9 incorporates a lot of the learnings from this process, and updates heavily the elementary exchange list of the ecoinvent database (see chapter 2.1).

[1] https://ecoinvent.org/activities/global-lca-data-access-network/

Continuing with the regular updates to Impact Assessment Methods, and benefiting from the updates to the elementary exchange list, several methods have been updated or added new to the v3.9 of the ecoinvent database (chapter 0).

Finally, with the v3.9, 100% of the products in the database have an associated Product Information to support users in the decision-making process of choosing inputs or outputs for their modelling work (see chapter 2.6), finishing what was initiated with v3.8 (Moreno-Ruiz et al. 2021).

2 Database-wide changes

2.1 Renamed activities and exchanges

Some activities or products were renamed for version 3.9. The changes are listed in the following tables, and in the sector-dedicated chapters if associated to it there was a change in the modelling. Furthermore, some elementary exchanges were renamed for version 3.9 (see Table 3) and the unit for gas elementary exchanges was renamed to standard cubic metres (Sm^3) to be more specific (see Table 4).

Table 1. Activities renamed for v3.9. Most of the changes aim at better defining the scope of the activity. More details of some changes are given in the corresponding chapters.

Activity Name v3.8	Activity Name v3.9
acrylic binder production, product in 34% solution state	acrylic binder production, with water, in 54% solution state
acrylic dispersion production, product in 65% solution state	acrylic dispersion production, with water, in 58% solution
acrylic varnish production, product in 87.5% solution state	acrylic varnish production, with water, in 53% solution state
battery cell production, Li-ion	battery cell production, Li-ion, LiMn2O4
battery production, Li-ion, rechargeable, prismatic	battery production, Li-ion, LiMn2O4, rechargeable, prismatic
battery production, NCA, Li-ion, rechargeable, prismatic	battery production, Li-ion, NCA, rechargeable, prismatic
battery production, NMC811, Li-ion, rechargeable, prismatic	battery production, Li-ion, NMC811, rechargeable, prismatic
biomethane pressure reduction from high to low pressure	biomethane pressure reduction, from high to low pressure
cathode production, LiMn2O4, for lithium-ion battery	cathode production, LiMn2O4, for Li-ion battery
cement production, alternative constituents 21-35%	cement production, CEM II/B
cement production, alternative constituents 45%	cement production, type general use
cement production, alternative constituents 6-20%	cement production, CEM II/A
cement production, blast furnace slag 18-30% and 18-30% other alternative constituents	cement production, CEM V/A
cement production, blast furnace slag 21-35%	cement production, CEM II/B-S
cement production, blast furnace slag 25-70%	cement production, type IS
cement production, blast furnace slag 31-50% and 31-50% other alternative constituents	cement production, CEM V/B
cement production, blast furnace slag 35-70%	cement production, CP III
cement production, blast furnace slag 36-65%	cement production, CEM III/A
cement production, blast furnace slag 40-70%	cement production, Portland Slag
cement production, blast furnace slag 5-25%	cement production, type I (SM)
cement production, blast furnace slag 6-20%	cement production, CEM II/A-S
cement production, blast furnace slag 6-34%	cement production, CP II-E
cement production, blast furnace slag 66-80%	cement production, CEM III/B
cement production, blast furnace slag 70-100%	cement production, type S
cement production, blast furnace slag 81-95%	cement production, CEM III/C
cement production, fly ash 21-35%	cement production, CEM II/B-V
cement production, fly ash 6-20%	cement production, CEM II/A-V
cement production, limestone 21-35%	cement production, CEM II/B-L

Activity Name v3.8	Activity Name v3.9
cement production, limestone 6-10%	cement production, CP II-F
cement production, limestone 6-20%	cement production, CEM II/A-L
cement production, pozzolana and fly ash 11-35%	cement production, CEM IV/A
cement production, pozzolana and fly ash 15-40%	cement production, type IP/P
cement production, pozzolana and fly ash 15-50%	cement production, CP IV
cement production, pozzolana and fly ash 25-35%	cement production, Pozzolana Portland
cement production, pozzolana and fly ash 36-55%	cement production, CEM IV/B
cement production, pozzolana and fly ash 5-15%	cement production, type I-PM
cement production, pozzolana and fly ash 6-14%	cement production, CP II-Z
cement production, sulphate resistant	cement production, CP V RS
concrete production 20MPa	concrete production, 20MPa, with cement, CEM II/B-V
concrete production 25-30MPa	concrete production, 25-30MPa, with cement, Portland
concrete production 25MPa	concrete production, 25MPa, for building construction, for interior use, with cement, Portland
concrete production 30-32MPa	concrete production, 30-32MPa, with cement, Portland
concrete production 30MPa	concrete production, 30MPa, with cement, CEM II/B-V
concrete production 40MPa	concrete production, 40MPa, with cement, CEM II/B-V
concrete production 45MPa	concrete production, 45MPa, with cement, CEM II/B-V
concrete production 50MPa	concrete production, 50MPa, with cement, CEM II/B-V
concrete production, 20MPa, ready-mix, with cement, alternative constituents 21-35%	concrete production, 20MPa, for building construction, with cement, ART
concrete production, 20MPa, ready-mix, with cement, limestone 21-35%	concrete production, 20MPa, for building construction, with cement, type ICo
concrete production, 20MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete production, 20MPa, for building construction, with cement, type IP
concrete production, 20MPa, self, construction, with cement, pozzolana and fly ash 36-55%	concrete production, 20MPa, self-construction, for building construction, with cement, type IP
concrete production, 20MPa, self-construction, with cement, alternative constituents 45%	concrete production, 20MPa, self-construction, for building construction, with cement, type general use
concrete production, 20MPa, self-construction, with cement, limestone 21-35%	concrete production, 20MPa, self-construction, for building construction, with cement, type ICo
concrete production, 20MPa, self-construction, with Portland cement	concrete production, 20MPa, self-construction, for building construction, with cement, Portland
concrete production, 25MPa, ready-mix, exposure class XC1	concrete production, 25MPa, for building construction, exposure class XC1, with cement, unspecified
concrete production, 25MPa, ready-mix, exposure class XC2	concrete production, 25MPa, for building construction, exposure class XC2, with cement, unspecified
concrete production, 25MPa, ready-mix, with cement blast furnace slag 35-70%	concrete production, 25MPa, for building construction, with cement, CEM IV/B
concrete production, 25MPa, ready-mix, with cement blast furnace slag 6-34%	concrete production, 25MPa, for building construction, with cement, CP-II-E
concrete production, 25MPa, ready-mix, with cement limestone 6-10%	concrete production, 25MPa, for building construction, with cement, CP-II-F
concrete production, 30MPa, ready-mix, exposure class XC3	concrete production, 30MPa, for building construction, exposure class XC3, with cement, unspecified
concrete production, 30MPa, ready-mix, exposure classes XC3/XD2/XF1/XA1	concrete production, 30MPa, exposure classes XC3/XD2/XF1/XA1, with cement, unspecified

Activity Name v3.8	Activity Name v3.9
concrete production, 30MPa, ready-mix, with cement blast furnace slag 35-70%	concrete production, 30MPa, for building construction, with cement, CEM III/A
concrete production, 30MPa, ready-mix, with cement blast furnace slag 6-34%	concrete production, 30MPa, for building construction, with cement, CP-II-E
concrete production, 30MPa, ready-mix, with cement limestone 6-10%	concrete production, 30MPa, for building construction, with cement, CP-II-F
concrete production, 35MPa, ready-mix, with cement blast furnace slag 35-70%	concrete production, 35MPa, for building construction, with cement, CEM III/A
concrete production, 35MPa, ready-mix, with cement blast furnace slag 6-34%	concrete production, 35MPa, for building construction, with cement, CP-II-E
concrete production, 35MPa, ready-mix, with cement limestone 6-10%	concrete production, 35MPa, for building construction, with cement, CEM II/A
concrete production, 40MPa, ready-mix, with cement blast furnace slag 35-70%	concrete production, 40MPa, for building construction, with cement, CEM III/A
concrete production, 40MPa, ready-mix, with cement blast furnace slag 6-34%	concrete production, 40MPa, for building construction, with cement, CP-II-E
concrete production, 40MPa, ready-mix, with cement limestone 6-10%	concrete production, 40MPa, for building construction, with cement, CEM II/A
concrete production, 40MPa, ready-mix, with cement, alternative constituents 21-35%	concrete production, 40MPa, for civil engineering, with cement, ART
concrete production, 40MPa, ready-mix, with cement, limestone 21-35%	concrete production, 40MPa, for civil engineering, with cement, CEM II/B
concrete production, 40MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete production, 40MPa, for civil engineering, with cement, CEM IV/B
concrete production, 40MPa, ready-mix, with Portland cement	concrete production, 40MPa, for civil engineering, with cement, Portland
concrete production, for building construction, with cement CEM II/A	concrete production, 25MPa, for building construction, with cement, CEM II/A
concrete production, for building construction, with cement CEM II/B	concrete production, 25MPa, for building construction, with cement, CEM II/B
concrete production, for drilled piles, with cement CEM I	concrete production, 37MPa, for civil engineering, with cement, Portland
concrete production, for drilled piles, with cement CEM II/A	concrete production, 37MPa, for civil engineering, with cement, CEM II/A
concrete production, for drilled piles, with cement CEM II/B	concrete production, 37MPa, for civil engineering, with cement, CEM II/B
iron (III) chloride production, product in 40% solution state	iron(III) chloride production, product in 40% solution state
market for acrylic binder, without water, in 34% solution state	market for acrylic binder, with water, in 54% solution state
market for acrylic dispersion, without water, in 65% solution state	market for acrylic dispersion, with water, in 58% solution
market for acrylic varnish, without water, in 87.5% solution state	market for acrylic varnish, with water, in 53% solution state
market for antimony slag, water quentched	market for antimony slag, water-quenched
market for battery cell, Li-ion	market for battery cell, Li-ion, LiMn2O4
market for battery, Li-ion, rechargeable, prismatic	market for battery, Li-ion, LiMn2O4, rechargeable, prismatic
market for cathode, LiMn2O4, for lithium-ion battery	market for cathode, LiMn2O4, for Li-ion battery
market for cement, alternative constituents 21-35%	market for cement, CEM II/B
market for cement, alternative constituents 45%	market for cement, type general use
market for cement, alternative constituents 6-20%	market for cement, CEM II/A
market for cement, blast furnace slag 18-30% and 18-30% other alternative constituents	market for cement, CEM V/A
market for cement, blast furnace slag 21-35%	market for cement, CEM II/B-S
market for cement, blast furnace slag 25-70%	market for cement, type IS
market for cement, blast furnace slag 31-50% and 31-50% other alternative constituents	market for cement, CEM V/B
market for cement, blast furnace slag 35-70%	market for cement, CP III

Activity Name v3.8	Activity Name v3.9
market for cement, blast furnace slag 36-65%	market for cement, CEM III/A
market for cement, blast furnace slag 40-70%	market for cement, Portland Slag
market for cement, blast furnace slag 5-25%	market for cement, type I (SM)
market for cement, blast furnace slag 6-20%	market for cement, CEM II/A-S
market for cement, blast furnace slag 6-34%	market for cement, CP II-E
market for cement, blast furnace slag 66-80%	market for cement, CEM III/B
market for cement, blast furnace slag 70-100%	market for cement, type S
market for cement, blast furnace slag 81-95%	market for cement, CEM III/C
market for cement, limestone 6-10%	market for cement, CP II-F
market for cement, limestone 6-20%	market for cement, CEM II/A-L
market for cement, portland fly ash cement 21-35%	market for cement, CEM II/B-V
market for cement, portland fly ash cement 6-20%	market for cement, CEM II/A-V
market for cement, pozzolana and fly ash 11-35%	market for cement, CEM IV/A
market for cement, pozzolana and fly ash 15-40%	market for cement, type IP/P
market for cement, pozzolana and fly ash 15-50%	market for cement, CP IV
market for cement, pozzolana and fly ash 25-35%	market for cement, Pozzolana Portland
market for cement, pozzolana and fly ash 36-55%	market for cement, CEM IV/B
market for cement, pozzolana and fly ash 5-15%	market for cement, type I-PM
market for cement, pozzolana and fly ash 6-14%	market for cement, CP II-Z
market for cement, sulphate resistant	market for cement, CP V RS
market for concrete, for de-icing salt contact	market for concrete, 37MPa
market for concrete, normal	market for concrete, normal strength
market for energy use and operation emissions, electric bicycle	market for energy use, electric bicycle
market for energy use and operation emissions, electric bicycle, electricity from renewable energy products	market for energy use, electric bicycle, electricity from renewable energy products
market for iron (III) chloride, without water, in 40% solution state	market for iron(III) chloride, without water, in 40% solution state
market for polar fleece production, energy use only	market for polar fleece, energy use only
market for soda ash, light, crystalline, heptahydrate	market for soda ash, light
market for stibnite ore, 70% stibnite	market for stibnite concentrate
market for zircon, 50% zirconium	market for zircon
market group for concrete, normal	market group for concrete, normal strength
natural gas pressure reduction from high to low pressure	natural gas pressure reduction, from high to low pressure
natural gas, burned in gas turbine, for compressor station	natural gas, burned in gas turbine
palm oil, refined, to generic market for vegetable oil	palm oil, refined, to generic market for vegetable oil, refined
petroleum and gas production, off-shore	petroleum and gas production, offshore
petroleum and gas production, on-shore	petroleum and gas production, onshore
stibnite mine operation, 70% stibnite	stibnite mine operation and beneficiation
treatment of antimony slag, water quentched, residual material landfill	treatment of antimony slag, water-quenched, residual material landfill
unreinforced concrete production, with cement CEM II/A	unreinforced concrete production, 15MPa, with cement, CEM II/A
unreinforced concrete production, with cement CEM II/B	unreinforced concrete production, 15MPa, with cement, CEM II/B

Table 2. Intermediate exchanges renamed for version 3.9. Most of the changes aim at improving the product name, increasing precision. More details of some changes are given in the corresponding chapters.

Product Name v3.8	Product Name v3.9
acrylic binder, without water, in 34% solution state	acrylic binder, with water, in 54% solution state
acrylic dispersion, without water, in 65% solution state	acrylic dispersion, with water, in 58% solution state
acrylic varnish, without water, in 87.5% solution state	acrylic varnish, with water, in 53% solution state
battery cell, Li-ion	battery cell, Li-ion, LiMn2O4
battery, Li-ion, rechargeable, prismatic	battery, Li-ion, LiMn2O4, rechargeable, prismatic
cathode, LiMn2O4, for lithium-ion battery	cathode, LiMn2O4, for Li-ion battery
cement, alternative constituents 21-35%	cement, CEM II/B
cement, alternative constituents 45%	cement, type general use
cement, alternative constituents 6-20%	cement, CEM II/A
cement, blast furnace slag 18-30% and 18-30% other alternative constituents	cement, CEM V/A
cement, blast furnace slag 21-35%	cement, CEM II/B-S
cement, blast furnace slag 25-70%	cement, type IS
cement, blast furnace slag 31-50% and 31-50% other alternative constituents	cement, CEM V/B
cement, blast furnace slag 35-70%	cement, CP III
cement, blast furnace slag 36-65%	cement, CEM III/A
cement, blast furnace slag 40-70%	cement, Portland Slag
cement, blast furnace slag 5-25%	cement, type I (SM)
cement, blast furnace slag 6-20%	cement, CEM II/A-S
cement, blast furnace slag 6-34%	cement, CP II-E
cement, blast furnace slag 66-80%	cement, CEM III/B
cement, blast furnace slag 70-100%	cement, type S
cement, blast furnace slag 81-95%	cement, CEM III/C
cement, limestone 21-35%	cement, CEM II/B-L
cement, limestone 6-10%	cement, CP II-F
cement, limestone 6-20%	cement, CEM II/A-L
cement, portland fly ash cement 21-35%	cement, CEM II/B-V
cement, portland fly ash cement 6-20%	cement, CEM II/A-V
cement, pozzolana and fly ash 11-35%	cement, CEM IV/A
cement, pozzolana and fly ash 15-40%	cement, type IP/P
cement, pozzolana and fly ash 15-50%	cement, CP IV
cement, pozzolana and fly ash 25-35%	cement, Pozzolana Portland
cement, pozzolana and fly ash 36-55%	cement, CEM IV/B
cement, pozzolana and fly ash 5-15%	cement, type I-PM
cement, pozzolana and fly ash 6-14%	cement, CP II-Z
cement, sulphate resistant	cement, CP V RS
concrete, for de-icing salt contact	concrete, 37MPa
concrete, normal	concrete, normal strength
energy use and operation emissions, electric bicycle	energy use, electric bicycle
energy use and operation emissions, electric bicycle, electricity from renewable energy products	energy use, electric bicycle, electricity from renewable energy products

Product Name v3.8	Product Name v3.9
polar fleece production, energy use only	polar fleece, energy use only
soda ash, light, crystalline, heptahydrate	soda ash, light
stibnite ore, 70% stibnite	stibnite concentrate
zircon, 50% zirconium	zircon

The list of elementary exchanges was revised and updated based on insights from ecoinvent' s participation in the GLAD project[2], in particular from the work of the nomenclature group[3]. The update includes

- improved names including, for example,
  - the removal of unnecessary information such as compartment information (e.g. ", in ground") and
  - the specification of metal oxidation states;
- added, extended, and aligned CAS numbers, formulas and synonyms;
- the removal of redundant exchanges;
- corrections of mistakes.

This improved list of elementary exchanges helps in ecoinvent' s internal data management and LCIA method implementation, but it also helps modelers using the ecoinvent database to easier identify and choose the data needed for their assessments. Furthermore, this update improves the interoperability of the ecoinvent database with other databases around the world and facilitates collaboration with LCIA method developers.

Table 3. Elementary exchanges renamed for version 3.9. Most of the changes aim at improving the elementary exchange name, increasing precision.

Elementary Exchange Name in v3.8	Elementary Exchange Name in v3.9
2-Methyl pentane	2-Methylpentane
Acrylate, ion	Acrylate
Aluminium	Aluminium III
Aluminium, in ground	Aluminium
Amine oxide	Amine oxides
Ammonium, ion	Ammonium
Anhydrite, in ground	Anhydrite
Antimony	Antimony ion
Antimony, in ground	Antimony
AOX, Adsorbable Organic Halogen as Cl	AOX, Adsorbable Organic Halogen
Arsenic	Arsenic ion
Arsenic, in ground	Arsenic
Arsenic, ion	Arsenic ion

[2] https://github.com/UNEP-Economy-Division/GLAD-ElementaryFlowResources

[3] https://www.lifecycleinitiative.org/resources-2/global-lca-data-network-glad-2/

Elementary Exchange Name in v3.8	Elementary Exchange Name in v3.9
Barium	Barium II
Barium, in ground	Barium
Basalt, in ground	Basalt
Benzene, dichloro	1,2-Dichlorobenzene
Beryllium	Beryllium II
Beryllium, in ground	Beryllium
Bicarbonate, ion	Bicarbonate
Borax, in ground	Borax
Bromine, in water	Bromine
Cadmium	Cadmium II
Cadmium, in ground	Cadmium
Cadmium, ion	Cadmium II
Calcite, in ground	Calcite
Calcium, in ground	Calcium
Calcium, ion	Calcium II
Carfentrazone ethyl ester	Carfentrazone-ethyl
Cerium, in ground	Cerium
Cesium	Caesium
Cesium-134	Caesium-134
Cesium-136	Caesium-136
Cesium-137	Caesium-137
Chromium	Chromium III
Chromium, in ground	Chromium
Chromium, ion	Chromium III
Chrysotile, in ground	Chrysotile
Clay, bentonite, in ground	Clay, bentonite
Clay, unspecified, in ground	Clay, unspecified
Coal, brown, in ground	Coal, brown
Coal, hard, unspecified, in ground	Coal, hard, unspecified
Cobalt	Cobalt II
Cobalt, in ground	Cobalt
Colemanite, in ground	Colemanite
Copper	Copper ion
Copper, in ground	Copper
Copper, ion	Copper ion
Diatomite, in ground	Diatomite
Diphenylether-compound	Diphenylether compounds
Dolomite, in ground	Dolomite
Dysprosium, in ground	Dysprosium
Ethene	Ethylene
Ethene, chloro-	Chloroethylene
Ethene, tetrachloro-	Tetrachloroethylene
Europium, in ground	Europium
Feldspar, in ground	Feldspar

Elementary Exchange Name in v3.8	Elementary Exchange Name in v3.9
Fluazifop-p-butyl	Fluazifop-P-butyl
Fluorine, in ground	Fluorine
Fluorochloridone	Flurochloridone
Fluorspar, in ground	Fluorspar
Gadolinium, in ground	Gadolinium
Gallium, in ground	Gallium
Gangue, in ground	Gangue
Gas, natural, in ground	Gas, natural
Gold, in ground	Gold
Granite, in ground	Granite
Gravel, in ground	Gravel
Gypsum, in ground	Gypsum
Hafnium, in ground	Hafnium
Hydrogen carbonate	Bicarbonate
Hydrogen chloride	Hydrochloric acid
Iodine, in water	Iodine
Iprodion	Iprodione
Iron	Iron ion
Iron, in ground	Iron
Iron, ion	Iron ion
Kaolinite, in ground	Kaolinite
Kieserite, in ground	Kieserite
Krypton, in air	Krypton
Lanthanum, in ground	Lanthanum
Laterite, in ground	Laterite
Lead	Lead II
Lead, in ground	Lead
Lithium	Lithium I
Lithium, in ground	Lithium
Lithium, ion	Lithium I
Magnesite, in ground	Magnesite
Magnesium, in ground	Magnesium
Manganese	Manganese II
Manganese, in ground	Manganese
Mercury	Mercury II
Mercury, in ground	Mercury
Metamorphous rock, graphite containing, in ground	Graphite
Methyl amine	Methylamine
Methyl pentane	2-Methylpentane
Molybdenum	Molybdenum VI
Molybdenum, in ground	Molybdenum
Monobutyltin	Monobutyltin (III)
Naphtalene	Naphthalene
Neodymium, in ground	Neodymium

Elementary Exchange Name in v3.8	Elementary Exchange Name in v3.9
Nickel	Nickel II
Nickel, in ground	Nickel
Nickel, ion	Nickel II
Niobium, in ground	Niobium
NMVOC, non-methane volatile organic compounds, unspecified origin	NMVOC, non-methane volatile organic compounds
o-Dichlorobenzene	1,2-Dichlorobenzene
Oil, crude, in ground	Oil, crude
Olivine, in ground	Olivine
Palladium	Palladium II
Palladium, in ground	Palladium
Particulates, < 2.5 um	Particulate Matter, < 2.5 um
Particulates, > 10 um	Particulate Matter, > 10 um
Particulates, > 2.5 um, and < 10um	Particulate Matter, > 2.5 um and < 10um
Peat, in ground	Peat
Perchlorate, ion	Perchlorate
Perlite, in ground	Perlite
Phosphorus, in ground	Phosphorus
Platinum, in ground	Platinum
Potassium	Potassium I
Potassium, in ground	Potassium
Potassium, ion	Potassium I
Praseodymium, in ground	Praseodymium
Prothioconazol	Prothioconazole
Pumice, in ground	Pumice
Pyraclostrobin (prop)	Pyraclostrobin
Pyrite, in ground	Pyrite
Rhenium, in ground	Rhenium
Rhodium	Rhodium III
Rhodium, in ground	Rhodium
Samarium, in ground	Samarium
Sand, unspecified, in ground	Sand, unspecified
Scandium, in ground	Scandium
Selenium	Selenium IV
Selenium, in ground	Selenium
Shale, in ground	Shale
Silicon, in ground	Silicon
Silver	Silver I
Silver, in ground	Silver
Silver, ion	Silver I
Sodium chloride, in ground	Sodium chloride
Sodium nitrate, in ground	Sodium nitrate
Sodium sulphate, various forms, in ground	Sodium sulphate, various forms
Sodium, in ground	Sodium
Sodium, ion	Sodium I

Elementary Exchange Name in v3.8	Elementary Exchange Name in v3.9
Spodumene, in ground	Spodumene
Steatite, in ground	Steatite
Strontium, in ground	Strontium
Sulfur, in ground	Sulfur
Sylvite, in ground	Sylvite
Talc, in ground	Talc
Tantalum, in ground	Tantalum
Tebupirimphos	Tebupirimfos
Tellurium, in ground	Tellurium
Terbium, in ground	Terbium
Thallium	Thallium I
Thiocyanate, ion	Thiocyanate
Tin	Tin ion
Tin, in ground	Tin
Tin, ion	Tin ion
Titanium	Titanium ion
Titanium, in ground	Titanium
Titanium, ion	Titanium ion
Tungsten, in ground	Tungsten
Ulexite, in ground	Ulexite
Uranium, in ground	Uranium
Vanadium	Vanadium V
Vanadium, in ground	Vanadium
Vanadium, ion	Vanadium V
Vermiculite, in ground	Vermiculite
VOC, volatile organic compounds, unspecified origin	VOC, volatile organic compounds
Xenon, in air	Xenon
Yttrium, in ground	Yttrium
Zinc	Zinc II
Zinc, in ground	Zinc
Zinc, ion	Zinc II
Zirconium, in ground	Zirconium

Table 4. Elementary exchange units renamed for version 3.9. “Sm3” stands for standard cubic metre, which is a cubic metre of gas at 15°C and 101.325 kPa

Elementary Exchange Name in v3.8	Unit in v3.8	Elementary Exchange Name in v3.9	Unit in v3.9
Gas, mine, off-gas, process, coal mining	m3	Gas, mine, off-gas, process, coal mining	Sm3
Gas, natural, in ground	m3	Gas, natural	Sm3

2.2 Modifications of Lower Heating Values of products

In v3.8, the Lower Heating Value (LHV) was added as a property to all relevant products in the database (Moreno-Ruiz et al., 2021). The LHVs were extracted from literature or were based on approximate relationships (Ioannidou et al., 2021). During this massive project, some values allocated to products were based on wrong assumptions or were not corresponding to the functional unit of the product. These values have been corrected in v3.9. In addition, following the project of update of the petroleum and natural gas sector, new LHVs were defined for these products. Table 5 includes all products where a correction to their LHV has been implemented in v3.9.

Table 5. Products with updated Lower Heating Values in v3.9. The Lower Heating Value is expressed in MJ per unit of product.

Product name	LHV Value in v3.8 (MJ)	LHV Value in 3.9 (MJ)
ethanol, without water, in 95% solution state, from fermentation	31.58	28.1
ethanol, without water, in 99.7% solution state, from ethylene	31.58	28.1
ethanol, without water, in 99.7% solution state, from fermentation	31.58	28.1
ethanol, without water, in 99.7% solution state, from fermentation, vehicle grade	31.58	28.1
pulverised lignite	8.8	1
lignite briquettes	8.8	19.5
lignite ash	0	21.7
biogas, from grass	29.09	19.74
glycerine	22.38	18
synthetic gas	6.21	5.2
methanol	26.49	20
bitumen seal	19.51	39.33
bitumen seal, Alu80	17.58	39.33
bitumen seal, polymer EP4 flame retardant	18.06	39.33
bitumen seal, V60	18.01	39.33
bitumen seal, VA4	18.92	39.33
natural gas, high pressure	39	36
natural gas, low pressure	39	36
natural gas, unprocessed, at extraction	39	36
natural gas, vented	39	36
natural gas, liquefied	39	36
natural gas, high pressure, vehicle grade	46.5	48.98
natural gas, low pressure, vehicle grade	46.5	48.98
natural gas, medium pressure, vehicle grade	46.5	48.98
petroleum	43.2	43.4

2.2.1 Modifications of heat production datasets

Associated to the change in Lower Heating Values, the natural gas consumption of natural gas boilers has been modified to account for a LHV of 36MJ/m3 of "natural gas, high pressure" and "natural gas, low pressure". In the datasets of Table 6, the input of natural gas has been adjusted accordingly.

Table 6. Modifications in heat production datasets. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. The unit of all reference products is MJ.

Activity Name	Geography	Time Period	Product Name
heat production, natural gas, at boiler atm. low-NOx condensing non-modulating <100kW	Europe without Switzerland; GLO	1990-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler atmospheric low-NOx non-modulating <100kW	Europe without Switzerland; GLO	1990-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler atmospheric non-modulating <100kW	Europe without Switzerland; GLO	2000-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler condensing modulating <100kW	CH; Europe without Switzerland; GLO	2000-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler condensing modulating >100kW	CA-QC	2000-2015	heat, district or industrial, natural gas
heat production, natural gas, at boiler condensing modulating >100kW	Europe without Switzerland; GLO	2000-2000	heat, district or industrial, natural gas
heat production, natural gas, at boiler fan burner low-NOx non-modulating <100kW	Europe without Switzerland; GLO	1990-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler fan burner non-modulating <100kW	Europe without Switzerland; GLO	2000-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler modulating <100kW	Europe without Switzerland; GLO	2000-2000	heat, central or small-scale, natural gas
heat production, natural gas, at boiler modulating >100kW	CA-QC	2000-2015	heat, district or industrial, natural gas
heat production, natural gas, at boiler modulating >100kW	Europe without Switzerland; GLO	2000-2000	heat, district or industrial, natural gas
heat production, natural gas, at diffusion absorption heat pump 4kW, future	CH; GLO	2000-2005	heat, future
heat production, natural gas, at industrial furnace >100kW	CA-QC	2000-2015	heat, district or industrial, natural gas
heat production, natural gas, at industrial furnace >100kW	Europe without Switzerland; GLO	2000-2000	heat, district or industrial, natural gas
heat production, natural gas, at industrial furnace low-NOx >100kW	CA-QC	1990-2015	heat, district or industrial, natural gas
heat production, natural gas, at industrial furnace low-NOx >100kW	Europe without Switzerland; GLO	1990-2000	heat, district or industrial, natural gas

2.3 Changes to Allocation, cut-off, EN15804 system model

2.3.1 Change in terminology

In v3.9, the most significant change introduced is the replacement of the "Recycled Content, cut-off" datasets with "burden-free production" datasets. A "burden-free production" dataset is a dataset that contains solely a recyclable product after its end-of-waste. The recyclable product is the reference product in the "burden-free production" dataset. A reminder here that the end-of-waste is represented by the cut-off point. According to the standard EN15804&A2:2019 and the guidance 16970, the "polluter pays" principle applies to the allocation of burdens related to the production of waste. Impacts from the treatment of waste generated by a product system belong to this initial product system, while the secondary product system carries only the burdens of additional processing. The new terminology was introduced to facilitate the users and make clear and transparent what this "burden-free production" dataset represents.

2.3.2 Change in product classification

In v3.9, the "aluminium scrap, new" in the Allocation, cut-off, EN15804 system model is classified as allocatable (in the previous version, it was recyclable). According to EN15804&A2:2019, "flows leaving the system at the end-of-waste boundary of the product stage (A1-A3) shall be allocated as co-products. Figure 1 depicts the supply chain of "aluminium scrap, new" in the Allocation, cut-off, EN15804 system model. Due to this change in classification, the activities consuming "aluminium scrap, new" have higher LCIA scores.

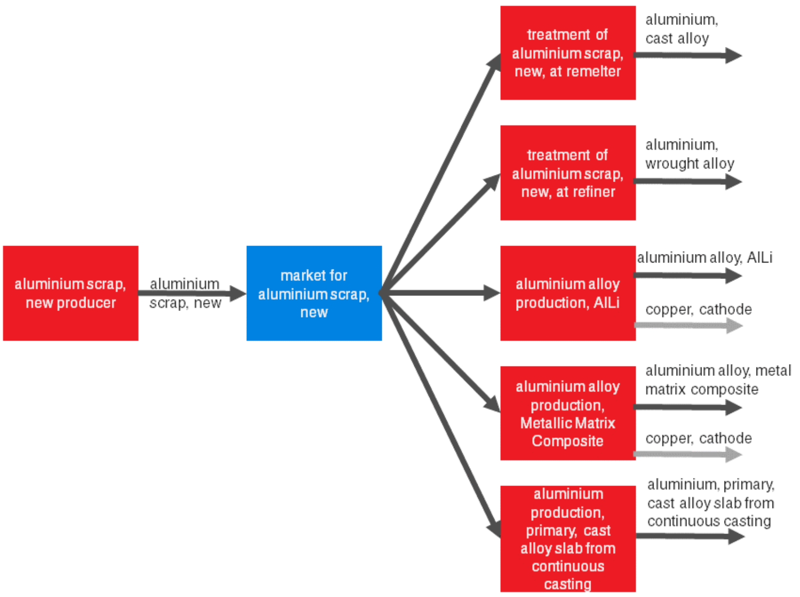

Figure 1: Supply chain of "aluminium scrap, new" in "Allocation, cut-off, EN15804".

2.3.3 New impact assessment methods and modifications of characterization factors

In v3.9, two impact assessment methods are available for the Allocation, cut-off, EN15804 system model plus the impact assessment method used for calculating the inventory indicators:

- *EF v3.0 EN15804* method and the updated *EF v3.1 EN15804*. More information on the implementation can be found in 2.5.3.2.

- TRACI v2.1

In the inventory indicators for the Allocation, cut-off, EN15804 system model, the elementary exchanges having a Characterization factor for the indicator ‘Use of net fresh water’ were corrected, as per Table 7.

Table 7 Changes applied in the ‘Use of net fresh water’ indicator

Name	Compartment	Subcompartment	CF old	CF
Water	water	unspecified	-1	-1
Water	water	surface water	-1	-1
Water	water	ground-	-1	-1
Water, cooling, unspecified natural origin	natural resource	in water	1	1
Water, river	natural resource	in water	1	1
Water, well, in ground	natural resource	in water	1	1
Water, unspecified natural origin	natural resource	in water	1	1
Water, lake	natural resource	in water	1	1
Water, turbine use, unspecified natural origin	natural resource	in water	1	1
Water, in air	natural resource	in air	1	1
Water	water	ocean	-1	0
Water, salt, sole	natural resource	in water	1	0
Water, salt, ocean	natural resource	in water	1	0

2.4 Changes to Allocation at the point of substitution (APOS) system model

2.4.1 Correction to specialty production supply chains

Specialty production datasets are treatment datasets that are modelled as regular transforming activities, where the waste (MFT) is an input. This reflects the fact that the driver of the process to happen is not the treatment of the MFT “*per se*”, but the manufacturing action.

One example is the input of waste wood used in the production of structural timber. During the first step of the system model, this dataset becomes a waste treatment, treating a small amount of waste wood, and producing structural timber as a by-product. This means that any process that was producing waste wood as a by-product (that needed to be treated) gets a credit for a large amount of structural timber, as a timber flow will be merged into the activity and allocated against the reference product, decreasing its relative impacts.

In any situation, the credit for the production of 1 kg of waste wood to be treated should not exceed that proportionally needed for manufacturing structural timber. When such cases are encountered, the credit attributed to the waste has been adjusted. The list of corrections (70 in total) is present in the Table below.

Table 8. Manually overwritten credits for waste treatments in the APOS system model. The columns Activity Name and Geography indicate which dataset carries the treatment. The waste treated is reported in column "Waste (W)", and the waste unit in column "W unit". The valuable product produced by the dataset is named in column "Valuable (V)". Its amount and unit are reported in columns V credit per "W unit" and "V kg".

Activity Name	Geography	Waste (W)	W unit	Valuable (V)	V unit	V credit per W unit	Note
glass production, for liquid crystal display	GLO	waste packaging glass, unsorted	kg	glass, for liquid crystal display	kg	1	assumes no loss of glass during the process
folding boxboard carton production	RoW	waste paper, sorted	kg	turpentine	kg	0	this by-product coming from wood inputs
folding boxboard carton production	RER	waste paper, sorted	kg	turpentine	kg	0	this by-product coming from wood inputs
aluminium alloy production, AlLi	CA-QC	aluminium scrap, new	kg	aluminium alloy, AlLi	kg	0.982	the scrap is only responsible for the Al content of the alloy
aluminium alloy production, AlLi	RoW	aluminium scrap, new	kg	aluminium alloy, AlLi	kg	0.982	the scrap is only responsible for the Al content of the alloy
aluminium alloy production, Metallic Matrix Composite	CA-QC	aluminium scrap, new	kg	aluminium alloy, metal matrix composite	kg	0.995	the scrap is only responsible for the Al content of the alloy
aluminium alloy production, Metallic Matrix Composite	RoW	aluminium scrap, new	kg	aluminium alloy, metal matrix composite	kg	0.995	the scrap is only responsible for the Al content of the alloy
aluminium production, primary, cast alloy slab from continuous casting	CA-QC	aluminium scrap, new	kg	aluminium, primary, cast alloy slab from continuous casting	kg	0.99	the scrap is only responsible for the Al content of the alloy
aluminium production, primary, cast alloy slab from continuous casting	RoW	aluminium scrap, new	kg	aluminium, primary, cast alloy slab from continuous casting	kg	0.99	the scrap is only responsible for the Al content of the alloy
cellulose fibre production	CH	waste paper, sorted	kg	cellulose fibre	kg	0.975826	based on carbon content
cellulose fibre production	RoW	waste paper, sorted	kg	cellulose fibre	kg	0.975826	based on carbon content
core board production	CA-QC	waste paper, sorted	kg	core board	kg	1.043179	credit calculated based on carbon content of the paper and board
core board production	RoW	waste paper, sorted	kg	core board	kg	1.043179	credit calculated based on carbon

Activity Name	Geography	Waste (W)	W unit	Valuable (V)	V unit	V credit per W unit	Note
							content of the paper and board
core board production	RER	waste paper, sorted	kg	core board	kg	1.043179	credit calculated based on carbon content of the paper and board
dewatering of ethanol from biomass, from 95% to 99.7% solution state	CN	bagasse, from sweet sorghum	kg	ethanol, without water, in 99.7% solution state, from fermentation	kg	0	bagasse is used as a fuel
esterification of vegetable oils and animal fats, average mix	BR	tallow, unrefined	kg	glycerine	kg	0.118892	based on carbon content: tallow brings 17.1% of the carbon
esterification of vegetable oils and animal fats, average mix	BR	tallow, unrefined	kg	fatty acid methyl ester	kg	0.884784	based on carbon content: tallow brings 17.1% of the carbon
ferrosilicon production	CN	coal tar	kg	ferrosilicon	kg	0	documentation states that the coal tar is used only for the production of the anode
ferrosilicon production	RoW	coal tar	kg	ferrosilicon	kg	0	documentation states that the coal tar is used only for the production of the anode
fibre cement roof slate production	CH	waste paper, unsorted	kg	fibre cement roof slate	kg	0.526315	paper represents 0.017/1.9 of the mass input
fibre cement roof slate production	RoW	waste paper, unsorted	kg	fibre cement roof slate	kg	0.526315	paper represents 0.017/1.9 of the mass input
fibreboard production, soft, from wet & dry processes	CA-QC	waste paper, sorted	kg	bark chips, wet, measured as dry mass	kg	0	the paper input is not responsible for the production of wood
fibreboard production, soft, from wet & dry processes	CA-QC	waste paper, sorted	kg	residual wood, dry	m3	0	the paper input is not responsible for the production of wood
fibreboard production, soft, from wet & dry processes	Europe without Switzerland	waste paper, sorted	kg	bark chips, wet, measured as dry mass	kg	0	the paper input is not responsible for the production of wood
fibreboard production, soft, from wet & dry processes	Europe without Switzerland	waste paper, sorted	kg	residual wood, dry	m3	0	the paper input is not responsible for the production of wood
fibreboard production, soft, from wet & dry processes	RoW	waste paper, sorted	kg	bark chips, wet, measured as dry mass	kg	0	the paper input is not responsible for the production of wood
fibreboard production, soft, from wet & dry processes	RoW	waste paper, sorted	kg	residual wood, dry	m3	0	the paper input is not responsible for the production of wood

Activity Name	Geography	Waste (W)	W unit	Valuable (V)	V unit	V credit per W unit	Note
fibreboard production, soft, from wet & dry processes	CA-QC	waste paper, sorted	kg	fibreboard, soft	m3	0.003355	waste paper provides 0.2% of the dry mass input
fibreboard production, soft, from wet & dry processes	Europe without Switzerland	waste paper, sorted	kg	fibreboard, soft	m3	0.003355	waste paper provides 0.2% of the dry mass input
fibreboard production, soft, from wet & dry processes	RoW	waste paper, sorted	kg	fibreboard, soft	m3	0.003355	waste paper provides 0.2% of the dry mass input
folding boxboard carton production	RoW	waste paper, sorted	kg	bark chips, wet, measured as dry mass	kg	0	the paper input is not responsible for the production of wood
folding boxboard carton production	RER	waste paper, sorted	kg	bark chips, wet, measured as dry mass	kg	0	the paper input is not responsible for the production of wood
folding boxboard carton production	RoW	waste paper, sorted	kg	folding boxboard carton	kg	0.702126	waste paper provides 0.8% of the dry mass input
folding boxboard carton production	RER	waste paper, sorted	kg	folding boxboard carton	kg	0.702126	waste paper provides 0.8% of the dry mass input
glued laminated timber production, average glue mix	Europe without Switzerland	waste wood, post-consumer	kg	glued laminated timber, average glue mix	m3	0.00175	waste wood provides 0.225% of mass input
glued laminated timber production, average glue mix	RoW	waste wood, post-consumer	kg	glued laminated timber, average glue mix	m3	0.00175	waste wood provides 0.225% of mass input
glued laminated timber production, average glue mix	Europe without Switzerland	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.208366	waste wood provides 0.228% of wood input
glued laminated timber production, average glue mix	RoW	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.208366	waste wood provides 0.228% of wood input
glued solid timber production	RoW	waste wood, post-consumer	kg	glued solid timber	m3	0.001591	waste wood is 0.81% of mass input
glued solid timber production	RER	waste wood, post-consumer	kg	glued solid timber	m3	0.001591	waste wood is 0.81% of mass input
glued solid timber production	RoW	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.316713	waste wood is 0.815% of wood input
glued solid timber production	RER	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.316713	waste wood is 0.815% of wood input
graphic paper production, 100% recycled	RoW	waste paper, unsorted	kg	graphic paper, 100% recycled	kg	1	90.3% of mass from waste paper

Activity Name	Geography	Waste (W)	W unit	Valuable (V)	V unit	V credit per W unit	Note
graphic paper production, 100% recycled	RER	waste paper, unsorted	kg	graphic paper, 100% recycled	kg	1	90.3% of mass from waste paper
gypsum fibreboard production	CH	waste paper, sorted	kg	gypsum fibreboard	kg	0.086284	waste paper represents 8.6% of the mass input
gypsum fibreboard production	RoW	waste paper, sorted	kg	gypsum fibreboard	kg	0.086284	waste paper represents 8.6% of the mass input
iron pellet production	IN	blast furnace gas	MJ	iron pellet	kg	0	the gas is used for energy
magnesium production, pidgeon process	CN	coal gas	MJ	magnesium	kg	0	the gas is used for energy
paper production, newsprint, recycled	Europe without Switzerland	waste newspaper	kg	paper, newsprint	kg	0.708894	waste paper is 52.6% of dry mass input
paper production, newsprint, recycled	RoW	waste newspaper	kg	paper, newsprint	kg	0.708894	waste paper is 52.6% of dry mass input
paper production, newsprint, recycled	CH	waste paper, sorted	kg	paper, newsprint	kg	0.615	82% of dry mass input from waste paper
structural timber production	RoW	waste wood, post-consumer	kg	structural timber	m3	0.001658	waste wood is 1% of the mass input
structural timber production	RER	waste wood, post-consumer	kg	structural timber	m3	0.001658	waste wood is 1% of the mass input
structural timber production	RoW	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.261691	waste wood is 1% of the wood input
structural timber production	RER	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.261691	waste wood is 1% of the wood input
synthetic graphite production, battery grade	CN	coal tar	kg	synthetic graphite, battery grade	kg	0.833333	the tar only provides 0.24/1.2 of the mass
synthetic graphite production, battery grade	RoW	coal tar	kg	synthetic graphite, battery grade	kg	0.833333	the tar only provides 0.24/1.2 of the mass
three and five layered board production	RoW	waste wood, post-consumer	kg	three and five layered board	m3	0.000827	represents 1.1% of mass input
three and five layered board production	RER	waste wood, post-consumer	kg	three and five layered board	m3	0.000827	represents 1.1% of mass input
three and five layered board production	RoW	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.599458	represents 1.1% of mass input
three and five layered board production	RER	waste wood, post-consumer	kg	wood chips, dry, measured as dry mass	kg	0.599458	represents 1.1% of mass input
white lined chipboard carton production	RoW	waste paper, sorted	kg	white lined chipboard carton	kg	0.745246	waste paper represents 74.5% of the mass input

Activity Name	Geography	Waste (W)	W unit	Valuable (V)	V unit	V credit per W unit	Note
white lined chipboard carton production	RER	waste paper, sorted	kg	white lined chipboard carton	kg	0.745246	waste paper represents 74.5% of the mass input

2.4.2 Threshold introduction after allocation

After the allocation at the point of substitution has been applied, several activities exist that represent all the datasets that were generating this waste (MFT) as a by-product, all producing the same product (the valuable product generated during the MFT treatment that had been merged into the manufacturing activity originally generating that MFT). Those activities are now renamed into the original treatment name and merged.

For example, the activity “treatment of aluminium scrap, new, at remelter” generating “aluminium, wrought alloy” merges 46 different datasets. However, the contributing amounts vary enormously, and depend on the production volume of the datasets where the aluminium scrap (MFT treated in “treatment of aluminium scrap, new, at remelter”) originates. In this example, 94% of the aluminium scrap comes from the dataset “internal combustion engine production, passenger car”. 2.5% comes from “casting of aluminium, lost-wax”. Including the next 3 largest aluminium scrap producers already covers 99.9% of the treated aluminium scrap.

When the activities are being renamed and merged, the exchanges of each copy of the waste treatment dataset are multiplied by a weight, relative to the production volume treated, before being combined into a single dataset. In the example above, it means that 41 datasets represent less than 0.1% of the volume treated. Their exchanges are therefore multiplied by a weight much smaller than 0.1%. This adds a large number of exchanges with very low numbers, having little to no impact on results. It was decided instead for v3.9, to select and merge the activities in decreasing order of contribution, until the threshold of 99.9% is attained. All other contributors are neglected.

If a contributor would be neglected, without any further actions, it would mean giving a credit to a dataset at the point of substitution (producing the waste), but without burdening the waste treatment. To avoid this, when a contributor is identified as negligeable at the treatment merging step, it is not credited at the point of substitution. This correction affects around 3’000 datasets, details are available in the file section of ecoQuery, under the name “3.9_APOS_treatment_merger_logs.xlsx”.

2.5 Impact assessment methods

2.5.1 Methods

For ecoinvent v3.9, these methods were added:

- Crustal Scarcity Indicator 2020
- Ecological Scarcity 2021
- EPS 2020
- IPCC 2021
- ReCiPe 2016
- TRACI v2.1

Furthermore, the ***EF v3.0*** method was updated to ***EF v3.1*** and with it, we updated *EF v3.0 EN15804* to *EF v3.1 EN15804* (see also Sonderegger and Stoikou 2022). The IPCC 2013 method did not need a change for implementation. Several other methods, on the other hand, received minor updates/corrections:

- CML v4.8 2016
- Cumulative Energy Demand (CED)
- Cumulative Exergy Demand (CExD)
- Ecological Footprint
- EF v3.0 (update of the implementation and implementation of EF v3.1)
- EF v3.0 EN15804 + EN15804 inventory indicators ISO21930 (update of the implementation and implementation of *EF v3.1 EN15804*)

While EF v3.0, EF v3.0 EN15804, and IPCC 2013 are superseded by newer versions, they are up to date and valid.

Finally, some methods implementation are not made publicly available anymore as they are outdated and/or superseded:

- CML 2001, v3.3
- ecological scarcity 1997
- ecological scarcity 2006
- ecological scarcity 2013
- EDIP 1997
- EF1.0.8 midpoint
- EF v2.0 2018
- EPS 2000
- IPCC 2001
- IPCC 2007
- ReCiPe 2008 Endpoint, v1.0
- ReCiPe 2008 Midpoint, v1.13 (SimaPro)
- ReCiPe 2008 Midpoint, v1.0
- TRACI, 2007

For the full list of implemented methods and for details about method implementation please consult the LCIA implementation report (Sonderegger and Stoikou 2022).

For more consistency, some methods were slightly renamed as shown in Table 9.

Table 9. Renaming of methods

Name	Name old
Cumulative Energy Demand (CED)	cumulative energy demand
Cumulative Exergy Demand (CExD)	cumulative exergy demand
Ecological Footprint	ecological footprint
Ecosystem Damage Potential	ecosystem damage potential
EDIP 2003	EDIP2003
EDIP 2003 no LT	EDIP2003 w/o LT
USEtox no LT	USEtox w/o LT

2.5.2 Impact categories and indicators

Indicators for the *Cumulative Energy Demand (CED)* and the *Cumulative Exergy Demand (CExD)* methods were summarized in new impact categories as shown in Table 10.

Table 10. New impact categories in the Cumulative Energy Demand (CED) and the Cumulative Exergy Demand (CExD) methods

Method	Category
Cumulative Energy Demand (CED)	energy resources: non-renewable
Cumulative Energy Demand (CED)	energy resources: renewable
Cumulative Energy Demand (CED)	energy resources: renewable, geothermal, solar, wind
Cumulative Energy Demand (CED)	total
Cumulative Exergy Demand (CExD)	energy resources: non-renewable
Cumulative Exergy Demand (CExD)	energy resources: renewable
Cumulative Exergy Demand (CExD)	material resources
Cumulative Exergy Demand (CExD)	total

For methods excluding long-term effects, the extension “w/o LT” was replaced with “no LT”. Table 11 shows updated category and indicator names. The main goals were

- to increase consistency of what is a category and what is an indicator,
- to use a common terminology for category naming,
- and having global warming potential indicators named consistently across methods.

Table 11. Updated category and indicator names

Method	Category	Indicator	Category old	Indicator old
CML v4.8 2016	climate change	global warming potential (GWP100)	climate change	GWP 100a
CML v4.8 2016 no LT	climate change no LT	global warming potential (GWP100) no LT	climate change no LT	GWP 100a w/o LT
Cumulative Energy Demand (CED)	energy resources: non-renewable, biomass	energy content (HHV)	primary forest	non-renewable energy resources, primary forest
	energy resources: non-renewable, fossil	energy content (HHV)	fossil	non-renewable energy resources, fossil
	energy resources: non-renewable, nuclear	energy content (HHV)	nuclear	non-renewable energy resources, nuclear
	energy resources: renewable, biomass	energy content (HHV)	biomass	renewable energy resources, biomass
	energy resources: renewable, geothermal	energy content (HHV)	geothermal	renewable energy resources, geothermal, converted
	energy resources: renewable, solar	energy content (HHV)	solar	renewable energy resources, solar, converted
	energy resources: renewable, water	energy content (HHV)	water	renewable energy resources, potential (in barrage water), converted
	energy resources: renewable, wind	energy content (HHV)	wind	renewable energy resources, kinetic (in wind), converted
Cumulative Exergy Demand (CExD)	energy resources: non-renewable, biomass	exergy content	primary forest	non-renewable energy resources, primary forest
	energy resources: non-renewable, fossil	exergy content	fossil	non-renewable energy resources, fossil
	energy resources: non-renewable, nuclear	exergy content	nuclear	non-renewable energy resources, nuclear
	energy resources: renewable, biomass	exergy content	biomass	renewable energy resources, biomass
	energy resources: renewable, solar	exergy content	solar	renewable energy resources, solar, converted
	energy resources: renewable, water	exergy content	water resources	renewable material resources, water
	energy resources: renewable, wind	exergy content	wind	renewable energy resources, kinetic (in wind), converted
	material resources: metals	exergy content	metals	non-renewable material resources, metals
	material resources: minerals	exergy content	minerals	non-renewable material resources, minerals
	material resources: water	exergy content	water	renewable energy resources, potential (in barrage water), converted
Ecological Footprint	CO2	global hectares	total	CO2
	land occupation	global hectares	total	land occupation
	nuclear	global hectares	total	nuclear

Method	Category	Indicator	Category old	Indicator old
	total	global hectares	total	total
Ecosystem Damage Potential	land occupation	ecosystem damage potential	total	linear, land occupation
	land transformation	ecosystem damage potential	total	linear, land transformation
	total	ecosystem damage potential	total	linear, land use, total
EF v3.0	acidification	accumulated exceedance (AE)	acidification	accumulated exceedance (ae)
	photochemical oxidant formation: human health	tropospheric ozone concentration increase	photochemical ozone formation: human health	tropospheric ozone concentration increase
EF v3.0 EN15804	acidification	accumulated exceedance (AE)	acidification	accumulated exceedance (ae)
	photochemical oxidant formation: human health	tropospheric ozone concentration increase	photochemical ozone formation: human health	tropospheric ozone concentration increase
EF v3.0 no LT	acidification no LT	accumulated exceedance (AE) no LT	acidification no LT	accumulated exceedance (ae) no LT
	photochemical oxidant formation: human health no LT	tropospheric ozone concentration increase no LT	photochemical ozone formation: human health no LT	tropospheric ozone concentration increase no LT
IPCC 2013	climate change	global temperature change potential (GTP100)	climate change	GTP 100a
	climate change	global temperature change potential (GTP20)	climate change	GTP 20a
	climate change	global warming potential (GWP100)	climate change	GWP 100a
	climate change	global warming potential (GWP20)	climate change	GWP 20a
IPCC 2013 no LT	climate change no LT	global temperature change potential (GTP100) no LT	climate change	GTP 100a
	climate change no LT	global temperature change potential (GTP20) no LT	climate change	GTP 20a
	climate change no LT	global warming potential (GWP100) no LT	climate change	GWP 100a
	climate change no LT	global warming potential (GWP20) no LT	climate change	GWP 20a

2.5.3 Characterization factors

2.5.3.1 Energy Resources

The major update across methods is the adaptation of CFs for oil and gas according to the update of corresponding datasets in the database. The energy content, which is key for this has been changed as shown in Table 12. This affects all updated methods except the *Ecological Footprint*.

Table 12 Updates of Higher Heating Values (HHV) and Lower Heating Values (LHV) for oil and gas.

Exchange	Unit	old		new	
		HHV [MJ / Unit]	LHV [MJ / Unit]	HHV [MJ / Unit]	LHV [MJ / Unit]
Gas, mine, off-gas, process, coal mining	Sm3	39.8	35.87	40	36
Gas, natural	Sm3	38.29	34.50	40	36
Oil, crude	kg	45.8	42.3	46	43.4

2.5.3.2 Added and deleted CFs for existing exchanges

The improved list of elementary exchanges (see section 0) allowed for updating existing mappings of methods. This concerns *CML v4.8 2016*, *EF v3.0*, and *EF v3.0 EN15804* (see Change Report Annex).

For the *Ecological Footprint* method, a CF of -2.6722 was added for the exchange "Carbon dioxide, to soil or biomass stock" following the implementation of other carbon dioxide CFs.

The *EF v3.0 EN15804* method was better aligned with the *EF v3.0* method by eliminating differences in the raw data that are not justified by documentation elsewhere (see Sonderegger and Stoikou 2022).

Table 13 Changes applied to the EF v3.0 EN15804 method

Category	Indicator	Name	Compart ment	Subcompartment	CF old	CF
climate change	global warming potential (GWP100)	Methane, fossil	air	low population density, long-term	36.75	36.8
climate change: fossil	global warming potential (GWP100)	Methane, fossil	air	low population density, long-term	36.75	36.8
climate change	global warming potential (GWP100)	Methane, fossil	air	non-urban air or from high stacks	36.75	36.8
climate change: fossil	global warming potential (GWP100)	Methane, fossil	air	non-urban air or from high stacks	36.75	36.8
climate change	global warming potential (GWP100)	Methane, fossil	air	unspecified	36.75	36.8
climate change: fossil	global warming potential (GWP100)	Methane, fossil	air	unspecified	36.75	36.8
climate change	global warming potential (GWP100)	Methane, fossil	air	urban air close to ground	36.75	36.8
climate change: fossil	global warming potential (GWP100)	Methane, fossil	air	urban air close to ground	36.75	36.8
climate change	global warming potential (GWP100)	Methane, non-fossil	air	non-urban air or from high stacks	36.75	34
climate change: biogenic	global warming potential (GWP100)	Methane, non-fossil	air	non-urban air or from high stacks	36.75	34

Category	Indicator	**Name**	**Compartment**	**Subcompartment**	**CF old**	**CF**
climate change	global warming potential (GWP100)	Methane, non-fossil	air	unspecified	36.75	34
climate change: biogenic	global warming potential (GWP100)	Methane, non-fossil	air	unspecified	36.75	34
climate change	global warming potential (GWP100)	Methane, non-fossil	air	urban air close to ground	36.75	34
climate change: biogenic	global warming potential (GWP100)	Methane, non-fossil	air	urban air close to ground	36.75	34
climate change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	low population density, long-term	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	low population density, long-term	36.75	36.8
climate change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	lower stratosphere + upper troposphere	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	lower stratosphere + upper troposphere	36.75	36.8
climate change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	non-urban air or from high stacks	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	non-urban air or from high stacks	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	unspecified	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	unspecified	36.75	36.8
climate change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	urban air close to ground	36.75	36.8
climate change: land use and land use change	global warming potential (GWP100)	Methane, from soil or biomass stock	air	urban air close to ground	36.75	36.8
climate change	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	non-urban air or from high stacks	1.57	0
climate change: biogenic	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	non-urban air or from high stacks	1.57	0
climate change	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	unspecified	1.57	0
climate change: biogenic	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	unspecified	1.57	0

Category	Indicator	Name	Compartment	Subcompartment	CF old	CF
climate change	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	urban air close to ground	1.57	0
climate change: biogenic	global warming potential (GWP100)	Carbon monoxide, non-fossil	air	urban air close to ground	1.57	0
ecotoxicity: freshwater	comparative toxic unit for ecosystems (CTUe)	Ethane, 1,1,2-trichloro-	air	unspecified	1.1505	0
ecotoxicity: freshwater	comparative toxic unit for ecosystems (CTUe)	Phosphorus	water	ground-	0	2.0314
human toxicity: carcinogenic	comparative toxic unit for human (CTUh)	Ethane, 1,1,2-trichloro-	air	unspecified	8.19E-05	0
human toxicity: non-carcinogenic	comparative toxic unit for human (CTUh)	Ethane, 1,1,2-trichloro-	air	unspecified	0.000256	0
human toxicity: non-carcinogenic	comparative toxic unit for human (CTUh)	Phosphorus	water	ground-	0	1.98E-09

Finally, CFs for water resources were updated for the *Cumulative Exergy Demand (CExD)* method. While they were deleted from the impact category *energy resources: renewable, water* (as they are not being used as energy resources), they were added to the impact category *material resources: water*. On the other hand, the opposite was applied to the flow "Energy, potential (in hydropower reservoir), converted" as this is an energy resource (Table 14).

Table 14 Changes applied in the Cumulative Exergy Demand (CExD) method

Category	Indicator	Name	CF old	CF
energy resources: renewable, water	exergy content	Energy, potential (in hydropower reservoir), converted		1
energy resources: renewable, water	exergy content	Water, cooling, unspecified natural origin	50	
energy resources: renewable, water	exergy content	Water, in air	50	
energy resources: renewable, water	exergy content	Water, lake	50	
energy resources: renewable, water	exergy content	Water, river	50	
energy resources: renewable, water	exergy content	Water, unspecified natural origin	50	
energy resources: renewable, water	exergy content	Water, well, in ground	50	
material resources: water	exergy content	Water, cooling, unspecified natural origin		50
material resources: water	exergy content	Water, lake		50
material resources: water	exergy content	Water, river		50
material resources: water	exergy content	Water, unspecified natural origin		50
material resources: water	exergy content	Water, well, in ground		50

material resources: water	exergy content	Water, in air		50
material resources: water	exergy content	Energy, potential (in hydropower reservoir), converted	1	

2.5.4 New inventory indicators

For the assessment of some method specific indicators and impact categories, "artificial" elementary exchanges are needed. This was already implemented for the 'Allocation, cut-off, EN15804' system model for the Life Cycle Inventory indicators referring to resource use, meaning use of renewable and non-renewable material resources, renewable and non-renewable primary energy and water (section 2.3.3).

Two of these "artificial" elementary exchanges were added for v3.9 for implementation of the Ecological Scarcity 2021 method: "Waste mass, total, placed in landfill" and "Organic carbon, placed in landfill" (see section 10.1.4).

2.6 Comfort features: Product Information

This section describes updates implemented in order to enhance user experience and increase the comfort they have with the database. All the updates listed below refer to data already published in v.3.8. Newly added data v3.9 already conform to the proper documentation.

This update offers comfort to users while employing the ecoinvent database. Overall, v3.9 contains 3571 unique products, those being physical products or refer to the provision of a service. The update documents and defines the products from a user perspective to help them identify products suitable for what they wish to model. The work started in v3.8 (Moreno-Ruiz et al. 2021), where a 85% coverage was reached. In version 3.9, 100% of the products in the ecoinvent database, feature product information.

Some key characteristics about products that fall under broad sectors are the following

- Secondary by-products such as wastes, and recyclable materials have been properly documented and described in full. They are categorised based on their production sources and all possible treatments or uses are listed. Key physical and chemical properties are shown, and the wastes are also characterised as hazardous or non-hazardous or potentially both. Modelling wastes in treatments or markets is explained as well.
- Metal products are described in terms of elemental purity, production process and potential applications.
- New products, created and published for the first time in 3.9. are defined based on the sector they may belong.
- New chemical products show specific information such as, their CAS number, the IUAC name, origin of the substance (organic or inorganic), modelling of the

substance (pure or diluted substance) and finally consumer use and industrial application. If relevant, the substance is also labelled based on the nutrient content (Nitrogen, Phosphorus and Potassium) they contain.

2.6.1 Services

Products that refer to service provision may not always be intuitive in terms of what they include or model, especially because there is no physical link of what is produced. The product information offers a service description that helps users understand the most crucial parameters related to the provision of a service. Additionally, guidance is offered to the users on how the product should be used within their models.

In other cases, a detailed description of what is required to provide a service, is offered within the product information. This aims mostly at informing the user of the system boundaries of the process providing the service. In those cases, the information is displayed to the user to facilitate any modification of the dataset, should that be required. This can be the case for certain infrastructure products.

Metal services are defined based on the process service they provide and the potential use of them is described.

3 Agriculture

3.1 Agriculture updates in Canada

The update was performed in collaboration with the University of British Columbia – Okanagan and the Food Systems PRISM Lab and resulted in the addition of a new products to the database and to Canada specific (navy bean, fava bean, red kidney bean and pinto beans).

Table 15. New activities added for v3.9 in the agriculture sector, related to Canadian production.

Activity Name	Geography	Time Period	Product Name
fava bean production	GLO; CA-MB; CA-SK; CA-AB	2020-2020	fava bean
market for fava bean	GLO	2020-2020	fava bean
market for navy bean	GLO	2020-2020	navy bean
market for pinto bean	GLO	2020-2020	pinto bean
market for red kidney bean	GLO	2020-2020	red kidney bean
navy bean production	GLO; CA-MB; CA-ON	2020-2020	navy bean
pinto bean production	GLO; CA-MB; CA-AB	2020-2020	pinto bean
red kidney bean production	GLO; CA-MB; CA-ON	2020-2020	red kidney bean

3.2 Agriculture updates in Brazil

The update was performed in collaboration with the Brazilian Agricultural Research Corporation (Embrapa) – division of Environment and resulted in the addition of a new products to the database and to Brazil specific (peanuts) but also updates on key crops such as coffee, soybean and maize. In v. 3.9, for the first time, activity names of agricultural processes feature specific information on crop rotation (first crop or second crop) when the crop is cultivated in a crop rotating system. Maize producing activities are updating the respective maize processes since 2016 and expanding the data coverage in new provinces of Brazil. Soybean and sugarcane refer to only updates in the currently published versions. Coffee production is updated and several production technologies are introduced.

Table 16. New and updated activities added/updated for v3.9 in the agriculture sector, related to Brazilian production.

Activity Name	Geography	Time Period	Product Name
coffee green bean production, arabica	BR-SP	2020-2022	coffee, green bean
coffee green bean production, arabica, irrigated	BR-MG	2020-2022	coffee, green bean
coffee green bean production, arabica, manual	BR-MG	2020-2022	coffee, green bean

Activity Name	Geography	Time Period	Product Name
coffee green bean production, arabica, mechanized	BR-MG	2020-2022	coffee, green bean
coffee green bean production, arabica, not irrigated	BR-MG	2020-2022	coffee, green bean
coffee green bean production, arabica, semi-mechanized	BR-MG	2020-2022	coffee, green bean
maize grain production, first crop	BR-PR; BR-PI; BR-GO; BR-RS; BR-MG; BR-MA; BR-BA	2015-2022	maize grain
maize grain production, second crop	BR-PR; BR-GO; BR-MG; BR-MA; BR-MT; BR-MS; BR-SP; BR-TO	2015-2022	maize grain
peanut production, reduced tillage	BR-SP	2020-2022	peanut
soybean production	BR-PR; BR-GO; BR-MG; BR-MA; BR-MT; BR-MS; BR-SP; BR-TO; BR-PI; BR-BA; BR-RS	2015-2022	soybean
sugarcane production	BR-SP; BR-MS; BR-PR; BR-GO; BR-MG; BR-MT	2012-2022	sugarcane

4 Building and construction materials

4.1 Adopting new nomenclature rules for cement and concrete production activities

As the cement and concrete production activities are increasing in the ecoinvent database, with many new additions in the last releases, we have identified the need for a clear set of nomenclature rules for the activity and product names. The goal of the new nomenclature rules is consistency across all geographies, alignment with the nomenclature used in industry standards and a clear structure that can facilitate the users understanding of the different cement and concrete types and the selection the product with the right properties for their study. Along with the change in nomenclature, the global datasets for cement and concrete production have also been restructured and only the most representative datasets for the global geography have been maintained. For example, from the datasets "cement production, blast furnace slag 25-70% / GLO", "cement production, blast furnace slag 35-70% / GLO", "cement production, blast furnace slag 36-65% / GLO" and "cement production, blast furnace slag 40-70% / GLO", only "cement production, blast furnace slag 36-65% / GLO" or "cement production, CEM III/A / GLO" (renamed dataset) is maintained. As a reminder, until v3.8, all regional datasets for cement and concrete production had a global copy. This change is expected to facilitate the selection of the right cement and concrete datasets by the users.

4.1.1 New nomenclature rules for cement

In the case of the cement activities and products, v3.9 adopts the nomenclature following the national standards. In Europe, Switzerland and South Africa the nomenclature follows the standard EN197-1:2011, in US the ASTM C150, C595 and C1157, in Brazil the ABNT NBR 16697:2018, in Colombia the technical norm NTC 121: 2014, in Peru the NTP 334.009 / ASTM C150 and in India the IS 455:2015, IS1489:2015. In the case of the global datasets and for the geography of CA-QC, the standard EN197-1:2011 is followed.

An example of this change in the nomenclature rules is the renaming of "cement production, blast furnace slag 36-65% / CH" to "cement production, CEM III/A / CH". Only exception to the above nomenclature rule is the case of "cement, Portland", as the name is used worldwide extensively. Table 17 presents the activity name, geography, and product name up to v3.8 and the corresponding names for v3.9. Alongside the changes in the nomenclature, new datasets were introduced, where needed. The products "cement, type IP" for Peru and "cement, CEM II/B-L" for South Africa did not have any regional markets in v3.8. In v3.9, new markets were created for the two products.

As a result of the new nomenclature rules, the exchanges in the Product Name in v3.8 column of Table 17, were renamed in all other instances in the database. All datasets using these exchanges from Technosphere are now modified to be supplied with the renamed exchanges.

Table 17. Activity name, geography, and product name for cement production activities up to v3.8 and the corresponding names for v3.9. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity", "U" stands for "Updated Activity".

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
cement production, alternative constituents 21-35%	cement, alternative constituents 21-35%	cement production, ART	cement, ART	CO	2014-2022	U
cement production, alternative constituents 6-20%	cement, alternative constituents 6-20%	cement production, CEM II/A	cement, CEM II/A	CA-QC	2005-2022	U
cement production, alternative constituents 6-20%	cement, alternative constituents 6-20%	cement production, CEM II/A	cement, CEM II/A	CH	2009-2022	U
cement production, alternative constituents 6-20%	cement, alternative constituents 6-20%	cement production, CEM II/A	cement, CEM II/A	RER w/o CH; GLO	2005-2022	U
cement production, limestone 6-20%	cement, limestone 6-20%	cement production, CEM II/A-L	cement, CEM II/A-L	ZA	2017-2022	U
cement production, blast furnace slag 6-20%	cement, blast furnace slag 6-20%	cement production, CEM II/A-S	cement, CEM II/A-S	ZA	2017-2022	U
cement production, fly ash 6-20%	cement, 40ortland fly ash cement 6-20%	cement production, CEM II/A-V	cement, CEM II/A-V	ZA	2017-2022	U
cement production, alternative constituents 21-35%	cement, alternative constituents 21-35%	cement production, CEM II/B	cement, CEM II/B	CH	2009-2022	U
cement production, alternative constituents 21-35%	cement, alternative constituents 21-35%	cement production, CEM II/B	cement, CEM II/B	RER w/o CH; GLO	2005-2022	U
cement production, limestone 21-35%	cement, limestone 21-35%	cement production, CEM II/B-L	cement, CEM II/B-L	ZA	2017-2022	U
cement production, blast furnace slag 21-35%	cement, blast furnace slag 21-35%	cement production, CEM II/B-S	cement, CEM II/B-S	ZA	2017-2022	U
cement production, fly ash 21-35%	cement, 40ortland fly ash cement 21-35%	cement production, CEM II/B-V	cement, CEM II/B-V	ZA	2017-2022	U
cement production, blast furnace slag 36-65%	cement, blast furnace slag 36-65%	cement production, CEM III/A	cement, CEM III/A	CH; RER w/o CH; GLO	2005-2022	U
cement production, blast furnace slag 36-65%	cement, blast furnace slag 36-65%	cement production, CEM III/A	cement, CEM III/A	ZA	2017-2022	U
cement production, blast furnace slag 66-80%	cement, blast furnace slag 66-80%	cement production, CEM III/B	cement, CEM III/B	CH; RER w/o CH; GLO	2005-2022	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
cement production, blast furnace slag 81-95%	cement, blast furnace slag 81-95%	cement production, CEM III/C	cement, CEM III/C	CH; RER w/o CH; GLO	2005-2022	U
cement production, pozzolana and fly ash 11-35%	cement, pozzolana and fly ash 11-35%	cement production, CEM IV/A	cement, CEM IV/A	CH; RER w/o CH; GLO	2005-2022	U
cement production, pozzolana and fly ash 36-55%	cement, pozzolana and fly ash 36-55%	cement production, CEM IV/B	cement, CEM IV/B	CH; RER w/o CH; GLO	2005-2022	U
cement production, blast furnace slag 18-30% and 18-30% other alternative constituents	cement, blast furnace slag 18-30% and 18-30% other alternative constituents	cement production, CEM V/A	cement, CEM V/A	CH; RER w/o CH; GLO	2005-2022	U
cement production, blast furnace slag 31-50% and 31-50% other alternative constituents	cement, blast furnace slag 31-50% and 31-50% other alternative constituents	cement production, CEM V/B	cement, CEM V/B	CH; RER w/o CH; GLO	2005-2022	U
cement production, blast furnace slag 6-34%	cement, blast furnace slag 6-34%	cement production, CP II-E	cement, CP II-E	BR	2016-2022	U
cement production, limestone 6-10%	cement, limestone 6-10%	cement production, CP II-F	cement, CP II-F	BR	2016-2022	U
cement production, blast furnace slag 35-70%	cement, blast furnace slag 35-70%	cement production, CP III	cement, CP III	BR	2016-2022	U
cement production, pozzolana and fly ash 6-14%	cement, pozzolana and fly ash 6-14%	cement production, CP II-Z	cement, CP II-Z	BR	2016-2022	U
cement production, pozzolana and fly ash 15-50%	cement, pozzolana and fly ash 15-50%	cement production, CP IV	cement, CP IV	BR	2016-2022	U
cement production, sulphate resistant	cement, sulphate resistant	cement production, CP V RS	cement, CP V RS	BR	2016-2022	U
cement production, blast furnace slag 40-70%	cement, blast furnace slag 40-70%	cement production, Portland Slag	cement, Portland Slag	IN	2014-2022	U
cement production, pozzolana and fly ash 25-35%	cement, pozzolana and fly ash 25-35%	cement production, Pozzolana Portland	cement, Pozzolana Portland	IN	2014-2022	U
cement production, alternative constituents 45%	cement, alternative constituents 45%	cement production, type general use	cement, type general use	CO	2014-2022	U
cement production, blast furnace slag 5-25%	cement, blast furnace slag 5-25%	cement production, type I (SM)	cement, type I (SM)	US	2005-2022	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
cement production, limestone 21-35%	cement, limestone 21-35%	cement production, type Ico	cement, type Ico	PE	2014-2022	U
cement production, pozzolana and fly ash 36-55%	cement, pozzolana and fly ash 36-55%	cement production, type IP	cement, type IP	PE	2014-2022	U
cement production, pozzolana and fly ash 15-40%	cement, pozzolana and fly ash 15-40%	cement production, type IP/P	cement, type IP/P	US	2005-2022	U
cement production, pozzolana and fly ash 5-15%	cement, pozzolana and fly ash 5-15%	cement production, type I-PM	cement, type I-PM	US	2005-2022	U
cement production, blast furnace slag 25-70%	cement, blast furnace slag 25-70%	cement production, type IS	cement, type IS	US	2005-2022	U
cement production, blast furnace slag 70-100%	cement, blast furnace slag 70-100%	cement production, type S	cement, type S	US	2005-2022	U
market for cement, alternative constituents 21-35%	cement, alternative constituents 21-35%	market for cement, ART	cement, ART	CO	2014-2017	U
market for cement, alternative constituents 6-20%	cement, alternative constituents 6-20%	market for cement, CEM II/A	cement, CEM II/A	CA-QC	2006-2006	U
market for cement, alternative constituents 6-20%	cement, alternative constituents 6-20%	market for cement, CEM II/A	cement, CEM II/A	CH; RER w/o CH; GLO	2005-2009	U
market for cement, limestone 6-20%	cement, limestone 6-20%	market for cement, CEM II/A-L	cement, CEM II/A-L	ZA	2017-2017	U
market for cement, blast furnace slag 6-20%	cement, blast furnace slag 6-20%	market for cement, CEM II/A-S	cement, CEM II/A-S	ZA	2017-2017	U
market for cement, 42ortland fly ash cement 6-20%	cement, 42ortland fly ash cement 6-20%	market for cement, CEM II/A-V	cement, CEM II/A-V	ZA	2017-2017	U
market for cement, alternative constituents 21-35%	cement, alternative constituents 21-35%	market for cement, CEM II/B	cement, CEM II/B	CH; RER w/o CH; GLO	2005-2009	U
market for cement, blast furnace slag 21-35%	cement, blast furnace slag 21-35%	market for cement, CEM II/B-S	cement, CEM II/B-S	ZA	2017-2017	U
market for cement, 42ortland fly ash cement 21-35%	cement, 42ortland fly ash cement 21-35%	market for cement, CEM II/B-V	cement, CEM II/B-V	ZA	2017-2017	U
market for cement, blast furnace slag 36-65%	cement, blast furnace slag 36-65%	market for cement, CEM III/A	cement, CEM III/A	CH; RER w/o CH	2005-2009	U
market for cement, blast furnace slag 36-65%	cement, blast furnace slag 36-65%	market for cement, CEM III/A	cement, CEM III/A	ZA; GLO	2017-2017	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
market for cement, blast furnace slag 66-80%	cement, blast furnace slag 66-80%	market for cement, CEM III/B	cement, CEM III/B	CH; RER w/o CH; GLO	2005-2009	U
market for cement, blast furnace slag 81-95%	cement, blast furnace slag 81-95%	market for cement, CEM III/C	cement, CEM III/C	CH; RER w/o CH; GLO	2005-2009	U
market for cement, pozzolana and fly ash 11-35%	cement, pozzolana and fly ash 11-35%	market for cement, CEM IV/A	cement, CEM IV/A	CH; RER w/o CH; GLO	2005-2009	U
market for cement, pozzolana and fly ash 36-55%	cement, pozzolana and fly ash 36-55%	market for cement, CEM IV/B	cement, CEM IV/B	CH; RER w/o CH; GLO	2005-2009	U
market for cement, blast furnace slag 18-30% and 18-30% other alternative constituents	cement, blast furnace slag 18-30% and 18-30% other alternative constituents	market for cement, CEM V/A	cement, CEM V/A	CH; RER w/o CH; GLO	2005-2009	U
market for cement, blast furnace slag 31-50% and 31-50% other alternative constituents	cement, blast furnace slag 31-50% and 31-50% other alternative constituents	market for cement, CEM V/B	cement, CEM V/B	CH; RER w/o CH; GLO	2005-2009	U
market for cement, blast furnace slag 6-34%	cement, blast furnace slag 6-34%	market for cement, CP II-E	cement, CP II-E	BR	2013-2014	U
market for cement, limestone 6-10%	cement, limestone 6-10%	market for cement, CP II-F	cement, CP II-F	BR	2013-2014	U
market for cement, blast furnace slag 35-70%	cement, blast furnace slag 35-70%	market for cement, CP III	cement, CP III	BR	2013-2014	U
market for cement, pozzolana and fly ash 6-14%	cement, pozzolana and fly ash 6-14%	market for cement, CP II-Z	cement, CP II-Z	BR	2013-2014	U
market for cement, pozzolana and fly ash 15-50%	cement, pozzolana and fly ash 15-50%	market for cement, CP IV	cement, CP IV	BR	2013-2014	U
market for cement, sulphate resistant	cement, sulphate resistant	market for cement, CP V RS	cement, CP V RS	BR	2016-2016	U
market for cement, blast furnace slag 40-70%	cement, blast furnace slag 40-70%	market for cement, Portland Slag	cement, Portland Slag	IN	2014-2017	U
market for cement, pozzolana and fly ash 25-35%	cement, pozzolana and fly ash 25-35%	market for cement, Pozzolana Portland	cement, Pozzolana Portland	IN	2014-2017	U
market for cement, alternative constituents 45%	cement, alternative constituents 45%	market for cement, type general use	cement, type general use	CO	2014-2017	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
market for cement, blast furnace slag 5-25%	cement, blast furnace slag 5-25%	market for cement, type I (SM)	cement, type I (SM)	US	2005-2009	U
market for cement, limestone 21-35%	cement, limestone 21-35%	market for cement, type Ico	cement, type Ico	PE	2014-2017	U
market for cement, pozzolana and fly ash 15-40%	cement, pozzolana and fly ash 15-40%	market for cement, type IP/P	cement, type IP/P	US	2005-2009	U
market for cement, pozzolana and fly ash 5-15%	cement, pozzolana and fly ash 5-15%	market for cement, type I-PM	cement, type I-PM	US	2005-2009	U
market for cement, blast furnace slag 25-70%	cement, blast furnace slag 25-70%	market for cement, type IS	cement, type IS	US	2005-2009	U
market for cement, blast furnace slag 70-100%	cement, blast furnace slag 70-100%	market for cement, type S	cement, type S	US	2005-2009	U
cement production, Portland	cement, Portland			CA-QC	2005-2022	U
cement production, Portland	cement, Portland			RER w/o CH; US	2005-2022	U
cement production, Portland	cement, Portland			GLO	2005-2022	U
cement production, Portland	cement, Portland			CH	2009-2022	U
cement production, Portland	cement, Portland			IN; PE	2014-2022	U
cement production, Portland	cement, Portland			BR	2016-2022	U
cement production, Portland	cement, Portland			ZA	2017-2022	U
market for cement, Portland	cement, Portland			GLO	2005-2009	U
		market for cement, type IP	cement, type IP	PE	2022-2022	N
		market for cement, CEM II/B-L	cement, CEM II/B-L	ZA	2022-2022	N

As mentioned previously, several Global datasets have been deleted and only some representative cement production datasets have been maintained to facilitate the users with a clean structure of the global cement production datasets. In Table 18, the column 'Recommendation to users' provides a suggestion on which activity to choose in the case of a global activity that is discontinued in v3.9, due to the new structure.

Table 18. Deleted Global activities in v3.9. The column 'Recommendation to users' provides a suggestion on which activity to choose in the case of a global activity that is discontinued in v3.9, due to the new structure.

Activity Name v3.8	Product Name v3.8	Recommendation to users
cement production, alternative constituents 45%	cement, alternative constituents 45%	use cement production, CEM II/B
cement production, blast furnace slag 21-35%	cement, blast furnace slag 21-35%	use cement production, CEM II/B
cement production, blast furnace slag 25-70%	cement, blast furnace slag 25-70%	use cement production, CEM III/A
cement production, blast furnace slag 35-70%	cement, blast furnace slag 35-70%	use cement production, CEM III/A
cement production, blast furnace slag 40-70%	cement, blast furnace slag 40-70%	use cement production, CEM III/A
cement production, blast furnace slag 5-25%	cement, blast furnace slag 5-25%	use cement production, CEM II/A
cement production, blast furnace slag 6-20%	cement, blast furnace slag 6-20%	use cement production, CEM II/A
cement production, blast furnace slag 6-34%	cement, blast furnace slag 6-34%	use cement production, CEM II/A
cement production, blast furnace slag 70-100%	cement, blast furnace slag 70-100%	use cement production, CEM III/B
cement production, fly ash 21-35%	cement, portland fly ash cement 21-35%	use cement production, CEM II/B
cement production, fly ash 6-20%	cement, portland fly ash cement 6-20%	use cement production, CEM II/A
cement production, limestone 21-35%	cement, limestone 21-35%	use cement production, CEM II/B
cement production, limestone 6-10%	cement, limestone 6-10%	use cement production, CEM II/A
cement production, limestone 6-20%	cement, limestone 6-20%	use cement production, CEM II/A
cement production, pozzolana and fly ash 15-40%	cement, pozzolana and fly ash 15-40%	use cement production, CEM IV/A
cement production, pozzolana and fly ash 15-50%	cement, pozzolana and fly ash 15-50%	use cement production, CEM IV/B
cement production, pozzolana and fly ash 25-35%	cement, pozzolana and fly ash 25-35%	use cement production, CEM IV/A
cement production, pozzolana and fly ash 5-15%	cement, pozzolana and fly ash 5-15%	use cement production, CEM IV/A
cement production, pozzolana and fly ash 6-14%	cement, pozzolana and fly ash 6-14%	use cement production, CEM IV/A
market for cement, alternative constituents 45%	cement, alternative constituents 45%	use market for cement, CEM II/B
market for cement, blast furnace slag 21-35%	cement, blast furnace slag 21-35%	use market for cement, CEM II/B
market for cement, blast furnace slag 25-70%	cement, blast furnace slag 25-70%	use market for cement, CEM III/A
market for cement, blast furnace slag 35-70%	cement, blast furnace slag 35-70%	use market for cement, CEM III/A
market for cement, blast furnace slag 40-70%	cement, blast furnace slag 40-70%	use market for cement, CEM III/A
market for cement, blast furnace slag 5-25%	cement, blast furnace slag 5-25%	use market for cement, CEM II/A
market for cement, blast furnace slag 6-20%	cement, blast furnace slag 6-20%	use market for cement, CEM II/A
market for cement, blast furnace slag 6-34%	cement, blast furnace slag 6-34%	use market for cement, CEM II/A
market for cement, blast furnace slag 70-100%	cement, blast furnace slag 70-100%	use market for cement, CEM III/B
market for cement, limestone 21-35%	cement, limestone 21-35%	use market for cement, CEM II/B

Activity Name v3.8	Product Name v3.8	Recommendation to users
market for cement, limestone 6-10%	cement, limestone 6-10%	use market for cement, CEM II/A
market for cement, limestone 6-20%	cement, limestone 6-20%	use market for cement, CEM II/A
market for cement, portland fly ash cement 21-35%	cement, portland fly ash cement 21-35%	use market for cement, CEM II/B
market for cement, portland fly ash cement 6-20%	cement, portland fly ash cement 6-20%	use market for cement, CEM II/A
market for cement, pozzolana and fly ash 15-40%	cement, pozzolana and fly ash 15-40%	use market for cement, CEM IV/A
market for cement, pozzolana and fly ash 15-50%	cement, pozzolana and fly ash 15-50%	use market for cement, CEM IV/B
market for cement, pozzolana and fly ash 25-35%	cement, pozzolana and fly ash 25-35%	use market for cement, CEM IV/A
market for cement, pozzolana and fly ash 5-15%	cement, pozzolana and fly ash 5-15%	use market for cement, CEM IV/A
market for cement, pozzolana and fly ash 6-14%	cement, pozzolana and fly ash 6-14%	use market for cement, CEM IV/A

4.1.2 New nomenclature rules for concrete

In the case of concrete production activities, v3.8 followed two different approaches for the name of activities in Switzerland or in all other countries. In v3.9, we harmonised the naming rules to ensure consistency. In addition, to support users in selecting between the different concrete production activities, all important information is now included in the name. The new activity name includes compressive strength, building application (e.g., for building construction, for civil engineering, for drilled piles), more specific application (optional, e.g., for interior use, for exterior use), and type of cement used. The name of the concrete products includes the compressive strength of concrete. As a result of the change in the nomenclature rules, “concrete production, 20MPa / ZA” becomes “concrete production, 20MPa, for building construction, with cement, CEM II/B-V / ZA”.

For mapping the old names of the concrete products for Switzerland to the new nomenclature structure, Table 19 was used.

Table 19. Mapping of existing names of concrete for Switzerland to the corresponding strength.

Name of concrete v3.8	Name of concrete v3.9
concrete, normal	unreinforced concrete, 15MPa
concrete, sole plate and foundation	concrete, 30MPa
concrete, for de-icing salt contact	concrete, 37MPa
concrete, high exacting requirements	concrete, 25MPa

Table 20 presents the activity name, geography, and product name up to v3.8 and the corresponding names for v3.9. One point to highlight here is the “concrete, normal strength", which replaces "concrete, normal". In the case of Switzerland and as per Table 19, the "concrete, normal" of v3.8 is now renamed to "unreinforced concrete, 15MPa" and the new "concrete, normal strength" of v3.9 is calculated as the weighted average of all types of concrete between 20 and 37MPa. The renaming also corrected an existing mistake: the "concrete production, for civil engineering, […]" activities are now instead "concrete production, for drilled piles, […]" and vice-versa. For all other geographies apart from Switzerland, the new "concrete, normal strength" of v3.9 is equivalent to the "concrete, normal" of v3.8.

Table 20 includes also the new datasets created in v3.9. The generic markets for "concrete, normal strength" for Austria and Switzerland were created as well as many new datasets for the global geography, as copies of the regional datasets.

Table 20. Activity name, geography, and product name for concrete production activities up to v3.8 and the corresponding names for v3.9. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity", "U" stands for "Updated Activity".

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
concrete production, 20MPa, ready-mix, with cement, alternative constituents 21-35%	concrete, 20MPa	concrete production, 20MPa, for building construction, with cement, ART	concrete, 20MPa	CO	2014-2017	U
concrete production, 20MPa, ready-mix, with Portland cement	concrete, 20MPa	concrete production, 20MPa, for building construction, with cement, Portland	concrete, 20MPa	PE	2014-2017	U
concrete production, 20MPa, ready-mix, with cement, limestone 21-35%	concrete, 20MPa	concrete production, 20MPa, for building construction, with cement, type ICo	concrete, 20MPa	PE	2014-2017	U
concrete production, 20MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete, 20MPa	concrete production, 20MPa, for building construction, with cement, type IP	concrete, 20MPa	PE	2014-2017	U
concrete production, 20MPa, self-construction, with Portland cement	concrete, 20MPa	concrete production, 20MPa, self-construction, for building construction, with cement, Portland	concrete, 20MPa	PE	2014-2017	U
concrete production, 20MPa, self-construction, with cement, alternative constituents 45%	concrete, 20MPa	concrete production, 20MPa, self-construction, for building construction, with cement, type general use	concrete, 20MPa	CO	2014-2017	U
concrete production, 20MPa, self-construction, with cement, limestone 21-35%	concrete, 20MPa	concrete production, 20MPa, self-construction, for building construction, with cement, type ICo	concrete, 20MPa	PE	2014-2017	U
concrete production, 20MPa, self, construction, with cement, pozzolana and fly ash 36-55%	concrete, 20MPa	concrete production, 20MPa, self-construction, for building construction, with cement, type IP	concrete, 20MPa	PE	2014-2017	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
concrete production 20MPa	concrete, 20MPa	concrete production, 20MPa, with cement, CEM II/B	concrete, 20MPa	GLO	2017-2022	U
concrete production 20MPa	concrete, 20MPa	concrete production, 20MPa, with cement, CEM II/B-V	concrete, 20MPa	ZA	2017-2017	U
concrete production 20MPa	concrete, 20MPa	concrete production, 20MPa, with cement, Portland	concrete, 20MPa	CA-QC; North America without Quebec	2006-2006	U
		concrete production, 20MPa, with cement, Portland	concrete, 20MPa	GLO	2006-2022	N
concrete production 25-30MPa	concrete, 25-30MPa	concrete production, 25-30MPa, with cement, Portland	concrete, 25-30MPa	IN	2014-2017	U
concrete production, 25MPa, ready-mix, exposure class XC1	concrete, 25MPa	concrete production, 25MPa, for building construction, exposure class XC1, with cement, unspecified	concrete, 25MPa	AT	2015-2019	U
concrete production, 25MPa, ready-mix, exposure class XC2	concrete, 25MPa	concrete production, 25MPa, for building construction, exposure class XC2, with cement, unspecified	concrete, 25MPa	AT	2015-2019	U
concrete production 25MPa	concrete, 25MPa	concrete production, 25MPa, for building construction, for interior use, with cement, Portland	concrete, 25MPa	CA-QC; North America without Quebec	2006-2006	U
		concrete production, 25MPa, for building construction, for interior use, with cement, Portland	concrete, 25MPa	GLO	2006-2022	N
concrete production, for building construction, with cement CEM II/A	concrete, high exacting requirements	concrete production, 25MPa, for building construction, with cement, CEM II/A	concrete, 25MPa	CH	2013-2013	U
concrete production, for building construction, with cement CEM II/B	concrete, high exacting requirements	concrete production, 25MPa, for building construction, with cement, CEM II/B	concrete, 25MPa	CH	2013-2013	U
concrete production 25MPa	concrete, 25MPa	concrete production, 25MPa, for building construction, with cement, CEM II/B-V	concrete, 25MPa	ZA	2017-2017	U
concrete production, 25MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 25MPa	concrete production, 25MPa, for building construction, with cement, CEM III/A	concrete, 25MPa	GLO	2015-2022	U
concrete production, 25MPa, ready-mix,	concrete, 25MPa	concrete production, 25MPa, for building	concrete, 25MPa	BR	2015-2017	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
with cement blast furnace slag 35-70%		construction, with cement, CP III				
concrete production, 25MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 25MPa	concrete production, 25MPa, for building construction, with cement, CP-II-E	concrete, 25MPa	BR	2015-2017	U
concrete production, 25MPa, ready-mix, with cement limestone 6-10%	concrete, 25MPa	concrete production, 25MPa, for building construction, with cement, CP-II-F	concrete, 25MPa	BR	2015-2017	U
		concrete production, 25MPa, for civil engineering, with cement, CEM II/A	concrete, 25MPa	GLO	2013-2022	N
		concrete production, 25MPa, for civil engineering, with cement, CEM II/B	concrete, 25MPa	GLO	2013-2022	N
concrete production 30-32MPa	concrete, 30-32MPa	concrete production, 30-32MPa, with cement, Portland	concrete, 30-32MPa	CA-QC; North America without Quebec	2006-2006	U
concrete production, 30MPa, ready-mix, exposure classes XC3/XD2/XF1/XA1	concrete, 30MPa	concrete production, 30MPa, exposure classes XC3/XD2/XF1/XA1, with cement, unspecified	concrete, 30MPa	AT	2015-2019	U
concrete production, 30MPa, ready-mix, exposure class XC3	concrete, 30MPa	concrete production, 30MPa, for building construction, exposure class XC3, with cement, unspecified	concrete, 30MPa	AT	2015-2019	U
concrete production, 30MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 30MPa	concrete production, 30MPa, for building construction, with cement, CEM III/A	concrete, 30MPa	GLO	2015-2022	U
concrete production, 30MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 30MPa	concrete production, 30MPa, for building construction, with cement, CP III	concrete, 30MPa	BR	2015-2017	U
concrete production, 30MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 30MPa	concrete production, 30MPa, for building construction, with cement, CP-II-E	concrete, 30MPa	BR	2015-2017	U
concrete production, 30MPa, ready-mix, with cement limestone 6-10%	concrete, 30MPa	concrete production, 30MPa, for building construction, with cement, CP-II-F	concrete, 30MPa	BR	2015-2017	U
concrete production, for civil engineering, with cement CEM II/A	concrete, sole plate and foundation	concrete production, 30MPa, for drilled piles, with cement, CEM II/A	concrete, 30MPa	CH	2013-2013	U
		concrete production, 30MPa, for drilled piles, with cement, CEM II/A	concrete, 30MPa	GLO	2013-2022	N

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
concrete production, for civil engineering, with cement CEM II/B	concrete, sole plate and foundation	concrete production, 30MPa, for drilled piles, with cement, CEM II/B	concrete, 30MPa	CH	2013-2013	U
		concrete production, 30MPa, for drilled piles, with cement, CEM II/B	concrete, 30MPa	GLO	2013-2022	N
concrete production, for civil engineering, with cement CEM I	concrete, sole plate and foundation	concrete production, 30MPa, for drilled piles, with cement, Portland	concrete, 30MPa	CH	2013-2013	U
		concrete production, 30MPa, for drilled piles, with cement, Portland	concrete, 30MPa	GLO	2013-2022	N
concrete production 30MPa	concrete, 30MPa	concrete production, 30MPa, with cement, CEM II/B-V	concrete, 30MPa	ZA	2017-2017	U
concrete production, 35MPa, ready-mix, with cement limestone 6-10%	concrete, 35MPa	concrete production, 35MPa, for building construction, with cement, CEM II/A	concrete, 35MPa	GLO	2015-2022	U
concrete production, 35MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 35MPa	concrete production, 35MPa, for building construction, with cement, CEM III/A	concrete, 35MPa	GLO	2015-2022	U
concrete production, 35MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 35MPa	concrete production, 35MPa, for building construction, with cement, CP III	concrete, 35MPa	BR	2015-2017	U
concrete production, 35MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 35MPa	concrete production, 35MPa, for building construction, with cement, CP-II-E	concrete, 35MPa	BR	2015-2017	U
concrete production, 35MPa, ready-mix, with cement limestone 6-10%	concrete, 35MPa	concrete production, 35MPa, for building construction, with cement, CP-II-F	concrete, 35MPa	BR	2015-2017	U
concrete production 35MPa	concrete, 35MPa	concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland	concrete, 35MPa	CA-QC; North America without Quebec	2006-2006	U
		concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland	concrete, 35MPa	GLO	2006-2022	N
concrete production 35MPa	concrete, 35MPa	concrete production, 35MPa, with cement, CEM II/B	concrete, 35MPa	GLO	2017-2022	U
concrete production 35MPa	concrete, 35MPa	concrete production, 35MPa, with cement, CEM II/B-V	concrete, 35MPa	ZA	2017-2017	U
concrete production, for drilled piles, with cement CEM II/A	concrete, for de-icing salt contact	concrete production, 37MPa, for civil engineering, with cement, CEM II/A	concrete, 37MPa	CH	2013-2013	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
concrete production, for drilled piles, with cement CEM II/B	concrete, for de-icing salt contact	concrete production, 37MPa, for civil engineering, with cement, CEM II/B	concrete, 37MPa	CH	2013-2013	U
concrete production, for drilled piles, with cement CEM I	concrete, for de-icing salt contact	concrete production, 37MPa, for civil engineering, with cement, Portland	concrete, 37MPa	CH	2013-2013	U
concrete production, 40MPa, ready-mix, with cement limestone 6-10%	concrete, 40MPa	concrete production, 40MPa, for building construction, with cement, CEM II/A	concrete, 40MPa	GLO	2015-2022	U
concrete production, 40MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 40MPa	concrete production, 40MPa, for building construction, with cement, CEM III/A	concrete, 40MPa	GLO	2015-2022	U
concrete production, 40MPa, ready-mix, with cement blast furnace slag 35-70%	concrete, 40MPa	concrete production, 40MPa, for building construction, with cement, CP III	concrete, 40MPa	BR	2015-2017	U
concrete production, 40MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 40MPa	concrete production, 40MPa, for building construction, with cement, CP-II-E	concrete, 40MPa	BR	2015-2017	U
concrete production, 40MPa, ready-mix, with cement limestone 6-10%	concrete, 40MPa	concrete production, 40MPa, for building construction, with cement, CP-II-F	concrete, 40MPa	BR	2015-2017	U
concrete production, 40MPa, ready-mix, with cement, alternative constituents 21-35%	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, ART	concrete, 40MPa	CO	2014-2017	U
concrete production, 40MPa, ready-mix, with cement, limestone 21-35%	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, CEM II/B	concrete, 40MPa	GLO	2014-2022	U
concrete production, 40MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, CEM IV/B	concrete, 40MPa	GLO	2014-2022	U
concrete production, 40MPa, ready-mix, with Portland cement	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, Portland	concrete, 40MPa	PE	2014-2017	U
concrete production, 40MPa, ready-mix, with Portland cement	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, Portland	concrete, 40MPa	GLO	2014-2017	U
concrete production, 40MPa, ready-mix, with cement, limestone 21-35%	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, type ICo	concrete, 40MPa	PE	2014-2017	U
concrete production, 40MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete, 40MPa	concrete production, 40MPa, for civil engineering, with cement, type IP	concrete, 40MPa	PE	2014-2017	U
concrete production 40MPa	concrete, 40MPa	concrete production, 40MPa, with cement, CEM II/B-V	concrete, 40MPa	ZA	2017-2017	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
concrete production 45MPa	concrete, 45MPa	concrete production, 45MPa, with cement, CEM II/B	concrete, 45MPa	GLO	2017-2022	U
concrete production 45MPa	concrete, 45MPa	concrete production, 45MPa, with cement, CEM II/B-V	concrete, 45MPa	ZA	2017-2017	U
concrete production 50MPa	concrete, 50MPa	concrete production, 50MPa, with cement, CEM II/B	concrete, 50MPa	GLO	2017-2022	U
concrete production 50MPa	concrete, 50MPa	concrete production, 50MPa, with cement, CEM II/B-V	concrete, 50MPa	ZA	2017-2017	U
concrete production 50MPa	concrete, 50MPa	concrete production, 50MPa, with cement, Portland	concrete, 50MPa	CA-QC; North America without Quebec	2006-2006	U
		concrete production, 50MPa, with cement, Portland	concrete, 50MPa	GLO	2019-2022	N
market for concrete, high exacting requirements	concrete, high exacting requirements	market for concrete, 25MPa	concrete, 25MPa	CH	2019-2022	U
market for concrete, sole plate and foundation	concrete, sole plate and foundation	market for concrete, 30MPa	concrete, 30MPa	CH	2019-2022	U
market for concrete, for de-icing salt contact	concrete, for de-icing salt contact	market for concrete, 37MPa	concrete, 37MPa	CH	2019-2022	U
market for concrete, normal	concrete, normal	market for concrete, normal strength	concrete, normal strength	BR; CO; GLO; IN; PE; RNA; ZA	2019-2019	U
market for concrete, normal	concrete, normal	market for unreinforced concrete, 15MPa	unreinforced concrete, 15MPa	CH	2019-2022	U
unreinforced concrete production, with cement CEM II/A	concrete, normal	unreinforced concrete production, 15MPa, with cement, CEM II/A	unreinforced concrete, 15MPa	CH	2013-2013	U
unreinforced concrete production, with cement CEM II/B	concrete, normal	unreinforced concrete production, 15MPa, with cement, CEM II/B	unreinforced concrete, 15MPa	CH	2013-2013	U
		market for concrete, normal strength	concrete, normal strength	CH	2022-2022	N
		market for concrete, normal strength	concrete, normal strength	AT	2022-2022	N
concrete, all types to generic market for concrete, medium strength	concrete, medium strength	concrete, all types to generic market for concrete, medium strength	concrete, medium strength	GLO	2019-2022	U
concrete, all types to generic market for concrete, normal	concrete, normal	concrete, all types to generic market for concrete, normal strength	concrete, normal strength	BR; CO; IN; PE;	2019-2019	U

Activity Name v3.8	Product Name v3.8	Activity Name v3.9	Product Name v3.9	Geography	Time Period	v3.9
				RNA; ZA		
concrete, all types to generic market for concrete, normal	concrete, normal	concrete, all types to generic market for concrete, normal strength	concrete, normal strength	CH	2019-2022	U
concrete, all types to generic market for concrete, normal	concrete, normal	concrete, all types to generic market for concrete, normal strength	concrete, normal strength	GLO	2019-2022	U
concrete, all types to generic market for concrete, normal	concrete, normal	concrete, all types to generic market for concrete, normal strength	concrete, normal strength	AT	2021-2021	U
concrete slab production	concrete slab			GLO	2014-2017	U

Similarly, to the case of cement, in concrete also some concrete production datasets for GLO are discontinued in v3.9. The goal has been to facilitate the users by providing all main concrete production activities and by avoiding overlaps between multiple activities. . In Table 21, the column 'Recommendation to users' provides a suggestion on which activity to choose in the case of a global activity that is discontinued in v3.9, due to the new structure.

As a result of the new nomenclature rules, all activities that included exchanges from Technosphere that have been renamed or discontinued in v3.9 (Table 20 and Table 21) have been modified to be supplied with the renamed exchanges. In addition, in the case of "concrete slab production / GLO", the exchange "concrete 25-30MPa" was replaced by "concrete 25MPa", as there is no global market for "concrete 25MPa" anymore.

Table 21. Deleted Global activities in v3.9. The column 'Recommendation to users' provides a suggestion on which activity to choose in the case of a global activity that is discontinued in v3.9, due to the new structure.

Activity Name v3.8	Product Name v3.8	Recommendation to users
concrete production, 20MPa, ready-mix, with cement, alternative constituents 21-35%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B
concrete production, 20MPa, ready-mix, with cement, limestone 21-35%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B
concrete production, 20MPa, ready-mix, with cement, pozzolana and fly ash 36-55%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B
concrete production, 20MPa, ready-mix, with Portland cement	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM I
concrete production, 20MPa, self, construction, with cement, pozzolana and fly ash 36-55%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B
concrete production, 20MPa, self-construction, with cement, alternative constituents 45%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B

Activity Name v3.8	Product Name v3.8	Recommendation to users
concrete production, 20MPa, self-construction, with cement, limestone 21-35%	concrete, 20MPa	Use concrete production, 20MPa, with cement CEM II/B
concrete production, 20MPa, self-construction, with Portland cement	concrete, 20MPa	Use concrete production, 20MPa, with cement, Portland
concrete production 25-30MPa	concrete, 25-30MPa	Use concrete production, 25MPa, for building construction, for interior use, with cement, Portland or concrete production, 30MPa, for drilled piles, with cement, Portland
market for concrete, 25-30MPa	concrete, 25-30MPa	Use market for concrete, 25MPa or market for concrete, 30MPa
concrete production 25MPa	concrete, 25MPa	Use concrete production, 25MPa, for building construction, with cement, CEM II/B
concrete production, 25MPa, ready-mix, exposure class XC1	concrete, 25MPa	Use concrete production, 25MPa, for building construction, with cement, CEM III/A or concrete production, 25MPa, for building construction, with cement, CEM II/A or concrete production, 25MPa, for building construction, with cement, CEM II/B or concrete production, 25MPa, for building construction, for interior use, with cement, Portland
concrete production, 25MPa, ready-mix, exposure class XC2	concrete, 25MPa	Use concrete production, 25MPa, for building construction, with cement, CEM III/A or concrete production, 25MPa, for building construction, with cement, CEM II/A or concrete production, 25MPa, for building construction, with cement, CEM II/B or concrete production, 25MPa, for building construction, for interior use, with cement, Portland
concrete production, 25MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 25MPa	Use concrete production, 25MPa, for building construction, with cement, CEM II/A
concrete production, 25MPa, ready-mix, with cement limestone 6-10%	concrete, 25MPa	Use concrete production, 25MPa, for building construction, with cement, CEM II/A
concrete production 30-32MPa	concrete, 30-32MPa	Use concrete production, 30MPa, for drilled piles, with cement, Portland
market for concrete, 30-32MPa	concrete, 30-32MPa	Use market for concrete, 30MPa
concrete production 30MPa	concrete, 30MPa	Use concrete production, 30MPa, for drilled piles, with cement CEM II/B
concrete production, 30MPa, ready-mix, exposure class XC3	concrete, 30MPa	Use concrete production, 30MPa, for drilled piles, with cement, Portland or concrete production, 30MPa, for drilled piles, with cement CEM II/A or concrete production, 30MPa, for drilled piles, with cement CEM II/B or concrete production, 30MPa, for building construction, with cement, CEM III/A
concrete production, 30MPa, ready-mix, exposure classes XC3/XD2/XF1/XA1	concrete, 30MPa	Use concrete production, 30MPa, for drilled piles, with cement, Portland or concrete production, 30MPa, for drilled piles, with cement CEM II/A or concrete production, 30MPa, for drilled piles, with cement CEM II/B or concrete production, 30MPa, for building construction, with cement, CEM III/A
concrete production, 30MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 30MPa	Use concrete production, 30MPa, for drilled piles, with cement CEM II/A
concrete production, 30MPa, ready-mix, with cement limestone 6-10%	concrete, 30MPa	Use concrete production, 30MPa, for drilled piles, with cement CEM II/A
concrete production, 35MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 35MPa	Use concrete production, 35MPa, for building construction, with cement CEM II/A

Activity Name v3.8	Product Name v3.8	Recommendation to users
concrete production 40MPa	concrete, 40MPa	Use concrete production, 40MPa, for civil engineering, with cement CEM II/B
concrete production, 40MPa, ready-mix, with cement blast furnace slag 6-34%	concrete, 40MPa	Use concrete production, 40MPa, for building construction, with cement CEM II/A
concrete production, 40MPa, ready-mix, with cement, alternative constituents 21-35%	concrete, 40MPa	Use concrete production, 40MPa, for civil engineering, with cement CEM II/B

4.2 New technologies for cement and concrete production

New production technologies of construction materials are being developed in recent years, aiming to reduce the environmental impact and reuse construction and demolition waste. The v3.9 includes new datasets on the production of cement and concrete with recycled aggregates and waste mixed aggregates for Switzerland (Table 22).

Table 22. New activities related to cement and concrete production in Switzerland.

Activity Name	Geography	Time Period	Product Name	Unit
cement production, ZN/D, new alternative constituents 36-50%, in conformity with SIA 2049	CH	2020-2020	cement, ZN/D, new alternative constituents 36-50%, in conformity with SIA 2049	kg
concrete production, 25MPa, for building construction, for interior use, with cement ZN/D	CH	2020-2020	concrete, 25MPa	m^3
concrete production, 25MPa, for building construction, for interior use, with cement ZN/D, with 50% RC-C aggregates	CH	2020-2020	concrete, 25MPa	m^3
concrete production, 25MPa, for building construction, for interior use, with cement ZN/D, with <30% RC-M aggregates	CH	2020-2020	concrete, 25MPa	m^3
concrete production, 30MPa, for building construction, for interior use, with cement ZN/D	CH	2020-2020	concrete, 30MPa	m^3
concrete production, 30MPa, for building construction, for interior use, with cement ZN/D, with 30% RC-M aggregates	CH	2020-2020	concrete, 30MPa	m^3
concrete production, 30MPa, for building construction, for interior use, with cement ZN/D, with 50% RC-C aggregates	CH	2020-2020	concrete, 30MPa	m^3
concrete production, 30MPa, for drilled piles, with cement ZN/D	CH	2020-2020	concrete, 30MPa	m^3
concrete production, 37MPa, for building construction, for exterior use, with cement ZN/D	CH	2020-2020	concrete, 37MPa	m^3
concrete production, 37MPa, for building construction, for interior	CH	2020-2020	concrete, 37MPa	m^3

Activity Name	Geography	Time Period	Product Name	Unit
use, with cement ZN/D, with 35% RC-C aggregates				
concrete production, 37MPa, for civil engineering, for deicing salt contact, with cement ZN/D	CH	2020-2020	concrete, 37MPa	m^3
lean concrete production, for building construction, with cement ZN/D	CH	2020-2020	lean concrete	m^3
lean concrete production, for building construction, with cement ZN/D, with 100% RC-M aggregates	CH	2020-2020	lean concrete	m^3
market for cement, ZN/D, new alternative constituents 36-50%, in conformity with SIA 2049	CH	2020-2020	cement, ZN/D, new alternative constituents 36-50%, in conformity with SIA 2049	kg
unreinforced concrete production, 15MPa, with cement ZN/D	CH	2020-2020	unreinforced concrete, 15MPa	m^3
market for waste mixed aggregates, from demolition	CH	2020-2020	waste mixed aggregates, from demolition	kg

4.3 Modification of existing datasets for cement and concrete

In addition to the renaming of the cement and concrete production and market datasets, in v3.9 some datasets in the sector were modified.

Transport in all Global markets for cement was aligned with the default transport data per commodity group of ecoinvent v3 (Borken-Kleefeld, 2012). More specifically, sea transport was added to all markets. Table 23 shows the markets for cement / GLO modified.

Table 23. Market activities where sea transport was added for v3.9. In the column v3.9, "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
market for cement, CEM IV/A	GLO	2005-2009	cement, CEM IV/A	kg	U
market for cement, CEM IV/B	GLO	2005-2009	cement, CEM IV/B	kg	U
market for cement, CEM II/A	GLO	2005-2009	cement, CEM II/A	kg	U
market for cement, CEM II/B	GLO	2005-2009	cement, CEM II/B	kg	U
market for cement, CEM III/A	GLO	2017-2017	cement, CEM III/A	kg	U
market for cement, CEM III/B	GLO	2005-2009	cement, CEM III/B	kg	U
market for cement, CEM III/C	GLO	2005-2009	cement, CEM III/C	kg	U
market for cement, CEM V/A	GLO	2005-2009	cement, CEM V/A	kg	U
market for cement, CEM V/B	GLO	2005-2009	cement, CEM V/B	kg	U

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
market for cement, Portland	GLO	2005-2009	cement, Portland	kg	U
market for cement, unspecified	GLO	2005-2009	cement, unspecified	kg	U

In addition, the Production Volumes of the cement production activities / GLO were also adjusted. Updated data of global and local production volumes of hydraulic cement were taken from USGS (2019). The shares of all cement technologies were approximated from the geography Europe without Switzerland. The global share of Portland cement, however, was estimated based on global production volume of hydraulic cement and global production volume of Portland cement for the year 2021 of USGS (2022) and IMARC Group (2022), respectively. Then, the shares for the other cement technologies were accordingly scaled. Furthermore, the Production Volume of all the regional cement production activities was updated with country-specific data from USGS (2019). For the geographies Switzerland and Europe without Switzerland, the shares of the types of cement were updated according to cemsuisse (2021) and European Commission (2017), respectively. For the other geographies the same initial market shares of each type of cement technology given by the data provider was maintained, since no updated source was found. Apart from the update on the Production Volume, two global cement production activities were modified: i) “cement production, Portland / GLO” was updated as a weighted average of all regional “cement production, Portland” activities; ii) “cement production, CEM IV/B, GLO” (previously named “cement, pozzolana and fly ash 36-55%”) is now a copy of the CH dataset, instead of the PE dataset.

Due to the change in Production Volumes and to the restructuring of cement and concrete datasets, the inputs in the renaming activities “cement, all types to generic market for cement, unspecified”, “concrete, all types to generic market for concrete, normal strength” and “concrete, all types to generic market for concrete, medium strength” were modified. Moreover, the Production Volumes of the concrete production activities / GLO were updated, where the total Production Volume of all activities GLO from v3.8 was redistributed considering the activities which are maintained for v3.9. Table 24 includes all datasets for cement and concrete that were modified in v3.9.

Table 24. Cement and concrete production activities where the Production Volume was updated for v3.9 or which were modified due to a change in Production Volume. In the column v3.9, “U” stands for “Updated Activity”.

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
cement, all types to generic market for cement, unspecified	CA-QC	2013-2022	cement, unspecified	kg	U
cement, all types to generic market for cement, unspecified	BR; IN; ZA	2013-2022	cement, unspecified	kg	U
cement, all types to generic market for cement, unspecified	CH; CO; Europe without Switzerland; GLO; PE; US	2013-2022	cement, unspecified	kg	U

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
cement, unspecified, import from Europe	CH	2022-2022	cement, unspecified	kg	U
cement production, Portland	BR	2016-2022	cement, Portland	kg	U
cement production, CP II-E	BR	2016-2022	cement, CP II-E	kg	U
cement production, CP II-F	BR	2016-2022	cement, CP II-F	kg	U
cement production, CP II-Z	BR	2016-2022	cement, CP II-Z	kg	U
cement production, CP III	BR	2016-2022	cement, CP III	kg	U
cement production, CP IV	BR	2016-2022	cement, CP IV	kg	U
cement production, CP V RS	BR	2016-2022	cement, CP V RS	kg	U
cement production, Portland	CA-QC	2005-2022	cement, Portland	kg	U
cement production, CEM II/A	CA-QC	2005-2022	cement, CEM II/A	kg	U
cement production, Portland	CH	2009-2022	cement, Portland	kg	U
cement production, CEM II/A	CH	2009-2022	cement, CEM II/A	kg	U
cement production, CEM II/B	CH	2009-2022	cement, CEM II/B	kg	U
cement production, CEM III/A	CH	2005-2022	cement, CEM III/A	kg	U
cement production, CEM III/B	CH	2005-2022	cement, CEM III/B	kg	U
cement production, CEM III/C	CH	2005-2022	cement, CEM III/C	kg	U
cement production, CEM IV/A	CH	2005-2022	cement, CEM IV/A	kg	U
cement production, CEM IV/B	CH	2005-2022	cement, CEM IV/B	kg	U
cement production, CEM V/A	CH	2005-2022	cement, CEM V/A	kg	U
cement production, CEM V/B	CH	2005-2022	cement, CEM V/B	kg	U
cement production, ART	CO	2014-2022	cement, ART	kg	U
cement production, type general use	CO	2014-2022	cement, type general use	kg	U
cement production, Portland	Europe without Switzerland	2005-2022	cement, Portland	kg	U
cement production, CEM II/A	Europe without Switzerland	2005-2022	cement, CEM II/A	kg	U
cement production, CEM II/B	Europe without Switzerland	2005-2022	cement, CEM II/B	kg	U
cement production, CEM III/A	Europe without Switzerland	2005-2022	cement, CEM III/A	kg	U
cement production, CEM III/B	Europe without Switzerland	2005-2022	cement, CEM III/B	kg	U
cement production, CEM III/C	Europe without Switzerland	2005-2022	cement, CEM III/C	kg	U
cement production, CEM IV/A	Europe without Switzerland	2005-2022	cement, CEM IV/A	kg	U
cement production, CEM IV/B	Europe without Switzerland	2005-2022	cement, CEM IV/B	kg	U
cement production, CEM V/A	Europe without Switzerland	2005-2022	cement, CEM V/A	kg	U

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
cement production, CEM V/B	Europe without Switzerland	2005-2022	cement, CEM V/B	kg	U
cement production, Portland	GLO	2005-2022	cement, Portland	kg	U
cement production, CEM II/A	GLO	2005-2022	cement, CEM II/A	kg	U
cement production, CEM II/B	GLO	2005-2022	cement, CEM II/B	kg	U
cement production, CEM III/A	GLO	2005-2022	cement, CEM III/A	kg	U
cement production, CEM III/B	GLO	2005-2022	cement, CEM III/B	kg	U
cement production, CEM III/C	GLO	2005-2022	cement, CEM III/C	kg	U
cement production, CEM IV/A	GLO	2005-2022	cement, CEM IV/A	kg	U
cement production, CEM IV/B	GLO	2005-2022	cement, CEM IV/B	kg	U
cement production, CEM V/A	GLO	2005-2022	cement, CEM V/A	kg	U
cement production, CEM V/B	GLO	2005-2022	cement, CEM V/B	kg	U
cement production, Portland	IN	2014-2022	cement, Portland	kg	U
cement production, Portland Slag	IN	2014-2022	cement, Portland Slag	kg	U
cement production, Pozzolana Portland	IN	2014-2022	cement, Pozzolana Portland	kg	U
cement production, Portland	PE	2014-2022	cement, Portland	kg	U
cement production, type ICo	PE	2014-2022	cement, type ICo	kg	U
cement production, type IP	PE	2014-2022	cement, type IP	kg	U
cement production, Portland	US	2005-2022	cement, Portland	kg	U
cement production, type I (SM)	US	2005-2022	cement, type I (SM)	kg	U
cement production, type I-PM	US	2005-2022	cement, type I-PM	kg	U
cement production, type IP/P	US	2005-2022	cement, type IP/P	kg	U
cement production, type IS	US	2005-2022	cement, type IS	kg	U
cement production, type S	US	2005-2022	cement, type S	kg	U
cement production, Portland	ZA	2017-2022	cement, Portland	kg	U
cement production, CEM II/A-L	ZA	2017-2022	cement, CEM II/A-L	kg	U
cement production, CEM II/A-S	ZA	2017-2022	cement, CEM II/A-S	kg	U
cement production, CEM II/A-V	ZA	2017-2022	cement, CEM II/A-V	kg	U
cement production, CEM II/B-L	ZA	2017-2022	cement, CEM II/B-L	kg	U
cement production, CEM II/B-S	ZA	2017-2022	cement, CEM II/B-S	kg	U
cement production, CEM II/B-V	ZA	2017-2022	cement, CEM II/B-V	kg	U
cement production, CEM III/A	ZA	2017-2022	cement, CEM III/A	kg	U

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
concrete production, 20MPa, with cement, CEM II/B	GLO	2017-2022	concrete, 20MPa	m^3	U
concrete production, 20MPa, with cement, Portland	GLO	2006-2022	concrete, 20MPa	m^3	U
concrete production, 25MPa, for building construction, for interior use, with cement, Portland	GLO	2006-2022	concrete, 25MPa	m^3	U
concrete production, 25MPa, for building construction, with cement, CEM II/A	GLO	2013-2022	concrete, 25MPa	m^3	U
concrete production, 25MPa, for building construction, with cement, CEM II/B	GLO	2013-2022	concrete, 25MPa	m^3	U
concrete production, 25MPa, for building construction, with cement, CEM III/A	GLO	2015-2022	concrete, 25MPa	m^3	U
concrete production, 30MPa, for building construction, with cement, CEM III/A	GLO	2015-2022	concrete, 30MPa	m^3	U
concrete production, 30MPa, for drilled piles, with cement, CEM II/A	GLO	2013-2022	concrete, 30MPa	m^3	U
concrete production, 30MPa, for drilled piles, with cement, CEM II/B	GLO	2013-2022	concrete, 30MPa	m^3	U
concrete production, 30MPa, for drilled piles, with cement, Portland	GLO	2013-2022	concrete, 30MPa	m^3	U
concrete production, 35MPa, for building construction, with cement, CEM II/A	GLO	2015-2022	concrete, 35MPa	m^3	U
concrete production, 35MPa, for building construction, with cement, CEM III/A	GLO	2015-2022	concrete, 35MPa	m^3	U
concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland	GLO	2006-2022	concrete, 35MPa	m^3	U
concrete production, 35MPa, with cement, CEM II/B	GLO	2017-2022	concrete, 35MPa	m^3	U
concrete production, 40MPa, for building construction, with cement, CEM II/A	GLO	2015-2022	concrete, 40MPa	m^3	U
concrete production, 40MPa, for building construction, with cement, CEM III/A	GLO	2015-2022	concrete, 40MPa	m^3	U
concrete production, 40MPa, for civil engineering, with cement, CEM II/B	GLO	2014-2022	concrete, 40MPa	m^3	U
concrete production, 40MPa, for civil engineering, with cement, CEM IV/B	GLO	2014-2022	concrete, 40MPa	m^3	U
concrete production, 40MPa, for civil engineering, with cement, Portland	GLO	2014-2022	concrete, 40MPa	m^3	U
concrete production, 45MPa, for building construction, with cement, CEM II/B	GLO	2017-2022	concrete, 45MPa	m^3	U
concrete production, 50MPa, with cement, CEM II/B	GLO	2017-2022	concrete, 50MPa	m^3	U
concrete production, 50MPa, with cement, Portland	GLO	2019-2022	concrete, 50MPa	m^3	U
concrete, all types to generic market for concrete, normal strength	GLO	2019-2022	concrete, normal strength	m^3	U
concrete, all types to generic market for concrete, medium strength	GLO	2019-2022	concrete, medium strength	m^3	U
concrete, all types to generic market for concrete, normal strength	CH	2019-2022	concrete, normal strength	m^3	U

Furthermore, the modelling of the concrete production activities of Table 25 was modified to include fly ash as a negative reference product.

Table 25. Concrete production activities modified to include fly ash in the inventory. In the column v3.9, "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
concrete production, 50MPa, with cement, Portland	CA-QC; North America without Quebec	2006-2006	concrete, 50MPa	m^3	U
concrete production, 50MPa, with cement, Portland	GLO	2019-2022	concrete, 50MPa	m^3	U
concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland	CA-QC; North America without Quebec	2006-2006	concrete, 35MPa	m^3	U
concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland	GLO	2022-2022	concrete, 35MPa	m^3	U
concrete production, 30-32MPa, with cement, Portland	CA-QC; North America without Quebec	2006-2006	concrete, 30-32MPa	m^3	U
concrete production, 25MPa, for building construction, for interior use, with cement, Portland	CA-QC; North America without Quebec	2005-2009	concrete, 25MPa	m^3	U
concrete production, 20MPa, with cement, Portland	CA-QC; North America without Quebec	2006-2006	concrete, 20MPa	m^3	U
concrete production, 20MPa, with cement, Portland	GLO	2006-2022	concrete, 20MPa	m^3	U

4.4 Other updates

The datasets of Table 26 related to supplementary cementitious materials were updated with respect to their Production Volumes. The global dataset for the "market for granulated blast furnace slag" was deleted and as a result, an activity link in "clinker production" was updated. In the case of mastic asphalt production, the amounts of heat and electricity were updated from a new source.

Table 26. Updated activities related to supplementary cementitious materials and mastic asphalt production. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
market for granulated blast furnace slag	GLO	2015-2019	granulated blast furnace slag	kg	D
calcined clay production	BR; GLO	2015-2022	calcined clay	kg	U
calcined clay to generic market for supplementary cementitious materials	BR; GLO	2019-2022	supplementary cementitious materials	kg	U

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
limestone, crushed, washed to generic market for supplementary cementitious materials	GLO	2019-2019	supplementary cementitious materials	kg	U
clinker production	GLO	1998-2017	clinker	kg	U
mastic asphalt production	CH; GLO	2000-2004	mastic asphalt	kg	U

4.5 Assessments for the next release

During the restructuring of the cement and concrete supply chains, the following possible issues were identified. Further assessments will be performed related to these issues for the next release of the database and if required, corrections will be implemented.

- The environmental impact of the activity “concrete production, 50MPa, with cement, CEM II/B” is higher than the impact of “concrete production, 50MPa, with cement, Portland” for the global geography. The former activity is a copy of the South African dataset while the latter of the North American one. For the next release, both inventories will be checked to ensure that the impact assessment results are indeed accurate.
- The type of concrete used in infrastructure datasets needs to be re-evaluated. Up to v3.8, a lot of infrastructure datasets for Switzerland were using concrete, normal, which is now renamed to unreinforced concrete, 15MPa. It is possible that some of these datasets should be supplied by a higher strength concrete. In addition, the infrastructure datasets for the global geography will be also assessed to ensure that they are aligned with the respective Swiss ones regarding the type of concrete they consume.

5 Chemicals

5.1 Inclusion of chemical products developed for the EF initiative

The ecoinvent association continues its engagement in the Environmental Footprint initiative and in the creation of EF data. Selected chemical related data developed within this context have been reworked based on the ecoinvent approach and are part of v3.9. The new datasets, 38 transforming activities and respective markets, represent products such as pesticides (herbicides, fungicides, insecticides), plasticisers and organic compounds. Transforming activities are listed in Table 27.

Table 27. Datasets transferred from the PEF project. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
1-methoxy-2-propanol production	GLO	2020-2020	1-methoxy-2-propanol	kg
1-methylcyclopropene production	GLO	2020-2020	1-methylcyclopropene	kg
1-naphthylacetic acid production	GLO	2020-2020	1-naphthylacetic acid	kg
6-benzyladenine production	GLO	2020-2020	6-benzyladenine	kg
adiponitrile production	RER; GLO	2020-2020	adiponitrile	kg
amidosulfuron production	GLO	2020-2020	amidosulfuron	kg
bromoxynil production	GLO	2020-2020	bromoxynil	kg
chloridazon production	GLO	2020-2020	chloridazon	kg
chlormequat chloride production	GLO	2020-2020	chlormequat chloride	kg
chlorpropham production	GLO	2020-2020	chlorpropham	kg
daminozide production	GLO	2020-2020	daminozide	kg
dichlobenil production	GLO	2020-2020	dichlobenil	kg
dioctyl adipate production	GLO	2020-2020	dioctyl adipate	kg
dioctyl terephthalate production	GLO	2020-2020	dioctyl terephthalate	kg
ethephon production	GLO	2020-2020	ethephon	kg
fluazifop-butyl production	GLO	2020-2020	fluazifop-butyl	kg
hexamethylene-1,6-diisocyanate production	RER; GLO	2020-2020	hexamethylene-1,6-diisoncyanate	kg
hexamethylenediamine production	RER; GLO	2020-2020	hexamethylenediamine	kg
indolylbutyric acid production	GLO	2020-2020	indolylbutyric acid	kg
ioxynil production	GLO	2020-2020	ioxynil	kg
isophorondiisocyanate production	RER; GLO	2020-2020	isophorondiisocyante	kg
lauric diethanolamide production	GLO	2020-2020	lauric diethanolamide	kg
maleic hydrazide production	GLO	2020-2020	maleic hydrazide	kg
maneb production	GLO	2020-2020	maneb	kg
mepiquat chloride production	GLO	2020-2020	mepiquat chloride	kg
metazachlor production	GLO	2020-2020	metazachlor	kg
methallylchloride production	GLO	2020-2020	methallylchloride	kg
paclobutrazol production	GLO	2020-2020	paclobutrazol	kg
prochloraz production	GLO	2020-2020	prochloraz	kg
prohexadione calcium production	GLO	2020-2020	prohexadione calcium	kg
sodium silver thiosulfate production	GLO	2020-2020	sodium silver thiosulfate	kg

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
tebuconazole production	GLO	2020-2020	tebuconazole	kg
triclopyr production	GLO	2020-2020	triclopyr	kg
trinexapac-ethyl production	GLO	2020-2020	trinexapac-ethyl	kg
zineb production	GLO	2020-2020	zineb	kg

The corresponding markets are listed in Table 28.

Table 28. Corresponding markets to new activities. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
market for 1-methoxy-2-propanol	GLO	2020-2020	1-methoxy-2-propanol	kg
market for 1-methylcyclopropene	GLO	2020-2020	1-methylcyclopropene	kg
market for 1-naphthylacetic acid	GLO	2020-2020	1-naphthylacetic acid	kg
market for 6-benzyladenine	GLO	2020-2020	6-benzyladenine	kg
market for adiponitrile	RER; GLO	2020-2020	adiponitrile	kg
market for amidosulfuron	GLO	2020-2020	amidosulfuron	kg
market for bromoxynil	GLO	2020-2020	bromoxynil	kg
market for chloridazon	GLO	2020-2020	chloridazon	kg
market for chlormequat chloride	GLO	2020-2020	chlormequat chloride	kg
market for chlorpropham	GLO	2020-2020	chlorpropham	kg
market for daminozide	GLO	2020-2020	daminozide	kg
market for dichlobenil	GLO	2020-2020	dichlobenil	kg
market for dioctyl adipate	GLO	2020-2020	dioctyl adipate	kg
market for dioctyl terephthalate	GLO	2020-2020	dioctyl terephthalate	kg
market for ethephon	GLO	2020-2020	ethephon	kg
market for fluazifop-butyl	GLO	2020-2020	fluazifop-butyl	kg
market for hexamethylene-1,6-diisoncyanate	RER; GLO	2020-2020	hexamethylene-1,6-diisoncyanate	kg
market for hexamethylenediamine	GLO	2020-2020	hexamethylenediamine	kg
market for indolylbutyric acid	GLO	2020-2020	indolylbutyric acid	kg
market for ioxynil	GLO	2020-2020	ioxynil	kg
market for isophorondiisocyante	RER; GLO	2020-2020	isophorondiisocyante	kg
market for lauric diethanolamide	GLO	2020-2020	lauric diethanolamide	kg
market for maleic hydrazide	GLO	2020-2020	maleic hydrazide	kg
market for maneb	GLO	2020-2020	maneb	kg
market for mepiquat chloride	GLO	2020-2020	mepiquat chloride	kg
market for metazachlor	GLO	2020-2020	metazachlor	kg
market for methallylchloride	GLO	2020-2020	methallylchloride	kg
market for paclobutrazol	GLO	2020-2020	paclobutrazol	kg
market for prochloraz	GLO	2020-2020	prochloraz	kg
market for prohexadione calcium	GLO	2020-2020	prohexadione calcium	kg
market for sodium silver thiosulfate	GLO	2020-2020	sodium silver thiosulfate	kg

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
market for tebuconazole	GLO	2020-2020	tebuconazole	kg
market for triclopyr	GLO	2020-2020	triclopyr	kg
market for trinexapac-ethyl	GLO	2020-2020	trinexapac-ethyl	kg
market for zineb	GLO	2020-2020	zineb	kg

5.2 New datasets/technologies

To keep the database up to date and in line with industrial progress, several datasets were remodelled to reflect the industrially applied processes. In addition, to broaden the coverage of the chemical sector, new production activities were added (Table 29). Some of the new activities replace outdated technologies present in the database.

Table 29. New and remodelled datasets. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity", "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
2,4-dinitrotoluene production	RER; GLO	2015-2020	2,4-dinitrotoluene	kg	N; U
carbon disulfide production	GLO	2000-2006	carbon disulfide	kg	D
carbon disulfide production, from charcoal	GLO	2000-2006	carbon disulfide	kg	N
carbon disulfide production, from natural gas	GLO	2000-2006	carbon disulfide	kg	U
ethylenediamine production	RER; GLO	2000-2020	ethylenediamine	kg	D
ethylenediamine production, from ethanolamine	RER; GLO	2000-2020	ethylenediamine	kg	N
ethylenediamine production, from ethylene dichloride	RER; GLO	2000-2020	ethylenediamine	kg	U
glucose production	GLO	2015-2020	glucose	kg	N
market for meta-phenylene diamine	GLO	2002-2002	meta-phenylene diamine	kg	D
market for resorcinol	GLO	2002-2002	resorcinol	kg	N
market for sodium ethyl xanthate	GLO	2022-2022	sodium ethyl xanthate	kg	N
phenylenediamine production	GLO	2002-2002	meta-phenylene diamine	kg	D
resorcinol production, benzene disulfonation	DE	2020-2002	resorcinol	kg	N
resorcinol production, hydroperoxidation of meta-diisopropylbenzene	GLO	2020-2002	resorcinol	kg	N
resorcinol production, hydrolysis of meta-phenylene diamine	GLO	2022-2022	resorcinol	kg	U
regenerative thermal oxidation of nitrous oxide	RER; GLO	2022-2022	N2O retained, by regenerative thermal oxidation	kg	N
sodium ethyl xanthate production	ZA; GLO	2014-2024	sodium ethyl xanthate	kg	N

5.3 Update of the hydrogen production

The dataset “hydrogen production, steam reforming” is included in version 3.9. The new production technology for now does not contribute to the market for hydrogen, liquid, the improvement of production and consumption mixes are planned for the following releases. The work will additionally include the revision of hydrogen in both gaseous and liquid form and its utilisation in different industries.

Compared to the current hydrogen markets – liquid and gaseous – the newly introduced steam reforming dataset has a global warming potential (IPCC 2021) which is more than 5 times higher. This GWP is in accordance with literature (Antonini et al., 2020).

5.4 Changes related to oil and gas update

With the release of ecoinvent v3.9, a comprehensive update for the oil and gas sector was implemented (see chapter 6). The revised wet and dry mass properties led to updates in linked datasets (Table 30).

Table 30. Datasets with changes due to the oil and gas update. If several geographies of the same activity with the same time period exist, all of them are listed in the “Geography” column. In the column v3.9, “U” stands for “Updated Activity”.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
natural gas liquids production	GLO	2000-2000	natural gas liquids	kg	U
natural gas production, high pressure, vehicle grade	CH; GLO	2001-2001	natural gas, high pressure, vehicle grade	kg	U
natural gas production, low pressure, vehicle grade	CH; GLO	2001-2001	natural gas, low pressure, vehicle grade	kg	U
natural gas production, medium pressure, vehicle grade	CH; GLO	2001-2001	natural gas, medium pressure, vehicle grade	kg	U

In addition, the oil and gas update led to several score changes in the petrochemical sector. In this section observations regarding GWP (IPCC 2021) are provided, for more on natural gas scores please see section 6.6. For activities with direct inputs of natural gas (e.g. carbon disulfide production, from natural gas) an increase up to 20% was observed. In datasets with indirect inputs of natural gas (e.g. through heat, from natural gas), an increase of maximum 7% was found.

Figure 2 depicts the score changes of the IPCC GWP 2021 100a in the chemical sector between ecoinvent v3.8 and v3.9. This figure mirrors changes not only based on the oil and gas update, but all updates in the sector. As visible, most scores changed between 0 and 10%, due to the indirect oil and gas input through e.g. “heat, from natural gas” in many chemical datasets or other corrections. The decrease in scores can be mainly explained by the remodelling of technologies and updates in prices. Higher increases are linked to direct inputs of natural gas or petroleum, like refinery outputs.

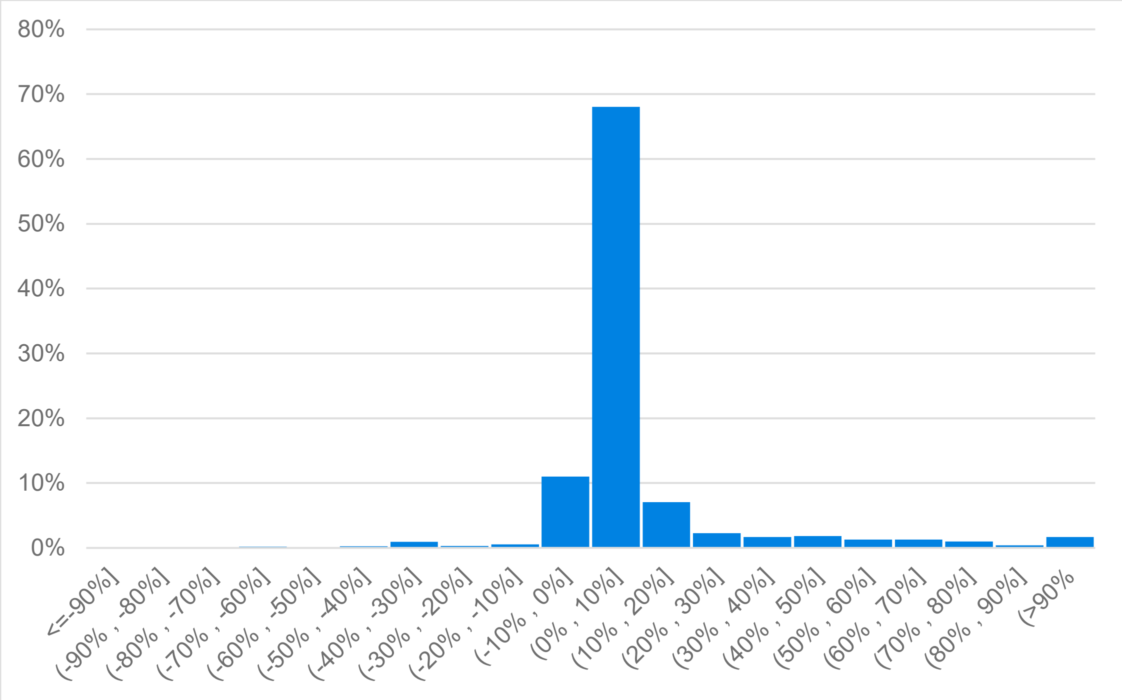

Figure 2: Comparison of results in the chemical sector between v3.8 and v3.9. This figure depicts IPCC GWP 100a in the "Allocation, cut-off by classification" system model. The vertical axis represents the proportion of the chemical sector affected by the change in score, represented in the horizontal axis as intervals.

Some key building blocks, e.g. ethylene and propylene, are older aggregated PlasticsEurope LCIs which remain unaffected by this update. New data for key products is planned in the upcoming release, specifically the introduction of the steam cracker process is in preparation.

5.5 Hydrochloric acid as by-product

Hydrochloric acid is produced as a valuable by-product in several industrial processes. The activities listed in Table 31 treated hydrochloric acid as a waste by neutralising it with a base, this was corrected in v3.9. Further examination of the handling of hydrochloric acid will be carried out for the upcoming releases.

The activity for the production of toluene diisocyanate replaces the outdated aggregated LCI from PlasticsEurope with a disaggregated process.

Table 31. Datasets in which hydrochloric acid was introduced as an allocatable by-product. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
methylene diphenyl diisocyanate production	RER; GLO	2015-2020	methylene diphenyl diisocyanate	kg	U
toluene diisocyanate production	RER; GLO	1995-2001	toluene diisocyanate	kg	U
trichloroethylene production	RER; GLO	2015-2020	trichloroethylene	kg	U

5.6 Other changes

5.6.1 Production volume updates

To reflect markets as realistically as possible, selected activities were deleted as they were representing the same technology. Production volumes of the following datasets were updated accordingly (Table 32).

For the datasets "pentane production" as well as "succinic acid production", dummy values for the production volume were introduced to reflect realistic market shares of intended production and production as by-product.

Table 32. Updated activities related to the chemical sector with production volume updates. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
acetone production, liquid	RER; GLO	1992-2001	acetone, liquid	kg	D
acetone production, from isopropanol	RER; GLO	2015-2020	acetone, liquid	kg	U
chichibabin pyridine synthesis	RER	2010-2010	pyridine	kg	U
ethylene dichloride production	RER; GLO	1997-2000	ethylene dichloride	kg	U
pentane production	RER; GLO	2001-2001	pentane	kg	U
phenol production	RER; GLO	2000-2020	phenol	kg	D
phenol production, from cumene	RER; GLO	2015-2020	phenol	kg	U
sodium sulfite production	RER; GLO	2010-2010	sodium sulfite	kg	U
succinic acid production	GLO	2015-2020	succinic acid	kg	U

5.6.2 UPR balance revision

Mass and water balances have been revised for the activities listed in Table 33. Where necessary, activity names, reference product names as well as properties have been adjusted.

Table 33. Datasets with updated properties. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
acrylic binder production, with water, in 54% solution state	RER; GLO	1995-1995	acrylic binder, with water, in 54% solution state	kg	U
acrylic dispersion production, with water, in 58% solution	RER; GLO	1996-1996	acrylic dispersion, with water, in 58% solution	kg	U
acrylic varnish production, with water, in 53% solution state	RER; GLO	1995-1995	acrylic varnish, with water, in 53% solution state	kg	U
barium sulfide production	GLO	2015-2020	barium sulfide	kg	U
carbon monoxide production	RER; GLO	1997-2000	carbon monoxide	kg	U
chichibabin amination	RER; GLO	2010-2010	aminopyridine	kg	U
soda production, solvay process	RER; GLO	1999-1999	soda ash, light	kg	U

5.6.3 Miscellaneous updates

In Table 34 is a summary of datasets with various updates. The updates include corrections of exchange amounts, improvements of the representation of emission abatement technologies or waste treatments, and replacements due to renaming.

Table 34. Datasets with various updates. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
activated silica production	GLO	2012-2020	activated silica	kg	U
adipic acid production	RER; GLO	1997-2000	adipic acid	kg	U
folpet production	RER; GLO	2000-2020	folpet	kg	U
fosetyl-Al production	RER; GLO	2000-2010	fosetyl-Al	kg	U
hexafluoroethane production, from fluorination of tetrafluoroethane	GLO	1998-1998	hexafluoroethane	kg	U
magnesium production, electrolysis	IL; GLO	2011-2012	magnesium	kg	U
market for tetrafluoroethane	GLO	2012-2012	tetrafluoroethane	kg	D
seawater reverse osmosis module production, 8-inch spiral wound, baseline	GLO	2012-2012	seawater reverse osmosis module	m2	U
seawater reverse osmosis module production, 8-inch spiral wound, enhanced	GLO	2012-2012	seawater reverse osmosis module	m2	U
tetrafluoroethane production	GLO	1994-1994	tetrafluoroethane	kg	D

Polycarbonate production replaces the outdated aggregated LCI from PlasticsEurope with a disaggregated process (Table 35).

Table 35. Disaggregated dataset for polycarbonate. In the column v3.9, “U” stands for “Updated Activity”.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
polycarbonate production	RER; GLO	2016-2024	polycarbonate	kg	U

6 Crude petroleum oil and natural gas supply

6.1 Introduction

Included with version 3.9 of the ecoinvent database is an extensive overhaul of the data on natural gas and crude petroleum oil supply. The update encompasses production, long-distance transport, and regional distribution, as far as possible reflecting the global supply situation in 2019. The geographical coverage provided in the database is expanded with data on the production of natural gas and crude petroleum oil in different countries and regions. When combined, the ecoinvent database now covers 90% of global production of crude oil, and nearly 80% of natural gas. In addition, regional consumption mixes for crude petroleum oil to North America and Europe are introduced, alongside new or updated natural gas supply to 44 countries, based on the situation in 2019.

The potential contribution to global warming from methane, released into the atmosphere from human activities and natural processes, has gained much attention in recent years. As a results, the oil and gas industry has come under increasing scrutiny as a major anthropogenic source of these emissions (see for example Lauvoux et al. 2019; Plant et al. 2022). The emission levels reported by official public bodies appear not to capture the full magnitude of the problem (IEA 2022). A central objective for the update of petroleum and natural gas production in the ecoinvent database was to incorporate information on these aspects from recent, consistent, and well-recognized datasets of global scope. Key features of the update for 3.9 are data on flaring of natural gas from *the Global Gas Flaring Reduction Partnership (GGFR)* of the World Bank, and on methane emissions from gas venting and fugitive emission source from the International Energy Agency's *Global Methane Tracker 2022*. Building on earlier studies commissioned by the Swiss Federal Office for the Environment (FOEN), the Swiss Federal Office for Energy (SFOE), the Swiss Gas Industry Association (Verband der Schweizerischen Gasindustrie, VSG), and Avenergy Suisse (previously Erdöl-Vereinigung), this update and the implementation into the ecoinvent database was commissioned by the ecoinvent Association, and prepared and delivered by ESU-services Ltd.

6.2 Overview of the update

The update to the supply of crude petroleum oil and natural gas for version 3.9 of the ecoinvent database largely maintain the structure introduced for version 3.4 (described in Faist-Emmenegger et al. 2017). The main aspects addressed by this latest update are summarized below, and described in detail in the subsequent sections:

- The data on the extraction of crude oil and natural gas was updated and expanded to represent 27 producing countries. Using a common modelling approach (described in Meili et al. 2022a), information on key aspects like production output, energy and water requirements, methane released from venting and fugitive emission sources, gas flaring etc. was compiled from global datasets and processed into consistent country-specific inventories. These inventories are as far as possible representative of the situation in 2019. The extraction of crude oil and natural gas in 3.9 is considered as combined production activities, only differentiating between offshore and onshore operations. The updated production activities are explained in further detail in chapter 6.3.

- The long-distance transport (transmission) of natural gas includes transport via pipelines and as liquefied natural gas (LNG). The energy requirements for long-distance pipeline transport, were updated with regional energy use factors (as share of gas consumed per 1'000km), whereas the loss (leakage) rates remain as in 3.8. The dataset for freight transport by sea (with tanker ship) was not updated for this release. The changes related to long-distance transport are described in section 6.5.
- Internal energy supply for the transmission, storge, and distribution of natural gas was updated and simplified through a single activity ('natural gas, burned in gas turbine') per country. This activity replaces 'natural gas, burned in gas turbine, for compressor station' and 'natural gas, burned in gas motor, for storage', used up until version 3.8 (described in section 6.5.1).
- Import of oil and gas to selected countries in Europe and North America was updated to reflect the mode (i.e., via pipelines vs. by freight ship) and average distances from the relevant countries of production. Domestic supply with seasonal storage is in version 3.9 modelled analogously to import activities (but without the transport requirements). Imports from countries with total gas exports clearly exceeding own production have been adjusted, now providing exports over the consumption mix to better represent the role of domestic production in this situation. The import part of the gas supply chain is covered in section 6.5.4.
- The supply of crude petroleum oil has been regionalized, from a single global market activity up until 3.8. Supply mixes reflecting the situation in 2019 are provided for Switzerland, Europe without Switzerland, and the region of North America (RNA). The Rest-of-the-World (RoW) mix in 3.9 was derived as the difference between the total global production and the cumulative supply to the regional market activities.
- Regionalized supply of natural gas (at high pressure) in 3.9 cover 44 geographies. The rest-of-Europe and Rest-of-the-World (RoW) mixes in 3.9 were derived as the difference between cumulative supply to the regional market activities and the total supply to EU-28 or total global production, respectively. Almost all of the market activities in 3.9 reflect the situation in 2019 (except Austria, Brazil, and Japan), and falls into one of the following three categories:
  - Supply representing consumption mixes, based on statistics from BP (2020; as described in Bussa et al. 2022).
  - Supply representing consumption mixes, based on data on gas trade from EuroStat (2022a;b; updated internally by ecoinvent).
  - Supply representing production mixes, as only domestic production considered as input to the local market activity. This is the case for most countries of production covered by the update. In several cases, the trade statistics suggest neglectable gas imports to these markets, meaning that production ≈ consumption mix. Notable exceptions, where this does not hold true, include China, Iraq, Kuwait, and the United Arab Emirates.

The implementation of the updated supply chains in the ecoinvent database 3.9 are illustrated in Figure 3 (crude petroleum oil) and Figure 4 (natural gas), respectively. A full account of the correspondence of datasets/activities between the underlying studies by Meili et al. (2022a; b) and Bussa et al. (2022) and the implementation of this data into 3.9 is provided in section 13 Annex to 'Crude petroleum oil and natural gas supply' – activity correspondence.

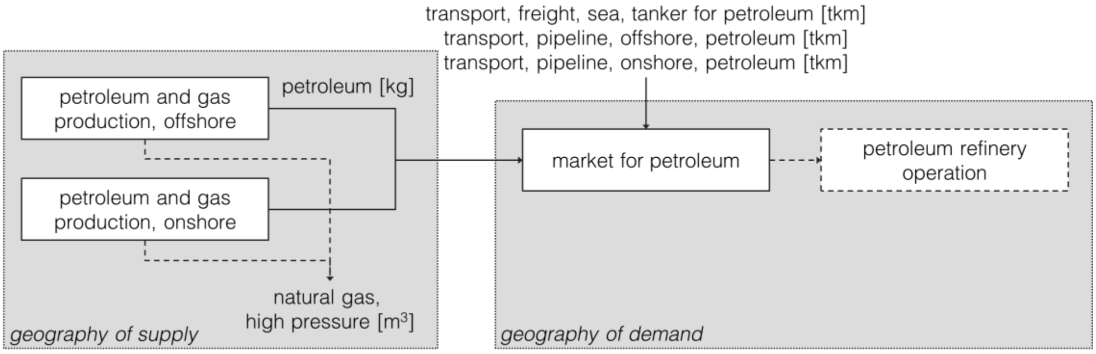

Figure 3. Schematic illustration of the supply chain modelling for crude petroleum oil in ecoinvent 3.9. Petroleum refinery operation was not updated for version 3.9, and is only included here to indicate the main downstream use for crude petroleum oil in the database.

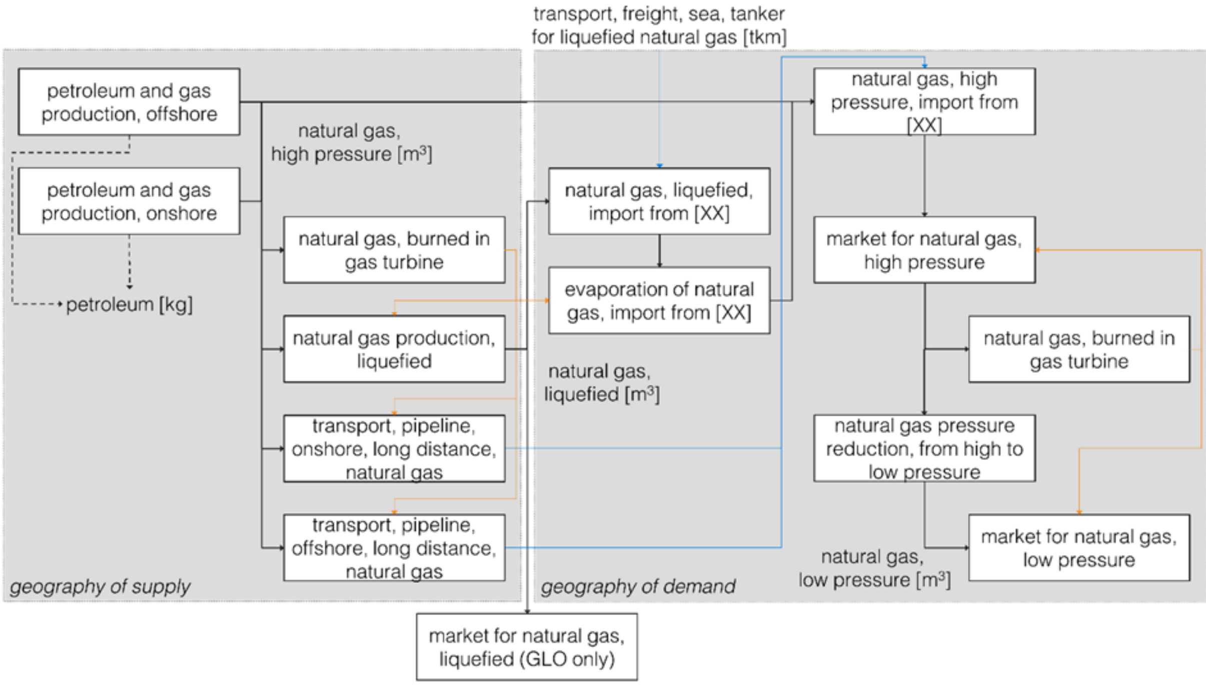

Figure 4. Schematic illustration of the main parts of the supply chain for the production, transmission (long-distance transport), and regional distribution of natural gas, as updated for ecoinvent 3.9. Solid black arrows indicate flows of natural gas, whereas orange arrows represent internal energy supply (from natural gas) and transport services are shown in blue.

6.3 Extraction of crude petroleum oil and natural gas

The new data on the extraction (i.e., production) of crude petroleum oil and natural gas in ecoinvent version 3.9 covers 27 countries (Table 36). Taken together, these countries represent approximately 90% of global production of crude oil, and nearly 80% of natural gas output. The underlying data sources and inventory modelling are described in Meili et al. (2022a). All country-specific datasets have been created using a common approach, relying extensively on global data sources to ensure a high degree of consistency between the geographies covered. As a result, the extraction of crude petroleum oil and natural gas, is modelled as average combined (i.e., associated) production of oil and gas, only distinguishing between offshore and onshore operations, for each country.

The main aspects considered for regionalisation of the extraction activities include emissions of methane (from gas venting and fugitive emission sources) and gas flaring, energy requirements, production data, and other important technical parameters. For this update, Meili et al. (2022a) relied on the latest version of key data sources, including from BP (2020), IEA (2022), IOGP (2020), and the World Bank (2022).

Table 36. New petroleum and gas extraction activities. Extraction of crude petroleum oil and natural gas is modelled as combined production activities in all geographies considered. For 24 of the 27 countries, production both offshore and onshore is provided, with Norway (NO; only offshore) and Algeria and Iraq (DZ and IQ; only onshore) as the exceptions.

Activity Name	Geography	Time Period	Product Name	Unit
petroleum and gas production, offshore	AE; AZ; BR; CA; CN; CO; DE; EC; GB; ID; IR; KW KZ; LY; MX; MY; NG; NL; NO; QA; RO; RU; SA; US; VE	2019-2022	natural gas, high pressure petroleum	m3 kg
petroleum and gas production, onshore	AE; AZ; BR; CA; CN; CO; DE; DZ; EC; GB; ID; IQ; IR; KW KZ; LY; MX; MY; NG; NL; QA; RO; RU; SA; US; VE	2019-2022	natural gas, high pressure petroleum	m3 kg

This update replaced all activities related to the production of crude oil and natural gas available up until version 3.8 of the ecoinvent database (Table 37). In most cases, the geographical scope of the new datasets is aligned with what was available in 3.8. Exceptions are production in Alberta (CA-AB; included in CA in 3.9), and Bolivia (BO), Region of Africa (RAF), Region of Middle East (RME), and the global (GLO) activities. Considering the extensive regional coverage the update introduces, no global (rest-of-the-world, RoW) producing activities exist in the calculated system models.

Table 37. Updated or replaced activities related to the extraction of crude petroleum oil and natural gas. In the column labelled v3.9, "U" indicates updated extraction activities (replaced by the corresponding activities listed in **Table 36**), whereas "D" stands for deleted activities without a direct match in v3.9.

Activity Name	Geography	Time Period	v3.9
natural gas production	CA-AB	2010-2010	D
natural gas production	DE	1996-2000	D
natural gas production	DZ; GLO	1989-2000	D
natural gas production	RU	2000-2012	D
natural gas production	US	2010-2010	D
petroleum and gas production, off-shore	BR	2018-2021	U
petroleum and gas production, off-shore	GB	1998-2000	U
petroleum and gas production, off-shore	GLO	2000-2000	D
petroleum and gas production, off-shore	NL; NO	2000-2000	U
petroleum and gas production, on-shore	BO	2018-2021	D
petroleum and gas production, on-shore	BR	2018-2021	U
petroleum and gas production, on-shore	CA-AB	1999-2000	D
petroleum and gas production, on-shore	GLO	2000-2012	D
petroleum and gas production, on-shore	NG	1999-2000	U
petroleum and gas production, on-shore	NL	2000-2012	U
petroleum and gas production, on-shore	US	1999-2000	U
petroleum production, onshore	GLO; RAF; RME; RU	2000-2000	D

The default properties for crude petroleum oil and natural gas in the ecoinvent database were adjusted to be aligned with this update (Table 38). Based on the reference properties used by BP (2020), Meili et al. (2022a) defined a net calorific value of 43.4 MJ/kg for crude oil and related products like condensates and natural gas liquids. For natural gas, the gross and net heating values were set to 40 and 36 MJ/m^3 (as standard cubic meters, measured at 15°C and 1013 mbar), respectively, with the gas density set to 0.735 kg/m^3 (Meili et al. 2022a, section 5.2.1). These default properties are applied in ecoinvent 3.9 to natural gas at high and low pressure as well for LNG. In line with the energy statistics in BP (2020), the reference properties for LNG refer to a cubic meter of natural gas under standard conditions (i.e., in gaseous state). Fossil carbon content of the three natural gas products and crude petroleum oil is based on the compositions in Bussa et al. (2022), tab. 3.1 and Meili et al. (2022) table 5.2, respectively.

Table 38. Comparison of the default properties for natural gas and crude petroleum oil (as intermediate exchanges) in the ecoinvent database versions 3.8 vs. 3.9.

Intermediate exchange	Property	Unit	Default value in 3.8	in 3.9
natural gas, high pressure [m3] natural gas, liquefied [m3] natural gas, low pressure [m3]	carbon content, fossil	dimensionless	0.602 0.746 0.695	0.741
	carbon content, non-fossil	dimensionless	0 (all)	0 (all)
	dry mass	kg	0.84 0.78 1	0.735*
	heating value, gross	MJ	-	40.0 (all)*
	heating value, net	MJ	39.0	36.0*
	water content	dimensionless	0 (all)	0 (all)
	water in wet mass	kg	0 (all)	0 (all)
	wet mass	kg	0.84 0.78 1	0.735*
petroleum [kg]	carbon content, fossil	dimensionless	0.85	0.84
	carbon content, non-fossil	dimensionless	0	0
	dry mass	kg	1	1
	heating value, net	MJ	43.2	43.4
	water content	dimensionless	0	0
	water in wet mass	kg	0	0
	wet mass	kg	1	1

* at standard conditions (15°C and 1013 mbar)

The inventories for combined crude petroleum oil and natural gas production activity are mainly sub-divided based on the net calorific values and the annual production volumes of the co-products. Methane released to the atmosphere through venting and fugitive emission of natural gas is based on the country-specific information for 2019 from IEA's *Global Methane Tracker 2022* (IEA 2022). The amounts of methane assigned to the extraction of crude oil and natural gas by IEA per country are used directly for the inventory generation. Due to the lack of reliable and consistent data for all geographies considered on the share of production from offshore and onshore, the methane emission factors are only calculated by country. Freshwater use and water discharge are allocated to crude petroleum oil only. (Meili et al. 2022a)

Besides the central production datasets listed in Table 36, several auxiliary activities were updated for 3.9 (Table 39). For onshore well drilling and oil/gas field infrastructure, the modifications consisted mainly of reduced area requirements. Furthermore, flaring and venting during exploration as well as the energy requirements to establish the wells are now included in the main production datasets, and hence not considered separately in the well production (Meili et al. 2022a, section 6.2). Similarly, total emissions of methane (CH_4), nitrogen oxides (NO_x), and sulphur dioxide (SO_2) are now accounted for in the main production activities, based on information from IEA's *Global Methane Tracker 2022* (for CH_4) and regional emission data for NO_x and SO_2 from IOGP (2020). These emissions are hence excluded from the auxiliary processes for fuel combustion and flaring (i.e., ‘diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction’, ‘sweet gas, burned in gas turbine’, and ‘treatment of waste natural gas, sweet, burned in production flare’) to avoid double-counting (Meili et al. 2022a, sections 9.2 and 9.5).

Table 39. Updated ‘auxiliary’ activities related to the extraction of crude petroleum oil and natural gas. In the column labelled v3.9, “N” stands for “New”, “U” for “Updated”, and “D” for “Deleted”.

Activity Name	Geography	Time Period	v3.9
diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction	GLO	1985-2019	N
market for diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction	GLO	1985-2022	N
offshore well production, oil/gas	GLO	1990-2019	U
onshore natural gas field infrastructure production	GLO	1989-2022	U
onshore petroleum field infrastructure construction	GLO	1990-2022	U
onshore well production, oil/gas	GLO	1990-2019	U
sweet gas, burned in gas turbine	GLO	1991-2019	U
sweet gas, burned in gas turbine	NO	1991-2000	D
treatment of waste natural gas, sweet, burned in production flare	GLO	1999-2019	U
treatment of water discharge from petroleum extraction, offshore	GLO	1980-2022	U
treatment of water discharge from petroleum extraction, onshore	GLO	1980-2022	U

The inventories for the two (global) activities representing the discharge of water generated in offshore and onshore operations were updated over 3.8, and the scope modified with respect to two aspects (following the approach described in Meili et al. 2022a, section 10.1): firstly, to enable regionalized assessment of water-related impacts, the water balance for the type of water input and reinjection and discharge of (treated) produced water is now modelled in the central production dataset at the country-level. Secondly, with data on oil spills from offshore and onshore operations available for different world regions from IOGP (2020), this emission is included directly in the inventory of crude oil production (Meili et al. 2022a, section 10.3). This means that the discharge treatment activities in Table 39 in 3.9 only encompass emissions to the environment (to the sub-compartments ocean and river, respectively) based on the chemical composition of the polluted discharged water, but neither the water output itself nor associated oil spills.

The updated modelling described in the paragraphs above is a result of better information becoming available on specific aspects of crude oil and natural gas production. It does, however, mean that the inventories of these ‘auxiliary’ processes are no longer complete nor mass-balanced (and hence should only be used when combined with production datasets which are complementary, i.e., created following the same approach). Potential solutions for re-establishing mass balances in these datasets will be evaluated for future database releases.

The combustion of sweet natural gas in Table 39 (‘sweet gas, burned in gas turbine’ and ‘treatment of waste natural gas, sweet, burned in production flare’) replaces previous version of the same activities. This is motivated by these activities being specific to oil and gas production. In contrast, the version available in 3.8 for 'diesel, burned in diesel-electric generating set, 10MW' might be applied more broadly by ecoinvent' s users. It was therefore decided to create a new activity, 'diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction', specifically for this update (based on Meili et al. 2022a).

6.4 Long-distance transport and supply of crude petroleum oil

The supply of crude petroleum oil up until version 3.8 of the ecoinvent database was modelled over a single market activity of global scope. The update for 3.9 introduces three new market activities with regional supply mixes for Switzerland, Europe without Switzerland, and the Region of North America (RNA), in Table 40.

Table 40. New and updated market activities for crude petroleum oil. In the column labelled v3.9, "N" indicates a new activity whereas "U" stands for updated activity.

Activity Name	Geography	Time Period	v3.9
market for petroleum	CH	2019-2022	N
market for petroleum	Europe without Switzerland	2019-2022	N
market for petroleum	GLO	2019-2022	U
market for petroleum	RNA	2019-2022	N

The production volumes as well as the supply mixes for Switzerland, Europe without Switzerland, the region of North America, and Global in 2019 were obtained from Meili et al. (2022a). The underlying data source for this analysis was primarily global energy statistics from BP (2020). To avoid geographical overlaps in the implementation for the ecoinvent database, the global supply situation had to be converted into the corresponding market shares for the Rest-of-the-World (RoW; i.e., GLO without RER, RNA) geography. The RoW mix was derived from the information in Meili et al. (2022a) as the difference between supply to the global geography and the sum of the region-specific markets (Table 41). The resulting supply situation in 2019, as implemented in ecoinvent version 3.9, is illustrated in Figure 5.

Table 41. Overview of demand and supply of crude petroleum oil in 2019, as implemented in ecoinvent 3.9. The production volumes as well as the supply mixes for Switzerland, Europe without Switzerland, the region of North America, and Global were obtained from Meili et al. (2022a), based on BP (2020). The market shares for the Rest-of-the-world (i.e., GLO without RER, RNA; in *italics*) were derived as the difference between supply to the global and the sum of the region-specific markets.

	Region of demand market for petroleum				
Country of production	**Switzerland**	**Europe without Switzerland**	**Region of North America**	**Global mix**	***Rest-of-the-World***
	Meili et al. (2022b)				***calc for 3.9***
United Arab Emirates, AE	0.0%	0.0%	0.0%	4.4%	*7.6%*
Azerbaijan, AZ	0.1%	2.9%	0.0%	0.9%	*0.8%*
Brazil, BR	0.0%	1.0%	1.8%	3.7%	*5.3%*
Canada, CA	0.0%	0.6%	24.6%	6.8%	*0.1%*
China, CN	0.0%	0.0%	0.0%	4.7%	*8.1%*
Colombia, CO	0.0%	0.3%	0.5%	1.1%	*1.6%*
Germany, DE	0.0%	0.4%	0.0%	0.1%	*0.0%*
Algeria, DZ	3.3%	3.7%	0.2%	1.6%	*1.7%*
Ecuador, EC	0.0%	0.2%	0.3%	0.7%	*1.0%*
United Kingdom, GB	0.0%	7.1%	0.2%	1.3%	*0.3%*
Indonesia, ID	0.0%	0.0%	0.1%	0.9%	*1.6%*
Iraq, IQ	0.0%	9.1%	1.5%	5.8%	*6.9%*
Iran, IR	0.0%	0.4%	0.0%	4.0%	*6.7%*
Kuwait, KW	0.0%	0.8%	0.2%	3.5%	*5.8%*
Kazakhstan, KZ	28.7%	7.0%	0.1%	2.3%	*2.0%*
Libya, LY	22.3%	3.3%	0.1%	1.4%	*1.5%*
Mexico, MX	0.0%	1.7%	6.1%	2.3%	*0.7%*
Malaysia, MY	0.0%	0.0%	0.0%	0.7%	*1.2%*
Nigeria, NG	34.2%	10.7%	1.4%	2.5%	*0.9%*
Netherlands, NL	0.0%	0.2%	0.0%	0.0%	*0.0%*
Norway, NO	0.0%	10.7%	0.3%	1.9%	*0.4%*
Qatar, QA	0.0%	0.2%	0.0%	1.9%	*3.3%*
Romania, RO	0.0%	0.5%	0.0%	0.1%	*0.0%*
Russian Federation, RU	1.1%	25.1%	0.7%	14.0%	*17.3%*
Saudi Arabia, SA	0.0%	6.5%	2.8%	13.7%	*20.6%*
United States of America, US	10.5%	7.5%	58.3%	18.4%	*2.8%*
Venezuela, VE	0.0%	0.3%	0.5%	1.1%	*1.6%*
Total	**100%**	**100%**	**100%**	**100%**	***100%***
Supply in 2019, as covered by update [kg]	**2.7E+09**	**6.1E+11**	**1.1E+12**	**4.1E+12**	***2.4E+12***
Share of consumption covered by update	**100%**	**93%**	**100%**	**91%**	***86%***

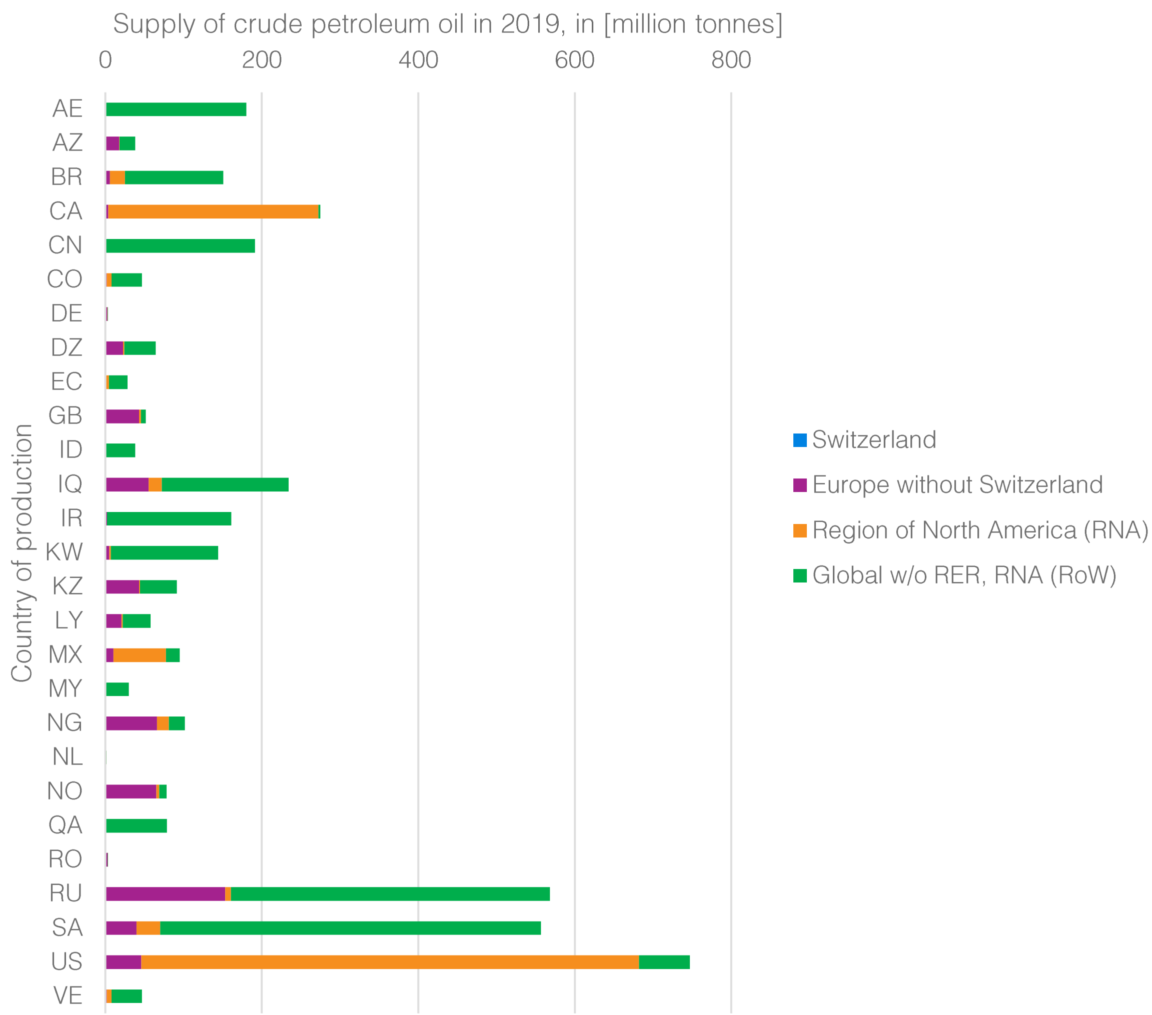

Figure 5. Overview of supply situation for crude petroleum oil in 2019, as implemented in ecoinvent version 3.9. The country of production is indicated on the vertical axis, and the receiving regions ('market for petroleum') on the horizontal axis

The activities for long-distance transport of petroleum, via pipelines or transoceanic tanker ship, were not updated compared to version 3.8.

Supply of crude oil to petroleum refineries in Brazil was updated within the Cornerstone project for version 3.8 of the ecoinvent database (Valebona et al. 2020). Based on the situation in 2018, nearly 94% of the petroleum input was linked directly to domestic production. These activity links were updated, without any quantitative changed, to point to the new production activities in 3.9. The activities concerned are listed in Table 42.

Table 42. Updated activities related to petroleum refinery operations in Brazil (BR). Only the linking to supply (input) of crude petroleum oil from domestic production was updated ("U"), the rest of the inventory is unchanged compared to 3.8.

Activity Name	Geography	Time Period	v3.9
base oil production, petroleum refinery operation	BR	2014-2017	U
C3 hydrocarbon production, mixture, petroleum refinery operation	BR	2014-2017	U
diesel production, low-sulfur, petroleum refinery operation	BR	2014-2017	U
diesel production, petroleum refinery operation	BR	2014-2017	U
heavy fuel oil production, petroleum refinery operation	BR	2014-2017	U
hydrogen production, gaseous, petroleum refinery operation	BR	2014-2017	U
kerosene production, petroleum refinery operation	BR	2014-2017	U
light fuel oil production, petroleum refinery operation	BR	2014-2017	U
liquefied petroleum gas production, petroleum refinery operation	BR	2014-2017	U
naphtha production, petroleum refinery operation	BR	2014-2017	U
petrol production, unleaded, petroleum refinery operation	BR	2014-2017	U
petroleum slack wax production, petroleum refinery operation	BR	2014-2017	U
pitch production, petroleum refinery operation	BR	2014-2017	U
refinery gas production, petroleum refinery operation	BR	2014-2017	U
reformate production, petroleum refinery operation	BR	2014-2017	U
sulfur production, petroleum refinery operation	BR	2014-2017	U
white spirit production, petroleum refinery operation	BR	2014-2017	U

6.5 Long-distance transport and regional distribution of natural gas

6.5.1 Internal energy supply from gas: natural gas, burned in gas turbine

As described in Bussa et al. (2022, section 4.2.2), this update includes a single activity 'natural gas, burned in gas turbine' used for all situations in which natural gas from internal supply is used to cover the energy requirements in the transmission and distribution of the gas. The inventories in the country- or regional-specific datasets created for the update (Table 43) differ only in the source of natural gas input but are otherwise identical. The activity 'natural gas, burned in gas turbine' replaces the three different datasets related to natural gas 'burned in' ('[…], in gas turbine', '[…], in gas turbine, for compressor station', and '[…], in gas motor for storage') from previous studies by Schori and Frischknecht (2012) and Faist Emmenegger et al. (2007).

Table 43. New and replaced (deleted) activities for internal energy supply from natural gas. In the column labelled v3.9, "N" indicates a new activity whereas "U" stands for updated activity, and "D" indicates "deleted" activities).

Activity Name	Geography	Time Period	v3.9
market for natural gas, burned in gas motor, for storage	GLO	2011-2011	D
market for natural gas, burned in gas turbine	GLO	2000-2022	N
natural gas, burned in gas motor, for storage	DE; DZ; GLO; NL; NO; RU	1990-2000	D
natural gas, burned in gas turbine	AE; AZ; BE; BR; CA; CH; CN; CO; DE; DZ; EC; ES; FR; GB; GLO; ID; IQ; IR; IT; KW; KZ; LY; MX; MY; NG; NL; NO; QA; RoE; RO; RU; SA; TR; US; VE	2000-2022	N
natural gas, burned in gas turbine, for compressor station	DE; DZ; NL; NO; RU	1990-2000	D
	CA-AB; CA-QC; GLO	2010-2010	D

6.5.2 Long-distance pipeline transport

The activities for long-distance transport (transmission) of natural gas in offshore and onshore pipelines have been updated and the geographical scope expanded for 3.9. Onshore pipeline transport is modelled for all geographies covered by the update, whereas offshore pipeline transport is only provided for countries where it was considered relevant (Table 44). The corresponding market activities for long-distance transport offshore/onshore in RER and GLO are deleted, as the country-specific inputs of these transport requirements are modelled with direct activity links. The update only encompasses the transport activities, the construction of pipeline infrastructure remains unchanged compared to version 3.8.

Table 44. New, updated, and replaced activities for long-distance transport of natural gas by pipeline. In the column labelled v3.9, "N" indicates a new activity, "U" stands for updated, and "D" for "deleted".

Activity Name	Geography	Time Period	v3.9
market for transport, pipeline, offshore, long distance, natural gas	RER	2011-2011	D
market for transport, pipeline, onshore, long distance, natural gas	RER	2011-2011	D
transport, pipeline, long distance, natural gas	DE; NL; RER without DE+NL+RU; RU	2000-2012	U
	GLO	1994-2000	U
transport, pipeline, offshore, long distance, natural gas	DZ; NO	2019-2022	U
	GB; ID; IR; LY, MY; NL; QA; RU; US	2019-2022	N
	GLO	2000-2012	D
transport, pipeline, onshore, long distance, natural gas	DZ; NO	2019-2022	U
	AE; AZ; BR; CA; CN; CO; DE; EC; GB; ID; IQ; IR; KW; KZ; LY; MX; MY; NG; NL; QA; RO; RU; SA; US; VE	2019-2022	N
	GLO	2000-2012	D

The inventory modelling of the updated pipeline transport activities, described in section 4.2.2 of Bussa et al. (2022) relies on several important assumptions. They are summarized here for easy point of reference: firstly, Bussa et al. derived energy use factors (in % of gas per 1'000 km transport) for Europe and North America (0.9%/1'000km) and for countries in other world regions[4] (2.2%/1'000km), respectively, from literature. Similarly, the set of leakage rates from Faist-Emmenegger et al. (2015; 2017) was applied, with a lower rate (0.019%/1'000km) for Europe and North America, and a higher rate (0.204%/1'000km) for other world regions. Furthermore, the authors assumed the refrigerant emissions and the amount of condensate generated to be equal in all areas. It was also assumed that energy requirements and emissions for offshore pipeline transport is the same as in onshore pipelines for each geography.

The activity 'transport, pipeline, long distance, natural gas' was not part of the update for 3.9. And while it is no longer needed to model gas supply to the country-specific consumption mixes provided by Bussa et al. (2022), this transport process is still used in the 'market for natural gas, high pressure' in other geographies established by Faist-Emmenegger et al. (2017). These markets were only updated for 3.9 with respect to the gas supply (input), to reflect the situation in 2019 (described further in section below), but remain unchanged otherwise. The energy requirements for 'transport, pipeline, long distance, natural gas' was up until version 3.8 supplied by 'natural gas, burned in gas turbine, for compressor station', which has been replaced by 'natural gas, burned in gas turbine' for 3.9 (*cf.* section 6.5.1). As the reference products for these two 'natural gas, burned in […]' activities differ, the values from tab. 7.14-7.15 in Faist Emmengger et al. (2007) were reintroduced for 3.9 to reflect that 'natural gas, burned in gas turbine' refers to the fuel input (rather than the output of electricity). In addition, these amounts were corrected for the difference in net calorific values (NCV; v2: 36.3 vs. v3.9: 36.0 MJ/m^3) applied in the modelling of the combustion datasets.

6.5.3 Production and transport of liquefied natural gas

The share of liquefied natural gas (LNG) in inter-regional trade of natural gas has increased steadily over the past decades, and it equalled the volume exported in pipelines around 2019-2020 (BP 2022). Up until version 3.8, the production of LNG was limited to the geographies Algeria (DZ) and the Region of Middle East (RME) in the ecoinvent database. The update for 3.9 includes nine major LNG-exporting countries (Table 45). These country-specific datasets were created based on a common default inventory and differ only in the sources of the natural gas input and process energy (from natural gas) but are otherwise identical. Data on energy use for the liquefaction stem from a review of common technologies from 2019, whereas the leakage rate and rest of the inventory relies on older sources.

[4] Regions of Africa, Asia, Latin America, and the Middle East.

Table 45. New, updated, and replaced activities for the production and supply of liquified natural gas. In the column labelled v3.9, "N" indicates a new activity, "U" stands for updated, and "D" for "deleted" or otherwise replaced activities.

Activity Name	Geography	Time Period	v3.9
natural gas production, liquefied	DZ	2019-2022	U
natural gas production, liquefied	AE; ID; MY; NG; NO; QA; RU; US	2019-2022	N
natural gas production, liquefied	GLO; RME	2012-2012	D
market for natural gas, liquefied	GLO	2011-2011	U
natural gas, liquefied, import from AE	GLO	2000-2022	N
natural gas, liquefied, import from DZ	Europe without Switzerland; GLO	2000-2022	N
natural gas, liquefied, import from ID	GLO; RNA	2000-2022	N
natural gas, liquefied, import from MY	GLO	2000-2022	N
natural gas, liquefied, import from NG	Europe without Switzerland; GLO; RNA	2000-2022	N
natural gas, liquefied, import from NO	Europe without Switzerland; GLO	2000-2022	N
natural gas, liquefied, import from QA	Europe without Switzerland; GLO	2000-2022	N
natural gas, liquefied, import from RU	Europe without Switzerland; GLO	2000-2022	N
natural gas, liquefied, import from US	Europe without Switzerland; GLO; RNA	2000-2022	N
evaporation of natural gas	GLO	2012-2012	D
evaporation of natural gas	RER	2001-2001	D
evaporation of natural gas, import from AE	GLO	2000-2022	N
evaporation of natural gas, import from DZ	Europe without Switzerland; GLO	2000-2022	N
evaporation of natural gas, import from ID	GLO; RNA	2000-2022	N
evaporation of natural gas, import from MY	GLO	2000-2022	N
evaporation of natural gas, import from NG	Europe without Switzerland; GLO; RNA	2000-2022	N
evaporation of natural gas, import from NO	Europe without Switzerland; GLO	2000—2022	N
evaporation of natural gas, import from QA	Europe without Switzerland; GLO	2000-2022	N
evaporation of natural gas, import from RU	Europe without Switzerland; GLO	2000-2022	N
evaporation of natural gas, import from US	Europe without Switzerland; GLO; RNA	2000-2022	N

The import activities for LNG listed in Table 45 connect the nine exporting countries with the world regions RER and RNA (as relevant for the consumption mixes provided by Bussa et al. 2022 and included in this update) and to the generic global market for LNG. Besides the input of LNG, the import activities only add the average transport requirements (by freight ship). For this input, the implementation in the ecoinvent database differs from the study by Bussa et al. 2022. The activity for 'transport, freight, sea, tanker for liquefied natural gas' available in ecoinvent was created during the *SRI_transport* project (Notten et al. 2018). This inventory does not consider dual inputs of fuel oil and natural gas to the ship engines explicitly, and the respective emission profiles in the inventories differ pronouncedly. As a consequence, LNG transport in tanker ship should either be revised as part of a larger update of the transport sector in the ecoinvent, or get replaced by the inventories from Bussa et al., in a subsequent release of the database.

The shares of the global market for LNG are based on total country exports of LNG for 2019 (in metric cubic meters, from BP 2022), and scaled to 100% for the producing countries available in the database (approx. 65% of global production). This market hence does not represent a 'rest-of-the-world' mix (i.e., after country- or region-specific supply has been subtracted). This was motivated by the lack of country- or region-specific market activities for LNG in the update, as the chains of gas liquefaction, import, and evaporation are modelled directly for the relevant combinations of origin and destination.

6.5.4 Imports, supply, and regional distribution of natural gas

Natural gas exchanged between supplying and receiving geographies are connected over import activities. The two main modes for this transfer are via pipelines or as liquefied natural gas (LNG), as described in the preceding sections of this chapter. All imports of natural gas in version 3.8 were modelled by directly connecting the demanding market activities to the corresponding production activities. This supply chain structure is generally maintained in the update for version 3.9, following the modelling approach described in section 4.4 of Bussa et al. (2022). Exceptions from the import linking found in 3.8, related to the import of natural gas to Switzerland and from countries with little to no own production, are described at the end of the section.

The activities 'natural gas, high pressure, import from [XX]' in ecoinvent 3.9 correspond to the datasets 'natural gas, production [XX], at long-distance pipeline' in Bussa et al., where 'XX' is the two-letter country code for the geography where the gas was produced. The geography of the import activity refers to the country receiving the gas. Within this step, the share of gas supplied via pipeline (with the corresponding input of long-distance transport, section 6.5.2) is combined with the share from LNG (for which the import and evaporation steps in RER, RNA or GLO are modelled separately; see section 6.5.3) for each combination of exporting and importing geographies. The new import activities based on the work of Bussa et al. (2022) are listed in Table 46.

Table 46. New import activities for natural gas from Bussa et al. (2022). In the column labelled v3.9, "N" indicates a new activity whereas "U" stands for updated activity and "D" for "deleted" activities.

Activity Name	Geography	Time Period	v3.9
natural gas, high pressure, domestic supply with seasonal storage	CA; DE; GB; MX; NL; US	2000-2022	N
natural gas, high pressure, import from AE	GLO	2000-2022	N
natural gas, high pressure, import from AZ	GLO; TR	2000-2022	N
natural gas, high pressure, import from BR	GLO	2000-2022	N
natural gas, high pressure, import from CA	GLO; US	2000-2022	N
natural gas, high pressure, import from CN	GLO	2000-2022	N
natural gas, high pressure, import from CO	GLO	2000-2022	N
natural gas, high pressure, import from DE	GLO; RER without AT, CH, DE, DK, PL	2000-2022	N
natural gas, high pressure, import from DZ	ES; FR; GB; GLO; IT; RER without CH, ES, FR, BR, IT, NL; TR	2000-2022	N
natural gas, high pressure, import from EC	GLO	2000-2022	N
natural gas, high pressure, import from GB	GLO; RER without BE, CH, DK, GB, IE, NL	2000-2022	N
natural gas, high pressure, import from ID	GLO; MX	2000-2022	N

Activity Name	Geography	Time Period	v3.9
natural gas, high pressure, import from IQ	GLO	2000-2022	N
natural gas, high pressure, import from IR	GLO; TR	2000-2022	N
natural gas, high pressure, import from KW	GLO	2000-2022	N
natural gas, high pressure, import from KZ	GLO	2000-2022	N
natural gas, high pressure, import from LY	GLO; IT; RER without CH, IT	2000-2022	N
natural gas, high pressure, import from MX	GLO; US	2000-2022	N
natural gas, high pressure, import from MY	GLO	2000-2022	N
natural gas, high pressure, import from NG	ES; FR; GB; GLO; IT; MX; RER without CH, ES, FR, GB, IT; TR; US	2000-2022	N
natural gas, high pressure, import from NL	BE; DE; FR; GB; GLO; IT; RER without BE, CH, DE, FR, GB, IT, NL	2000-2022	N
natural gas, high pressure, import from NO	BE; DE; ES; FR; GB; GLO; IT; NL; RoE; TR	2000-2022	N
natural gas, high pressure, import from QA	BE; ES; FR; GB; GLO; IT; RER without BE, CH, ES, FR, GB, IT; TR	2000-2022	N
natural gas, high pressure, import from RO	Europe without Switzerland; GLO	2000-2022	N
natural gas, high pressure, import from RU	BE; DE; ES; FR; GB; GLO; IT; NL; RoE; TR	2000-2022	N
natural gas, high pressure, import from SA	GLO	2000-2022	N
natural gas, high pressure, import from US	BE; CA; ES; FR; GB; GLO; IT; MX; RER without BE, CH, ES, FR, GB, IT; TR	2000-2022	N
natural gas, high pressure, import from VE	GLO	2000-2022	N

The supply of natural gas to Switzerland (CH) in version 3.8 was modelled over import activities connecting the market activity in CH to production activities in relevant geographies in a single step. In contrast, Bussa et al. (2022; section 2.2) used the shares of gas imported from four surrounding (adjacent or nearby, in the case of NL) countries. The gas inputs were taken directly from the consumption mixes (referred to as ''natural gas, at long-distance pipeline') in the respective countries, and hence only indirectly linked to the sources of production. The authors did not consider any additional efforts for this step as the requirements and emissions arising during seasonal storage and long-distance transport were accounted for in the (import) datasets supplying the first mix. For the implementation in ecoinvent version 3.9, this linking approach was replicated by inserting import activities that connect the market activity in the receiving geography (e.g., to CH) with the corresponding market activity in the supplying location (e.g., from FR). Only the transfer of one cubic meter of natural gas at high pressure from one geography to another is considered in this process. The new or updated import activities following this approach are listed in Table 47.

According to Eurostat (2022a), the export from Germany (DE) to the EU-28 region amounted to 10.7 billion cubic meters in 2019. This export exceeded domestic production in the same period (in the range of 5.3 to 6.0 billion cubic meters based on the information in Eurostat 2022b and BP 2020). The net export must consequently have been supplied from imports or change in stocks. With the bulk of domestic production already accounted for in the consumption mix for DE by Bussa et al. (2022), it was assumed that also AT, DK, and PL (alongside CH) receive supply from Germany over the market activity for natural gas at high pressure in DE. The same approach was applied for further cases listed in Table 47 with neglectable own production, namely for supply from Belgium (BE) and Finland (FI) to Sweden (SE), and from Turkey (TR) to Greece (GR).

Table 47. New, updated, and deleted/replaced import activities for natural gas. In the column labelled v3.9, “N” indicates a new activity whereas “U” stands for updated activity, and “D” indicates “deleted” activities.

Activity Name	Geography	Time Period	v3.9
natural gas, high pressure, import from BE	SE	2000-2022	N
natural gas, high pressure, import from BO	BR; GLO	2018-2021	D
natural gas, high pressure, import from CA-AB	CA-QC; GLO	2010-2010	D
natural gas, high pressure, import from DE	AT; CH; DK; PL	2000-2022	U
natural gas, high pressure, import from DZ	CH; GR; NL; PL	2012-2012	D
natural gas, high pressure, import from FI	SE	2000-2022	N
natural gas, high pressure, import from FR	CH	2000-2022	N
natural gas, high pressure, import from GB	BE; CH; DK; IE; NL	2012-2012	D
natural gas, high pressure, import from IT	CH	2000--2022	N
natural gas, high pressure, import from NL	AT; DK; PL	2012-2012	D
natural gas, high pressure, import from NL	CH	2000-2022	U
natural gas, high pressure, import from NO	AT; CH; CZ; DK; PL; SE	2012-2012	D
natural gas, high pressure, import from TR	GR	2000-2022	N
natural gas, high pressure, import from RU	AT; CH; CZ; DK; FI; GR; HU; PL; SK	2012-2012	D

The full overview of the market activities for natural gas (at high- and low-pressure levels) included in 3.9 is provided in Table 48. Bussa et al. (2022) provide country-specific consumption mixes and regional distribution efforts for twelve geographies (BE, CA, CH, DE, ES, FR, GB, IT, MX, NL, TR, and US), as well as the regional mixes for RER and RNA, and the global (GLO) supply situation in 2019 based on BP (2020). For the integration into ecoinvent v3.9, these mixes (in ‘natural gas, at long-distance pipeline’, in [Nm3]) and regional distribution inventories (‘natural gas, high pressure, at consumer’, in [MJ]; scaled to [m3]) from Bussa et al. were combined into the corresponding ‘market for natural gas, high pressure’ (in [m3]). For the other producing countries (21 geographies) included in the submission, market activities for ‘natural gas, high pressure’ were created based on the dataset ‘natural gas, high pressure, at consumer’ for GLO provided Bussa et al. Most of these countries are net-exporters of natural gas, with some exceptions, e.g., Brazil (BR), China (CN), and the United Arab Emirates (AE). For this first implementation, it was decided to disregard any imports for these market activities. These market activities consequently represent domestic supply (‘production mixes’) only.

Version 3.8 of the ecoinvent database included fifteen[5] additional country-specific markets for natural gas at high pressure, not available from Bussa et al. (2022). Of these, Brazil (BR), Algeria (DZ), Norway (NO), Romania (RO), and Russia (RU) were updated as described above for the new producing geographies. While imports from other countries

[5] AT; BR; CZ; DK; DZ; FI; GR; HU; IE; NO; PL; RO; RU; SE; SK

were neglected for DZ, NO, and RU, the market activities for BR and RO receive inputs from other geographies. The inputs to the market in RO were updated with supplementary information of gas trade within Europe from Eurostat, as described below. The supply situation for natural gas in Brazil (in 2018) was updated within the Cornerstone project for version 3.8 of the ecoinvent database (Valebona et al. 2020). The market shares were not updated for 3.9, but the omission of production in Bolivia (BO) in 3.9 meant that a different geography (Colombia, CO) had to be used as a proxy for this input.

Table 48. New and updated market activities for natural gas, high/low pressure. In the column labelled v3.9, "N" "N" stands for "new", "U" for "updated", and "D" for "deleted".

Activity Name	Geography	Time Period	v3.9
market for natural gas, high pressure	BE; CH; DE; ES; FR; GB; GLO; IT; NL; US	2019-2022	U[1]
market for natural gas, high pressure	CA; MX; RoE; TR	2019-2022	N[1]
market for natural gas, high pressure	AE; AZ; CN; CO; EC; ID; IQ; IR; KW; KZ; LY; MY; NG; QA; RO; SA; TR; VE	2019-2022	N[2]
market for natural gas, high pressure	DZ; NO; RU	2019-2022	U[2]
market for natural gas, high pressure	CZ; DK; FI; GR; HU; IE; PL; SE; SK	2000-2000	U[3]
market for natural gas, high pressure	AT	1997-2000	U[4]
market for natural gas, high pressure	BR	2019-2022	U[4]
market for natural gas, high pressure	JP	2000-2005	U[4]
market for natural gas, high pressure	CA-AB; CA-QC	2010-2010	D
market for natural gas, low pressure	CH; GLO	2019-2022	U[1]
market for natural gas, low pressure	BE; CA; DE; ES; FR; GB; IT; MX; NL; RoE; TR; US	2000-2022	N[1]
natural gas pressure reduction, from high to low pressure	CH; GLO	2010-2010	U[1]
natural gas pressure reduction, from high to low pressure	BE; CA; DE; ES; FR; GB; IT; MX; NL; RoE; TR; US	2010-2010	N
market group for natural gas, high pressure	Europe without Switzerland; GLO	2015-2022	U
market group for natural gas, high pressure	CA	2015-2015	D

[1] based on country-specific inventory, or derived from dataset for RER, in Bussa et al. (2022)
[2] distribution efforts from GLO inventory in Bussa et al. (2022)
[3] only market shares, production volumes, and loss rate updated over v3.8
[4] only production volumes and loss rate updated over v3.8

The remaining market activities for natural gas at high pressure were introduced for version 3.4 (Faist Emmenegger et al. 2017). For 3.9, it was decided to only update the supply (input mix) to these markets and to adjust the market volume to reflect the situation in 2019 for better consistency with those of the countries provided in Bussa et al. (2022). Furthermore, the default loss rate used by Bussa et al. for distribution in high-pressure networks (0.10%), which was based on reported methane emissions for the Swiss distribution network in 2018, was applied also to these market activities. The rest of the inventories (i.e., energy requirements, transport and infrastructure inputs, and emission factors) were not updated compared to 3.8.

The country-specific market activities available in the ecoinvent database within the Region of Europe (RER) represent nearly 90% of European gas consumption in 2019 (based on BP 2020). The countries provided in Bussa et al. (2022), i.e., BE, CH, DE, ES, FR, GB, IT, and NL, made up 78%, whereas the other market activities available in the database within the RER geography combined to 17%. The remaining supply mix ('Rest-of-RER') was derived by first combining the information provided in tables 2.1 and 2.6 in Bussa et al. to calculate the difference between the total input to the EU-28 and the country-specific datasets provided in that report. In a second step, the combined supply to the other country-specific was subtracted from the residual from the first step. The resulting shares for the 'Rest of RER' are shown in Table 49. Further work is needed to reconcile the gas statistics available for Europe from various sources, to improve the representation of the country- and region-specific supply situation. The supply mix for the residual 'Rest of RER' geography in 2019 implemented in 3.9 should only be considered a first approximation associated with large uncertainties.

Table 49. Overview of demand and supply of natural gas in Europe without Switzerland in 2019, as implemented in ecoinvent 3.9. The EU supply mix in Bussa et al. (2022) was based on BP (2020). The market shares in the parts of Europe without a country-specific market activity were derived as the difference between the supply to RER (in Bussa et al.) and the combined consumption of the individual markets covered in the in the database.

	Region of demand, market for natural gas, high pressure			
	EU supply mix in 2019	**BE, DE, ES, FR, GB, IT, NL**	**AT, CZ, DK, FI, GR, HU, IE, PL, SE, SK**	***Rest of RER***
Country of production	**(Bussa et al.)**	**(Bussa et al.)**	**internal update (based on Eurostat 2022)**	***calculated for 3.9***
Russian Federation, RU	39.4%	29.0%	68.1%	57.2%
Norway, NO	23.7%	30.6%	3.6%	4.4%
United Kingdom, GB	8.2%	10.5%	3.5%	0.0%
Algeria, DZ	6.4%	8.5%	0.7%	1.2%
Qatar, QA	6.1%	7.2%	3.4%	1.8%
Netherlands, NL	5.8%	5.6%	0.7%	16.4%
United States of America, US	3.5%	3.3%	1.4%	9.0%
Nigeria, NG	2.7%	2.3%	0.5%	10.0%
Romania, RO	2.0%	0.0%	12.1%	0.0%
Libya, LY	1.1%	1.6%	0%	*0.0%*
Germany, DE	1.1%	1.2%	6%	*0.0%*
Total	**100%**	**100%**	**100%**	***100%***
Supply in 2019, as covered by submission [billion m³]	**442**	**327**	**82**	***33****
Share of total supply covered by submission	**94%**	**88%** (71-98%)	**100%**	*****

* The remaining (unassigned) supply exceeds consumption in Rest of RER, potentially due to re-exports and inconsistencies between the data sources consulted.

The RoW mix was derived, analogously to petroleum, as the difference between supply to the global geography and the sum of the country-specific market activities covered in version 3.9 (Table 50). The alignment between supply and demand covered by the submission is high (97% of consumption). As a result, the RoW mix that can be generated from these 27 producing countries only represents 33% of the remaining gas consumption worldwide. In the future, further countries of production should be added to increase the coverage and representativeness of global gas supply, e.g., from Australia, Egypt, Turkmenistan, Oman, Trinidad and Tobago, and Uzbekistan.

Table 50. Overview of global demand and supply of natural gas in 2019, as implemented in ecoinvent 3.9. The global mix in Bussa et al. (2022) was based on BP (2020). The market shares for the Rest-of-the-world (RoW; in italics) were derived as the difference between supply to the global mix and the sum of the region-specific markets.

	Region of demand, market for natural gas, high pressure		
Country of production	**Sum of country-specific supply in 3.9**	**Global supply mix (Bussa et al.)**	***Rest-of-the-World calculated for 3.9***
United Arab Emirates, AE	2.2%	1.9%	*0.0%*
Azerbaijan, AZ	0.7%	0.8%	*1.1%*
Brazil, BR	0.9%	0.8%	*0.0%*
Canada, CA	5.8%	5.4%	*1.8%*
China, CN	6.1%	5.5%	*0.0%*
Colombia, CO	0.4%	0.4%	*0.0%*
Germany, DE	0.2%	0.2%	*0.0%*
Algeria, DZ	2.8%	2.7%	*1.9%*
Ecuador, EC	0.0%	0.0%	*0.0%*
United Kingdom, GB	1.3%	1.2%	*0.0%*
Indonesia, ID	1.5%	2.1%	*7.9%*
Iraq, IQ	0.4%	0.3%	*0.0%*
Iran, IR	7.8%	7.6%	*6.2%*
Kuwait, KW	0.6%	0.6%	*0.0%*
Kazakhstan, KZ	0.6%	0.7%	*2.3%*
Libya, LY	0.4%	0.3%	*0.0%*
Mexico, MX	1.2%	1.1%	*0.0%*
Malaysia, MY	1.6%	2.5%	*11.4%*
Nigeria, NG	1.2%	1.5%	*4.7%*
Netherlands, NL	0.9%	0.9%	*0.3%*
Norway, NO	3.8%	3.6%	*1.1%*
Qatar, QA	2.5%	5.5%	*31.7%*
Romania, RO	0.3%	0.3%	*0.0%*
Russian Federation, RU	22.1%	21.1%	*12.0%*
Saudi Arabia, SA	3.8%	3.5%	*0.8%*
United States of America, US	30.0%	28.7%	*16.6%*
Venezuela, VE	0.9%	0.8%	*0.2%*
Total	**100%**	**100%**	***100%***
Supply in 2019, as covered by submission [m^3]	**2.9E+12**	**3.2E+12**	***3.0E+11***
Share of total consumption covered by submission	**97%**	**82%**	***33%***

6.6 Life cycle impact assessment results

The aim of this section is to provide an overview of the changes in life cycle impact assessment (LCIA) scores for the supply of crude petroleum oil and natural gas in the ecoinvent database version 3.9. The comparison is made against version 3.8, released in 2021, and it encompasses all EF 3.0 recommended methods to cover a broad range of indicators. The focus of this analysis is primarily placed on the results of the attributional 'allocation, cut-off by classification' system model. A summary of the impact categories for which larger differences in the results were obtained in the 'substitution, consequential, long-term' system model (compared to 'allocation, cut-off by classification') is provided at the end, in section 6.6.3.

6.6.1 Crude petroleum oil supply

The score comparison for the three new regional markets for petroleum in 3.9 (i.e., for Switzerland, Europe without Switzerland, and the Region of North America) as well as for Rest-of-the-World against the corresponding global market activity in 3.8 is provided in Figure 6. The discussion below focuses on the indicators that display either a pronounced increase or decrease in relative scores across all geographies.

The relative increases in contribution to climate change (based on GWP 100a, total) are mainly driven by venting and flaring of natural gas during oil extraction. With onshore production in Nigeria (NG) as the sole exception, the climate footprint of production has increased across all comparable geographies with this update. The scores of the new markets for petroleum in Europe without Switzerland, Region of North America (RNA), and Rest-of-the-World (RoW) increased 134-172% over that of the global market for petroleum in 3.8. The supply of petroleum to Switzerland in 3.9 stands out, with three-fold score increase. This is explained by the share of supply from Libya (22%) in 2019, for which production is associated with a high climate footprint of approximately 1.7 kg CO_2-eq. per kg crude oil.

The freshwater ecotoxicity impacts of the market activities (+21-104% over 3.8) see the largest contributions from supply from onshore production, which in turn are driven by the input of extraction well and water discharged in these activities. The emission inventory for water discharge ('treatment of water discharge from petroleum/natural gas extraction, onshore') has been updated for 3.9, as described in Meili et al. 2021, section 10.1.5. With this update, the specific impact (per kg water discharged to surface water) has increased by 50%, due mainly to a higher amount of chloride to surface water. The treatment of the drilling waste is responsible for about 90% of the impact of the onshore well production, which is essential unchanged since version 3.8. Instead, the overall results reflect the sensitivity of specific input of onshore well into the production activities. The onshore production of crude petroleum oil in the US has one of the highest inputs of well among the production activities covered in in this update, which explains the difference observed in Figure 6 between the market in RNA compared to CH, Europe without Switzerland, and the RoW for this indicator.

The main process contributions for the impact on freshwater eutrophication stem from the oil supply as well as the inputs of 'transport, pipeline, onshore, petroleum'. Pipeline transport was not considered in the global market activity in version 3.8. The contribution of the production activities is dominated by the supply of electricity and infrastructure requirements. The underlying driver for these results can be traced back, over electricity generation and steel production, to the mining of lignite and hard coal.

The results for **human toxicity**, both as cancerogenic (+77-108%) and non-cancerogenic (+67-91%) comparative toxic units for humans (CTUh), are sensitive to the input of infrastructure in petroleum production: the cancerogenic-related impacts are primarily induced through the extraction well and other infrastructure requirements (e.g., pipelines), which are in turn driven by steel production (e.g., due to emissions of benzo(a)pyrene in coking) and landfarming of drilling waste. The non-cancerogenic impact category is strongly influence by the water discharge in production (due to emissions of 'Barium II' to ocean for offshore, and by 'Chloride' and 'Barium II' to surface water for onshore), and by direct emissions from energy supply from sweet gas burned in gas turbine and heavy fuel oil burned in refinery furnace.

The potential contribution to **photochemical oxidant formation** (+115-346%) is mainly caused by the venting of natural gas during production in most geographies included in 3.9. Further contributions come from the direct emissions of nitrogen oxides (NOx) and inputs of 'pipeline, natural gas, long distance, high capacity, onshore' (from the supply of reinforcing steel and 'diesel, burned in building machine' during construction).

Systematic decreases in scores compared to the global market for petroleum in version 3.8 can be observed for the indicators for acidification (-34-55%), ionizing radiation (-92-96%), land use (-46-70%), and ozone depletion (-90-95%). The potential contribution to **acidification** from petroleum supply in 3.8 was strongly dominated by supply from Russia, with onshore production in RU representing 63% of the total score of the global market activity, despite a market share of only 13%. The second-largest contribution (18%) came from the input of 'transport, freight, sea, tanker for petroleum'. In the update for 3.9, the data on direct emissions of SO_2 and NOx (the main drivers for acidification in production) in Meili et al. (2022a) was sourced from IOGP (2020). The values provided for the region 'Russia & Central Asia' are here in line with those of other areas, and close to the global averages.

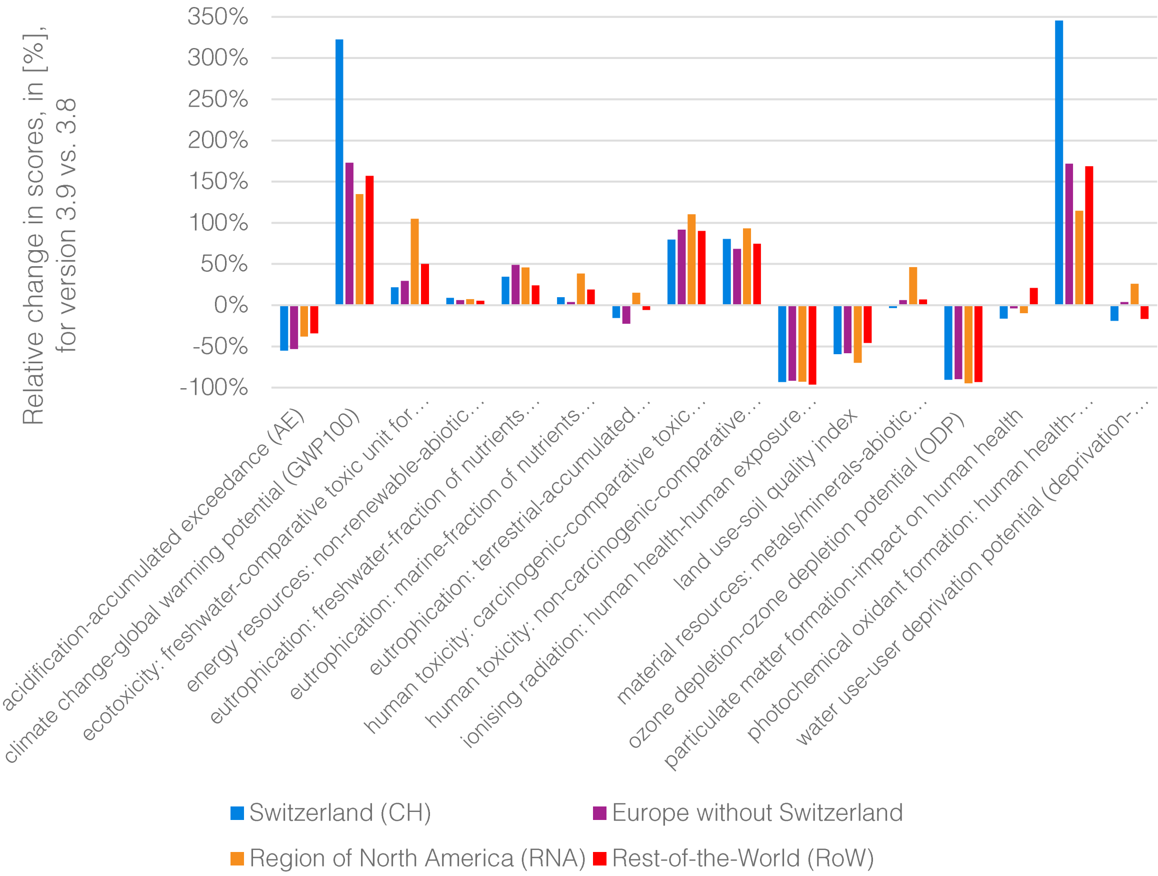

Figure 6. Relative change in scores (EF 3.0 recommended methods) for 'market for petroleum', for all geographies included in 3.9 vs. global (GLO) in 3.8 (system model: allocation, cut-off).

The reduced potential contribution to ionizing radiation is mainly driven by the changed assumption regarding the waste generated in production (previously 'low level radioactive waste', in 3.9 'hazardous waste, for underground deposit') as well as by the inputs of electricity throughout the crude oil supply chain. As described in chapter 6 of Meili et al. (2022a), the specific area requirements for the wells, as well as the lifetimes of the production plants, for onshore oil and gas extraction are set lower than in preceding studies, which are the main reasons for the decreased land use scores compared to version 3.8. The relative decrease in the potential contribution to ozone depletion is explained by the changed modelling of the use and emissions of Halon 1301 (bromotrifluoromethane) for fire suppression in petroleum and gas production, as described in section 9.6 in Meili et al. (2022a). As a result, emissions of 'Methane, bromotrifluoro-, Halon 1301' are only considered for offshore operation, and no longer in onshore operations. This combined with the relative proportions of offshore and onshore production leads to a net decrease in the ozone depletion potential across all four market activities for petroleum in 3.9.

The relevance of these changes for downstream use in petroleum refinery operations is exemplified in Figure 7 for selected refined petroleum products in Europe without

Switzerland. The results are relatively consistent across this product range, and reflect the patterns observed in Figure 6 and discussed above. Notably, though, the results in several indicators (including for climate change) for naphtha from petroleum refinery operations are more sensitive than the other refinery products to the change in upstream impacts. This can be explained by the lower additional burden from petroleum refinery operations assigned to naphtha, compared to other more extensively refined outputs.

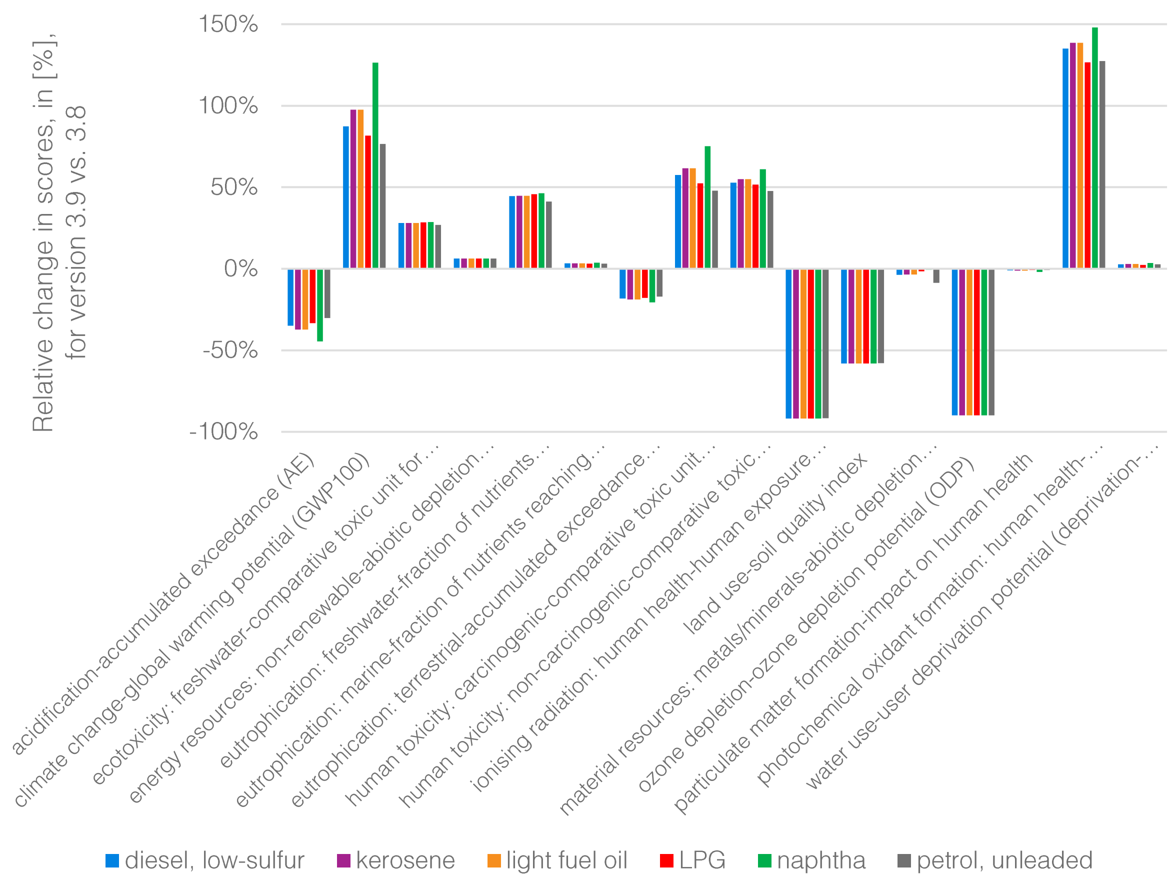

Figure 7. Relative changes in scores (EF 3.0 recommended methods) between versions 3.9 and 3.8 (system model: allocation, cut-off) for selected outputs of petroleum refinery operations in Europe without Switzerland.

Taken from a full life cycle perspective, the combustion of fossil fuels typically represents the largest contribution to climate change and other impact categories driven mainly by direct emissions. To put this update, and the changes in results presented above, further into context, some common applications for refined petroleum products are considered next. The range of relative changes (as minimum, median, and maximum) observed for the activity ‘electricity production, oil’ in all geographies with a direct correspondence in 3.8 are provided in Table 51. The resulting increase in potential contribution to climate change (+7-12%) corresponds well to the ranges observed for other uses, e.g., global datasets for diesel burned in agricultural machinery (+8%), construction machine (+11%), diesel-electric generating set (+10-11%), or fishing vessel (+11%). Similarly, the increase for non-refrigerated freight transport by lorry across all geographies was in the range of 8-18%

(except in Brazil, where the net change was only +3-9%, due to the degree of biofuel blend-in in the diesel for road vehicles).

Table 51. Comparison of relative change in scores (EF 3.0 recommended methods) between version 3.8 and 3.9 (system model: allocation, cut-off) for the activities 'electricity production, oil' with unchanged geographies between the two version (n=107).

LCIA impact category	Relative change in total score, version 3.9 vs. 3.8		
EF 3.0 recommended methods	Minimum	Median	Maximum
acidification; accumulated exceedance (AE)	-24%	-4%	-2%
climate change; global warming potential (GWP100)	7%	10%	12%
ecotoxicity: freshwater; comparative toxic unit for ecosystems (CTUe)	19%	61%	63%
energy resources: non-renewable; abiotic depletion potential (ADP): fossil fuels	4%	6%	6%
eutrophication: freshwater; fraction of nutrients reaching freshwater end compartment (P)	1%	19%	27%
eutrophication: marine; fraction of nutrients reaching marine end compartment (N)	0%	3%	3%
eutrophication: terrestrial; accumulated exceedance (AE)	-8%	0%	0%
human toxicity: carcinogenic; comparative toxic unit for human (CTUh)	2%	8%	20%
human toxicity: non-carcinogenic; comparative toxic unit for human (CTUh)	4%	38%	41%
ionising radiation: human health; human exposure efficiency relative to u235	-95%	-94%	-89%
land use; soil quality index	-54%	-50%	-31%
material resources: metals/minerals; abiotic depletion potential (ADP): elements (ultimate reserves)	-30%	-22%	-21%
ozone depletion; ozone depletion potential (ODP)	-94%	-94%	-90%
particulate matter formation; impact on human health	0%	0%	1%
photochemical oxidant formation: human health; tropospheric ozone concentration increase	18%	23%	70%
water use; user deprivation potential (deprivation-weighted water consumption)	-3%	-1%	1%

6.6.2 Supply of natural gas

The LCIA results for the supply of natural gas in ecoinvent version 3.9 largely follow the patterns described for crude petroleum oil in the previous section. The natural gas supply chains in the ecoinvent database are, however, more complex than those of petroleum (*cf.* Figure 3 *versus* Figure 4). Besides origin of production, the mode and distance of long-distance gas transport (i.e., in pipeline or as LNG by ship) may also vary between the imports to the country-specific market activities for natural gas in the database. The main aim of this section is to describe the general trends (with respect to changes over 3.8), rather than explain each of the 47 market activities (and associated market groups) for natural gas at high pressure available in version 3.9 of the database.

Figure 8 illustrates the relative change in scores over the EF 3.0 recommended LCIA methods between 3.8 and 3.9 for the eight markets for natural gas, at high pressure, in Europe that were updated based on Bussa et al. (2022). The general trend across these markets is captured well by the corresponding results for the market group for natural gas, at high pressure, for Europe without Switzerland in Figure 9. For some indicators, such as for acidification, the tendency across the geographies in Figure 8 is ambiguous (unlike the case for petroleum supply, in Figure 6). Comparing the cases of GB and IT, with opposing directions for the changes in contributions to acidification from 3.8 to 3.9, suggests that while the burden of most gas imports (per m^3 supplied) has increased with 3.9, this might not always counteract the decrease observed for gas supply from RU. (The data basis underpinning this aspect of the update was discussed for the corresponding supply of petroleum in the previous section). Imports of LNG, i.e., transported by ships, are also associated with higher impacts on acidification compared to supply via pipeline in 3.9.

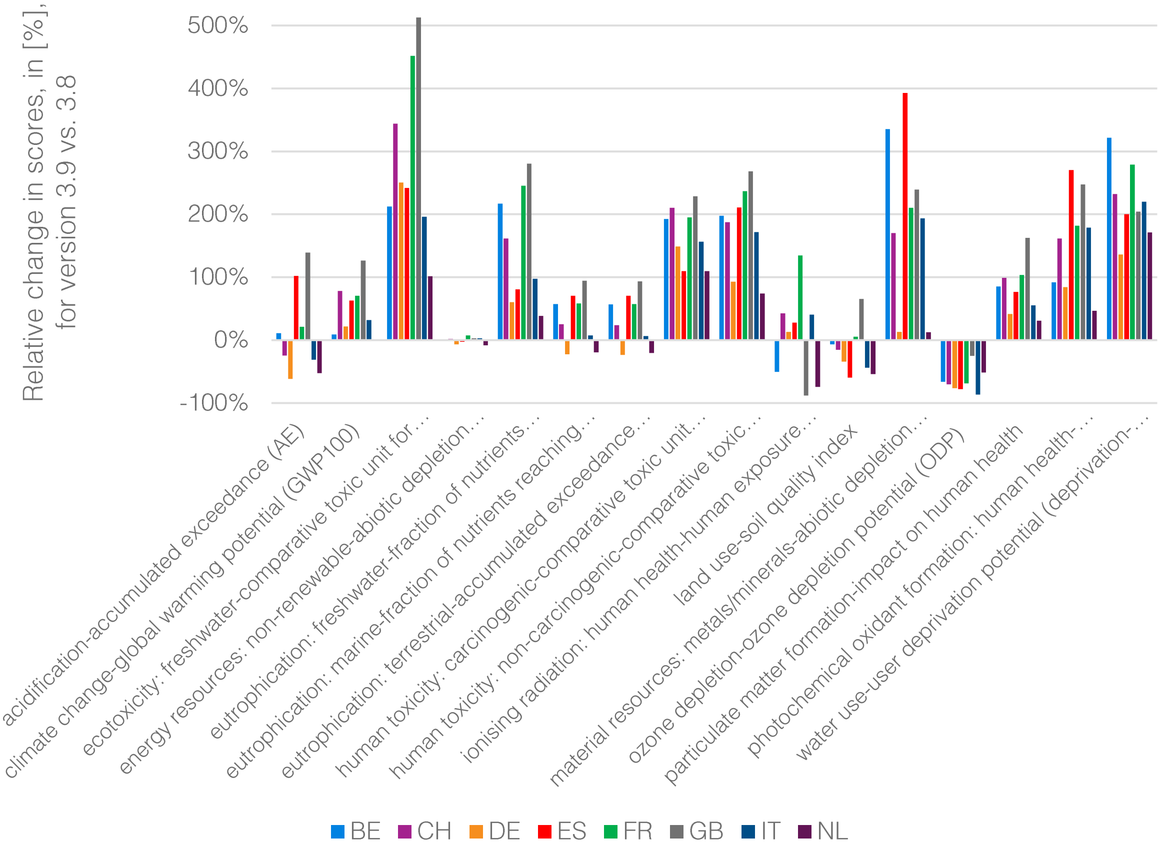

Figure 8. Relative changes in scores (for EF 3.0 recommended methods) for selected markets for natural gas at high pressure within Europe between ecoinvent versions 3.9 and 3.8 (system model: allocation, cut-off).

The freshwater ecotoxicity impacts of the market activities in Figure 8 (+101-513% over 3.8) see the largest contributions from gas imports from RU and (to a lesser extent) from QA and the US. As for petroleum, the impact of onshore production is sensitive to the input amount of extraction well (which has increased in nearly all geographies), which in turn is driven by the treatment of drilling waste. Emissions from water discharge in the combined production is only assigned to the petroleum output, and is hence not relevant here.

Other important differences in Figure 8 compared to the trends observed for crude petroleum oil (in Figure 6) can be observed for the impact categories for material resources (metals/minerals-abiotic depletion potential, ADP) and water deprivation potential. The results for the countries presented in Figure 8 increases by 13-393% and 136-322%, respectively, over the levels in version 3.8. As described in section 7.2 of Meili et al. (2022a), the water flows in production are fully allocated to the output of petroleum. Instead, the impact of production in this category is mainly driven by infrastructure requirements (e.g., the input ‘onshore well, oil/gas’ to onshore production in the U.S. or the input of ‘pipeline, natural gas, long distance, high capacity, onshore’ in RU is responsible for 63 and 62%, respectively of the total water deprivation potential of these activities in 3.9). Another important contribution in several markets is the input of sodium hypochlorite to the evaporation of imported LNG. These process inputs also drive dominates the results for material resources. Similarly, the scores for particulate matter formation (+31-163% in Figure 8) are strongly influenced by the inputs of long-distance pipeline infrastructure in production and import activities (and to a lesser extent by LNG ship transport). With the upstream burdens of these inputs largely unchanged between 3.8 and 3.9, the results for these natural gas markets prove sensitive to the share of supply from LNG as well as the infrastructure inputs in production.

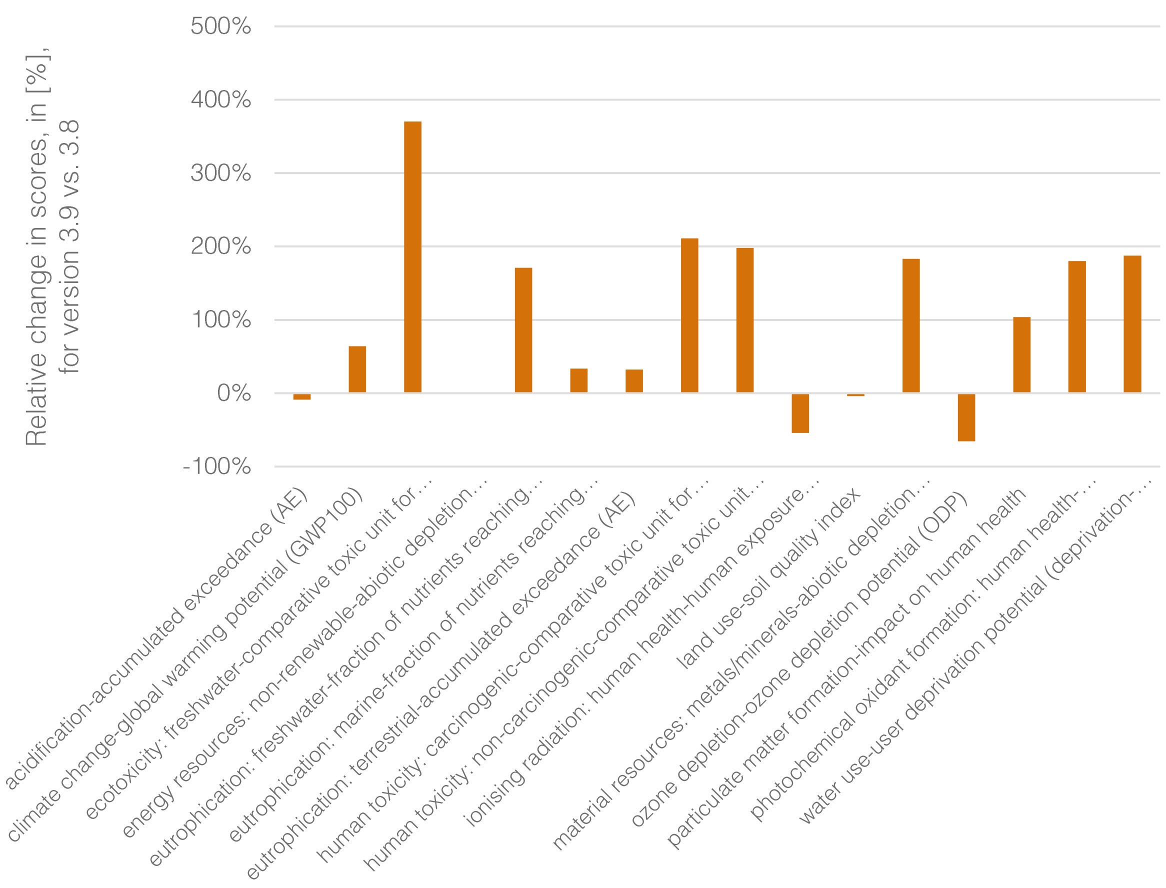

Figure 9. Relative change in scores (EF 3.0 recommended methods) for 'market group for natural gas, high pressure', in Europe without Switzerland, for 3.9 compared to 3.8 (allocation, cut-off).

Figure 10 shows the relative change in scores over the EF 3.0 recommended LCIA methods between 3.8 and 3.9 for natural gas supply (at high pressure) in Brazil (BR), Canada (CA), and the US. With the general patterns by-and-large aligned with those discussed for selected countries in Europe (in Figure 8) above, focus here will only be placed on three aspects that stands out in Figure 10, all related to Canada (CA): natural gas supply in Canada was up until version 3.8 modelled as a market group made up of provincial markets for natural gas in Alberta (CA-AB) and in Quebec (CA-QC) representing 95% and 5% of the total annual volume, respectively.

The supply to both CA-AB and CA-QC in 3.8 was completely covered by production in CA-AB. In contrast, the new market activity for natural gas in Canada in version 3.9 is supplied by domestic production (88%) and imports from the US (12%). These changes in modelling approach and linking help to explain the results that stands out in Figure 10. The changes in freshwater ecotoxicity (driven by input of the exploration and extraction wells, due to treatment of drilling waste), human toxicity (non-cancerogenic; due to direct emissions of mercury and carbon monoxide from sweet gas burned in turbine, as well as from the inputs of wells and pipeline infrastructure), and water deprivation (mainly over electricity supply, but also from inputs of wells and pipeline infrastructure), as already discussed for the selected countries in Europe in Figure 8.

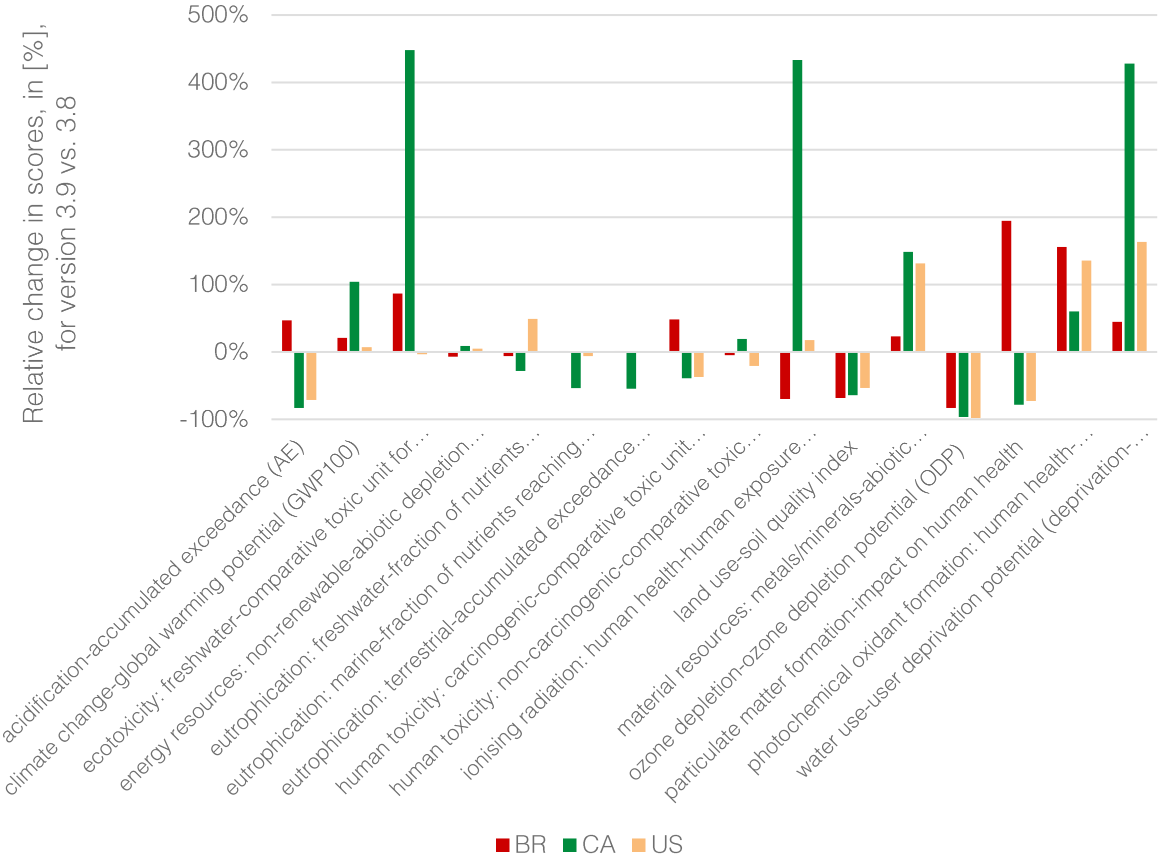

Figure 10. Relative change in scores (EF 3.0 recommended methods) for 'market for natural gas, high pressure', in selected geographies (Brazil, BR; Canada, CA, and; the US), for 3.9 compared to 3.8 (system model: allocation, cut-off).

As for the discusison on crude petroluem oil in section 6.6.1, the changes to the LCIA scores for natural gas supply in 3.9 are here put in context by analysing the downstream effects in key uses. Again focusing on the generation of electricity, Table 52 presents the range of relative changes (as minimum, median, and maximum) observed for the activities 'electricity production, natural gas, conventional power plant' and 'electricity production, natural gas, combined cycle power plant' for all geographies with a direct correspondence between 3.8 to 3.9. (The full comparison across all indicators and geographies are illustrated for 'electricity production, natural gas, conventional power plant' in Figure 11).

Table 52. Comparison of relative change in scores (EF 3.0 recommended methods) between version 3.8 and 3.9 (system model: allocation, cut-off) for the activities 'electricity production, natural gas, conventional power plant' (n=101) and 'electricity production, natural gas, combined cycle power plant' (n=109) with unchanged geographies between the two version. The values shown for each activity type represent the minimum (Min.), median, and maximum (Max.) change observed across each set.

electricity production, natural gas	conventional power plant			combined cycle power plant		
EF 3.0 recommended methods	Min.	Median	Max.	Min.	Median	Max.
acidification; accumulated exceedance (AE)	-64%	-29%	45%	-69%	-28%	79%
climate change; global warming potential (GWP100)	-6%	6%	21%	-4%	6%	21%
ecotoxicity: freshwater; comparative toxic unit for ecosystems (CTUe)	-82%	21%	582%	-87%	23%	597%
energy resources: non-renewable; abiotic depletion potential (ADP): fossil fuels	-9%	14%	21%	-3%	14%	21%
eutrophication: freshwater; fraction of nutrients reaching freshwater end compartment (P)	-17%	41%	261%	-20%	67%	339%
eutrophication: marine; fraction of nutrients reaching marine end compartment (N)	-25%	7%	43%	-30%	10%	91%
eutrophication: terrestrial; accumulated exceedance (AE)	-25%	8%	44%	-30%	11%	93%
human toxicity: carcinogenic; comparative toxic unit for human (CTUh)	-33%	156%	313%	-31%	187%	303%
human toxicity: non-carcinogenic; comparative toxic unit for human (CTUh)	-45%	-6%	404%	-60%	-8%	439%
ionising radiation: human health; human exposure efficiency relative to u235	-95%	9%	357%	-95%	-36%	408%
land use; soil quality index	-57%	-34%	51%	-71%	-45%	59%
material resources: metals/minerals; abiotic depletion potential (ADP): elements (ultimate reserves)	-40%	-33%	178%	-33%	28%	253%
ozone depletion; ozone depletion potential (ODP)	-98%	-87%	78%	-96%	-81%	91%
particulate matter formation; impact on human health	-70%	40%	149%	-73%	49%	173%
photochemical oxidant formation: human health; tropospheric ozone concentration increase	-7%	67%	148%	-8%	81%	280%
water use; user deprivation potential (deprivation-weighted water consumption)	3%	20%	63%	3%	23%	64%

The ranges of potential contributions to climate change (as EF 3.0-recommended method for global warming potential, 100 years) in Table 52 corresponds well to the relative changes in other imporant applications of natural gas:

- 'heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical' (n=36): in the range of -4 to +21%, for the outputs of electricity and heat alike
- 'market for heat, central or small-scale, natural gas'
  - CH: +5%
  - RER w/o CH: +2%
  - RoW: 0%
- 'market for heat, district or industrial, natural gas'
  - CA-QC: -14%
  - CH: +6%

    - Europe without Switzerland: 9%
    - RoW: +1%)
- production of liquid ammonia from steam reforming (n=10): in the range of -4% to +11%

Another important industrial use for natural gas, hydrogen production from steam reforming (or steam methane reforming, SMR), was only introduced to the ecoinvent database with version 3.9. A direct comparsion of the GWP score changes between 3.8 and 3.9 is therefore not relevant here. But the input of natural gas to this activity in RER and RoW represents 25 and 22%, respectively, of the total impact of the process on climate change in 3.9 (system model: attributional, cut-off by classification).

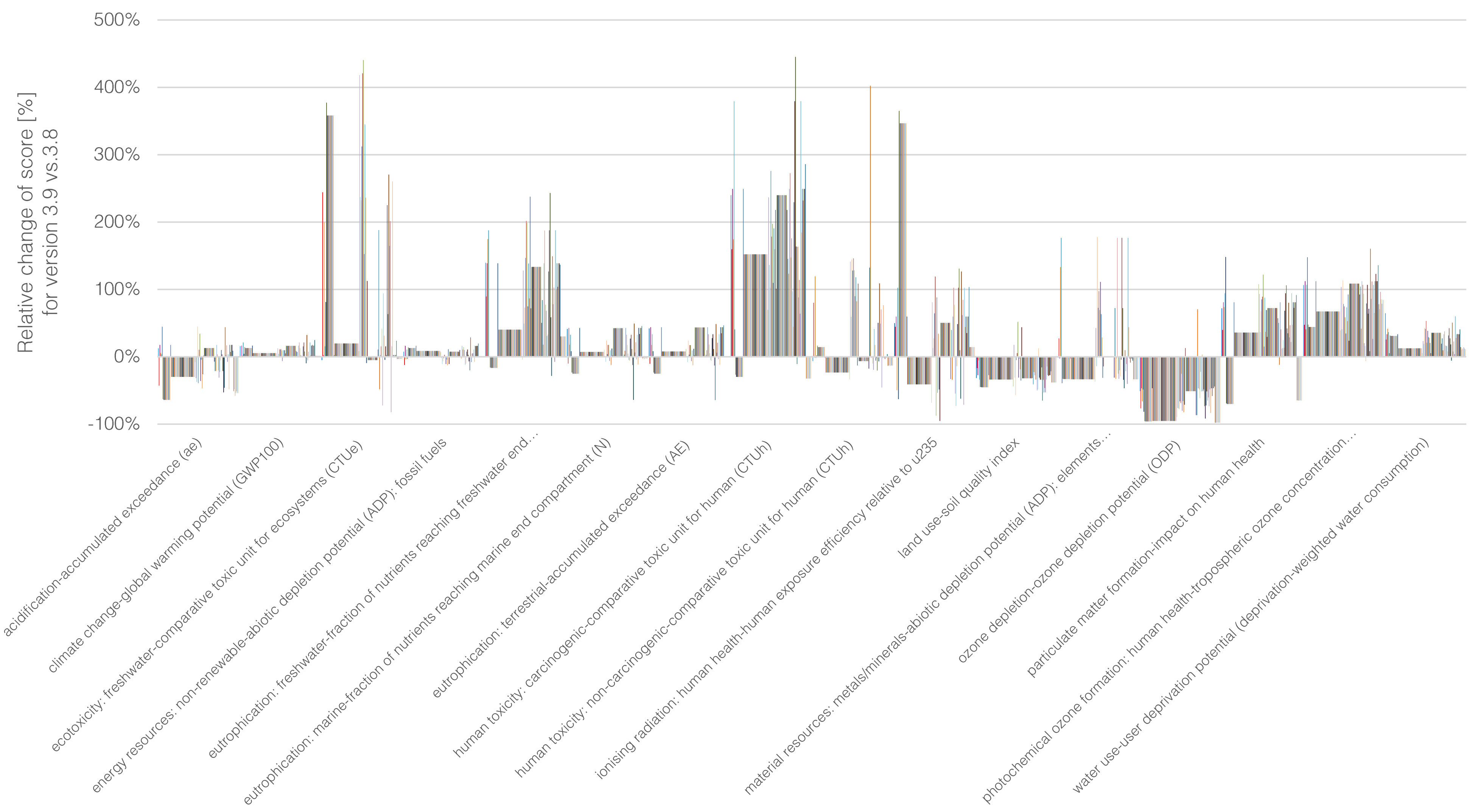

Figure 11. Comparison of relative change in scores (EF 3.0 recommended methods) between version 3.8 and 3.9 (system model: allocation, cut-off) for the activities 'electricity production, natural gas, conventional power plant' with unchanged geographies between the two version.

6.6.3 Supply of petroleum and natural gas in the consequential system model

The (absolute) results for the update of petroleum and natural gas supply chains in 3.9 in the system model 'consequential, long-term' are generally closely aligned with the results in 'attributional, cut-off by classification'. Further work is needed to establish and implement a consequential model for the sector in the database. The direct linking of these supply chains is hence essentially identical across the different system models in version 3.9. Any differences in results are consequently caused further upstream, in the product system of process inputs or waste treatment services. Using an arbitrary threshold of ±5% (based on 'unweighted' average over all geographies available), the impact categories among the EF 3.0-recommended methods, for which larger score discrepancies are obtained for the main market activities, are listed below. Based on a limited sample, the score differences between the attributional and consequential modelling of electricity and metals supply (for infrastructure) appear to be the main underlying causes for these discrepancies.

- eutrophication: freshwater-fraction of nutrients reaching freshwater end compartment (P)
- human toxicity: carcinogenic-comparative toxic unit for human (CTUh)
- human toxicity: non-carcinogenic-comparative toxic unit for human (CTUh)
- ionising radiation: human health-human exposure efficiency relative to u235
- land use-soil quality index
- material resources: metals/minerals-abiotic depletion potential (ADP): elements (ultimate reserves)
- particulate matter formation-impact on human health
- water use-user deprivation potential (deprivation-weighted water consumption)

7 Electricity

7.1 Changes in geographies

7.1.1 China

The State Grid Corporation of China (CN-SGCC) region was split up into six subregions as shown in Table 53. New electricity markets were created for all subregions and the CN-SGCC electricity market was transformed into a market group, containing all six sub grids.

Table 53. New sub grids of the former CN-SGCC geography.

Geography	Name	Contained provinces	Names of provinces
CN-NCGC	State Grid North China Branch	CN-BJ, CN-TJ, CN-HB, CN-SX, CN-SD	China, Beijing (北京), China, Tianjin (天津), China, Hebei (河北), China, Shanxi (山西), China, Shandong (山东)
CN-ECGC	State Grid East China Branch	CN-SH, CN-JS, CN-ZJ, CN-FJ, CN-AH	China, Shanghai (上海), China, Jiangsu (江苏), China, Zhejiang (浙江), China, Fujian (福建), China, Anhui (安徽)
CN-CCG	State Grid Central China Branch	CN-HU, CN-HN, CN-HE, CN-JX	China, Hubei (湖北), China, Hunan (湖南), China, Henan (河南), China, Jiangxi (江西)
CN-NECG	State Grid Northeast China Branch	CN-LN, CN-JL, CN-HL, CN-NM	China, Liaoning (辽宁), China, Jilin (吉林), China, Heilongjiang (黑龙江省), China, Inner Mongol (内蒙古自治区)
CN-NWG	State Grid Northwest China Branch	CN-SA, CN-GS, CN-QH, CN-NX, CN-XJ	China, Shaanxi (陕西), China, Gansu (甘肃), China, Qinghai (青海), China, Ningxia (宁夏回族自治区), China, Xinjiang (新疆维吾尔自治区)
CN-SWG	State Grid Southwest China Branch	CN-SC, CN-CQ, CN-XZ	China, Sichuan (四川), China, Chongqing (重庆), China, Xizang (西藏自治区)

7.1.2 Brazil

Up to v3.8 the electricity sector in Brazil was split into five regions (North-eastern, Northern, South-eastern, Southern, Mid-western). From v3.9 onwards the South-eastern (BR-South-eastern grid) and Mid-western (BR-Mid-western grid) are merged into South-easter/Midwestern grid (BR-South-eastern/Mid-western grid) due to the structure of the available data for national statistics (EPE, 2021). The markets for “BR-Midwestern grid” and “BR-South-eastern grid” were removed together with the accompanying datasets (Table 61).

7.1.3 USA

Power plants in the US NERC regions "US-ASCC" (Alaska) and “US-HICC” (Hawaii) could not be attributed to these regions on a plant-by-plant level by the EIA as before due to a lack of raw data. Thus, they now assume that all plants in Alaska and Hawaii are part of the corresponding NERC regions (EPA, 2022), which then also has a minor effect on the generation shares for ecoinvent market mixes in these two regions.

7.2 Attributional electricity market updates

The production volumes, trade volumes and loss volumes of electricity supply in the attributional system models, cut-off and APOS, were updated to represent 2019 electricity mixes, based on primary data from the International Energy Agency (IEA). Canadian and US power grids were updated to represent the year 2020 due the availability of more recent data. Not included in this package are the electricity mixes in Brazil, India and China These were updated separately, based on national statistics (see Section 7.3).

The Rest of the World (RoW) markets for electricity are no longer generated in the attributional system models. 100% of statistically available global electricity supply is covered with specific mixes; no data is available for the remaining geographies, mostly small countries and island states.

The following sections describe the changes performed for the update of the electricity market mixes. Table 54 shows for which geographies the electricity market mixes were updated in the attributional system models.

Table 54. Updated electricity transformation datasets. If several geographies of the same activity with the same time period and system model exist, all of them are listed in the “Geography” column.

System model	Activity Name	Geography	Time Period	Product Name	Unit
Allocation, cut-off; Allocation, APOS	market for electricity, high voltage	AE; AL; AM; AO; AR; AT; AU; AZ; BA; BD; BE; BG; BH; BJ; BN; BO; BW; BY; CA-AB; CA-BC; CA-MB; CA-NB; CA-NF; CA-NS; CA-NT; CA-NU; CA-ON; CA-PE; CA-QC; CA-SK; CA-YK; CD; CG; CI; CL; CM; CO; CR; CU; CW; CY; CZ; DE; DK; DO; DZ; EC; EE; EG; ER; ES; ET; FI; FR; GA; GB; GE; GH; GI; GLO; GR; GT; HK; HN; HR; HT; HU; ID; IE; IL; IQ; IR; IS; IT; JM; JO; JP; KE; KG; KH; KP; KR; KW; KZ; LB; LK; LT; LU; LV; LY; MA; MD; ME; MK; MM; MN; MT; MU; MX; MY; MZ; NA; NE; NG; NI; NL; NO; NP; NZ; OM; PA; PE; PH; PK; PL; PT; PY; QA; RO; RS; RU; SA; SD; SE; SG; SI; SK; SN; SS; SV; SY; TG; TH; TJ; TM; TN; TR; TT; TW; TZ; UA; US-ASCC; US-PR; US-HICC; US-MRO; US-NPCC; US-RFC; US-SERC; US-TRE; US-WECC; UY; UZ; VE; VN; XK; YE; ZA; ZM; ZW	2014-2017	electricity, high voltage	kWh
Allocation, cut-off; Allocation, APOS	market for electricity, medium voltage	AE; AL; AM; AO; AR; AT; AU; AZ; BA; BD; BE; BG; BH; BJ; BN; BO; BW; BY; CA-AB; CA-BC; CA-MB; CA-NB; CA-NF; CA-NS; CA-NT; CA-NU; CA-ON; CA-PE; CA-QC; CA-SK; CA-YK; CD; CG; CI; CL; CM; CO; CR; CU; CW; CY; CZ; DE; DK; DO; DZ; EC; EE; EG; ER; ES; ET; FI; FR; GA; GB; GE; GH; GI; GLO; GR; GT; HK; HN; HR; HT; HU; ID; IE; IL; IQ; IR; IS; IT; JM; JO; JP; KE; KG; KH; KP; KR; KW; KZ; LB; LK; LT; LU; LV; LY; MA; MD; ME; MK; MM; MN; MT; MU; MX; MY; MZ; NA; NE; NG; NI; NL; NO; NP; NZ; OM; PA; PE; PH; PK; PL; PT; PY; QA; RO; RS; RU; SA; SD; SE; SG; SI;	2014-2017	electricity, medium voltage	kWh

System model	Activity Name	Geography	Time Period	Product Name	Unit
		SK; SN; SS; SV; SY; TG; TH; TJ; TM; TN; TR; TT; TW; TZ; UA; US-ASCC; US-PR; US-HICC; US-MRO; US-NPCC; US-RFC; US-SERC; US-TRE; US-WECC; UY; UZ; VE; VN; XK; YE; ZA; ZM; ZW			
Allocation, cut-off; Allocation, APOS	market for electricity, low voltage	AE; AL; AM; AO; AR; AT; AU; AZ; BA; BD; BE; BG; BH; BJ; BN; BO; BW; BY; CA-AB; CA-BC; CA-MB; CA-NB; CA-NF; CA-NS; CA-NT; CA-NU; CA-ON; CA-PE; CA-QC; CA-SK; CA-YK; CD; CG; CI; CL; CM; CO; CR; CU; CW; CY; CZ; DE; DK; DO; DZ; EC; EE; EG; ER; ES; ET; FI; FR; GA; GB; GE; GH; GI; GLO; GR; GT; HK; HN; HR; HT; HU; ID; IE; IL; IQ; IR; IS; IT; JM; JO; JP; KE; KG; KH; KP; KR; KW; KZ; LB; LK; LT; LU; LV; LY; MA; MD; ME; MK; MM; MN; MT; MU; MX; MY; MZ; NA; NE; NG; NI; NL; NO; NP; NZ; OM; PA; PE; PH; PK; PL; PT; PY; QA; RO; RS; RU; SA; SD; SE; SG; SI; SK; SN; SS; SV; SY; TG; TH; TJ; TM; TN; TR; TT; TW; TZ; UA; US-ASCC; US-PR; US-HICC; US-MRO; US-NPCC; US-RFC; US-SERC; US-TRE; US-WECC; UY; UZ; VE; VN; XK; YE; ZA; ZM; ZW	2014-2017	electricity, low voltage	kWh

7.2.1 Changes to production, trade and loss volume

The electricity market mixes from Table 54 were updated analogue to the previous versions v3.6, v3.7.1 and v3.8. See the corresponding change reports (https://ecoinvent.org/the-ecoinvent-database/data-releases) for information on the used data sources. Deviating from the previous procedure is the data for European mixes. They used to be a combination from ENTSO-E and data from the IEA, while now the mixes are based exclusively on IEA data due to a format change of ENTSO-E data. Furthermore, the electricity import data for the US was only updated to 2019 because of lack of more recent data. A few additional adjustments were performed as listed in the following.

7.2.2 New import and technology splits

Some electricity import origins were added because the respective imports were not included in previous versions of ecoinvent or some imports were missing. All the new splits are listed in Table 55. Temporal inconsistencies may occur due to limited data availability. Please note that these splits are only used to distribute electricity imports that are not documented per import region in the primary data sources (e.g. International Energy Agency (IEA)), so the resulting import mix per market can deviate from these splits.

Table 55. New import splits for updated electricity markets. Columns "Data year" and "Data source" represent the year in which the data on technology splits is valid for and the according source respectively.

Importing geography	Import splits	Data year	Data source
SD	100 % electricity, high voltage, import from EG* (based on new interconnector location that has been inaugurated in 2019)	2019	Egypt Oil and Gas (2019)
SN	100% electricity, high voltage, import from RAF* (Interconnections of Senegal with Mali and Mauritania exist, with the purpose being the distribution of electricity from Manantali and Felou hydro power plants in Mali. RAF because ML does not exist in IEA data sources and therefore has no own ecoinvent market.)	N/A	African Development Bank (2020); European Commission (2017)

Some splits for electricity generation technologies had to be added because they were not included in the previous ecoinvent versions. These splits are listed in Table 56 below. Temporal inconsistencies occur due to limited data availability.

Table 56. New technology splits for updated electricity markets. The activities listed in the "Technology splits" column represent the production means with which the countries of column "Geography" produce electricity from the fuel in column "Fuel type". Columns "Data year" and "Data source" represent the year in which the data on technology splits is valid for and the according source respectively.

Geography	Fuel type	Technology split	Data years	Data source
GI	natural gas (non-CHP)	100% electricity production, natural gas, conventional power plant	2019	S&P Global (2022)
TM	hydro (non-pumped)	100% electricity production, hydro, run-of-river (only one plant, Gindukushskaya HPP, which is very small at 1.2 MW, so assume it has no own dam)	2019	S&P Global (2022)
KW	solar thermal	100% electricity production, solar thermal parabolic trough, 50 MW (only one plant, Shagaya solar thermal trough-based power plant, completed in 2018)	2019	S&P Global (2022)
SN	wind (total)	100% electricity production, wind, >3MW turbine, onshore (only one wind park, Taïba Ndiaye, with turbines >3MW)	2019	The windpower (2022)

7.2.3 New import datasets

With the update of electricity data, especially trade volumes, certain new import datasets had to be created to represent the trade of electricity mentioned in the statistics. Table 57 lists all newly created import datasets with their respective origin and destination.

Table 57. New import activities for electricity.

Activity Name	Geography	Time Period	Product name	Unit
electricity, high voltage, import from BE	GB	2020-2020	electricity, high voltage	kWh
electricity, high voltage, import from DK	NL	2020-2020	electricity, high voltage	kWh
electricity, high voltage, import from EG	SD	2020-2020	electricity, high voltage	kWh
electricity, high voltage, import from NL	DK	2020-2020	electricity, high voltage	kWh
electricity, high voltage, import from RAF	SN	2020-2020	electricity, high voltage	kWh

7.2.4 Swiss electricity markets update for attributional system models

The Swiss electricity markets were updated analogous to the procedure for v3.8 of the ecoinvent database and represent the year 2020 for v3.9. See the corresponding change report (https://ecoinvent.org/the-ecoinvent-database/data-releases/) for data sources and explanation.

Table 58. Updated Swiss electricity markets.

Activity Name	Geography	Time Period	Product name	Unit
market for electricity, high voltage	CH	2014-2017	electricity, high voltage	kWh
market for electricity, medium voltage	CH	2014-2017	electricity, medium voltage	kWh
market for electricity, low voltage	CH	2014-2017	electricity, low voltage	kWh
market for electricity, high voltage, renewable energy products	CH	2011-2015	electricity, high voltage, renewable energy products	kWh
market for electricity, medium voltage, renewable energy products	CH	2011-2015	electricity, medium voltage, renewable energy products	kWh
market for electricity, low voltage, renewable energy products	CH	2011-2015	electricity, low voltage, renewable energy products	kWh
electricity, high voltage, production mix	CH	2021-2021	electricity, high voltage	kWh
electricity, high voltage, renewable energy products, production mix	CH	2021-2021	electricity, high voltage, renewable energy products	kWh
market for electricity, high voltage	CH	2014-2017	electricity, high voltage	kWh

7.3 Update of China, India and Brazil

Due to their size, the electricity mixes for the countries of China, India and Brazil are represented in several regions and these regions could not be updated with the approach described in Section 7.2. For v3.9 of the ecoinvent database, national statistics of these countries were analysed individually and the electricity mixes for all their subregions updated.

7.3.1 China

The Chinese electricity markets were updated based on data from national statistics of the year 2020. The following data sources were used for the update:

- Generation data: National Bureau of Statistics Database Year 2020. Accessible via: https://data.stats.gov.cn/english/adv.htm?m=advquery&cn=E0101
- Technology mapping to ecoinvent: S&P Global (2022). Platts World Electric Power Plant (WEPP) database, version March 2022. https://www.spglobal.com/marketintelligence/en/
- Total transmission and distribution losses: 2020 electricity & other energy statistics, translated and accessed via: https://chinaenergyportal.org/en/2020-electricity-other-energy-statistics-preliminary/
- Inter-provincial exchanges: Li, W., Long, R., Zhang, L., He, Z., Chen, F. and Chen, H., 2020. Greenhouse Gas Emission Transfer of Inter-Provincial Electricity Trade in China. International Journal of Environmental Research and Public Health, 17(22), p.8375.
- Technology split for wind power: The windpower (2022). Wind farms. https://www.thewindpower.net/windfarms_list_en.php

The distribution of transmission losses among the voltage levels of the electricity markets was performed in accordance with all other electricity markets and based on Itten (2014). Due to the unavailability of more recent data, the inter-provincial exchanges are based on the year 2017.

The updated and added electricity market mixes, transformation datasets, import datasets as well as several new electricity production datasets required for the update are listed in Table 59. As described in Section 7.1.1 the CN-SGCC electricity market has been split into six sub grids while the CN-SGCC market was retained as a market group for electricity.

Table 59. New and updated datasets for the Chinese electricity markets. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity production, hydro, pumped storage	CN-BJ, CN-HA, CN-JL, CN-JM, CN-SC, CN-XZ	1945-2015	electricity, high voltage	kWh	N
electricity production, hydro, run-of-river	CN-SD	1945-2015	electricity, high voltage	kWh	N
electricity production, nuclear, pressure water reactor	CN-FJ, CN-GX, CN-HA, CN-LN, CN-SD	1990-2015	electricity, high voltage	kWh	N
electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted	CN-FJ, CN-GZ, CN-GZ	2005-2015	electricity, low voltage	kWh	N
electricity production, photovoltaic, 570kWp open ground installation, multi-Si	CN-AH, CN-FJ, CN-GZ, CN-HU, CN-JX, CN-SH, CN-SX, CN-ZJ	2008-2015	electricity, low voltage	kWh	N

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity production, wind, 1-3MW turbine, offshore	CN-FJ, CN-HB, CN-TJ, CN-ZJ	2000-2015	electricity, high voltage	kWh	N
market group for electricity, high voltage	CN-SGCC	2020-2020	electricity, high voltage	kWh	N
market group for electricity, low voltage	CN-SGCC	2020-2020	electricity, low voltage	kWh	N
market group for electricity, medium voltage	CN-SGCC	2020-2020	electricity, medium voltage	kWh	N
electricity, high voltage, import from CN-CCG	CN-CSG	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-CSG	CN-SWG	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-ECGC	CN-CSG	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-NCGC	CN-CCG, CN-ECGC	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-NECG	CN-ECGC, CN-NCGC, CN-NWG	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-NWG	CN-CCG, CN-ECGC, CN-NCGC, CN-SWG	2021-2021	electricity, high voltage	kWh	N
electricity, high voltage, import from CN-SWG	CN-CCG, CN-ECGC	2021-2021	electricity, high voltage	kWh	U
electricity voltage transformation from high to medium voltage	CN-CSG	2012-2012	electricity, medium voltage	kWh	U
electricity voltage transformation from medium to low voltage	CN-CSG	2012-2012	electricity, low voltage	kWh	U
market for electricity, high voltage	CN-CSG	2014-2017	electricity, high voltage	kWh	U
market for electricity, low voltage	CN-CSG	2014-2017	electricity, low voltage	kWh	U
market for electricity, medium voltage	CN-CSG	2014-2017	electricity, medium voltage	kWh	U
electricity voltage transformation from high to medium voltage	CN-CCG, CN-ECGC, CN-NCGC, CN-NECG, CN-NWG, CN-SWG	2020-2020	electricity, medium voltage	kWh	N
electricity voltage transformation from high to medium voltage	CN-CCG, CN-ECGC, CN-NCGC, CN-NECG, CN-NWG, CN-SWG	2020-2020	electricity, low voltage	kWh	N
market for electricity, high voltage	CN-CCG, CN-ECGC, CN-NCGC, CN-NECG, CN-NWG, CN-SWG	2020-2020	electricity, high voltage	kWh	N
market for electricity, low voltage	CN-CCG, CN-ECGC, CN-NCGC, CN-NECG, CN-NWG, CN-SWG	2020-2020	electricity, low voltage	kWh	N
market for electricity, medium voltage	CN-CCG, CN-ECGC, CN-NCGC, CN-NECG, CN-NWG, CN-SWG	2020-2020	electricity, medium voltage	kWh	N
market for electricity, high voltage	CN-SGCC	2020-2020	electricity, high voltage	kWh	D
market for electricity, low voltage	CN-SGCC	2020-2020	electricity, low voltage	kWh	D
market for electricity, medium voltage	CN-SGCC	2020-2020	electricity, medium voltage	kWh	D

7.3.2 India

The Indian electricity markets were updated based on data from national statistics of the year 2019-20. The fiscal year of India starts on 1 April and ends on 31 March and all statistics are reported for this time period, which means the electricity markets for India also represent this time period. The following data sources were used for the update:

- Generation data: General Review 2021, All India Electricity Statistics containing data for the year 2019-20, Central Electricity Authority, 2021
- Technology mapping to ecoinvent: S&P Global (2022). Platts World Electric Power Plant (WEPP) database, version March 2022. https://www.spglobal.com/marketintelligence/en/
- Total transmission and distribution losses: General Review 2021, All India Electricity Statistics containing data for the year 2019-20, Central Electricity Authority, 2021
- Inter-regional exchanges: POSOCO (2020). Operational Performance Report for the month of March-2020. Power System Operation Corporation LTD, National Load Despatch Centre, New Delhi
- Technology split for wind power: The windpower (2022). Wind farms. https://www.thewindpower.net/windfarms_list_en.php
- Technology split for hydro power: Individual research per power plant.

The distribution of transmission losses among the voltage levels of the electricity markets was performed in accordance with all other electricity markets and based on Itten (2014).

The updated and added electricity market mixes, transformation datasets, import datasets as well as several new electricity production datasets required for the update are listed in Table 60.

Table 60. New and updated datasets for the Indian electricity markets. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity production, oil	IN-AP; IN-AS; IN-BR; IN-CT; IN-DL; IN-DN; IN-GA; IN-GJ; IN-HP; IN-HR; IN-JH; IN-JK; IN-MH; IN-ML; IN-MN; IN-MP; IN-MZ; IN-NL; IN-OR; IN-PB; IN-RJ; IN-SK; IN-UP; IN-UT; IN-WB	1980-2015	electricity, high voltage	kWh	N
electricity production, wind, <1MW turbine, onshore	IN-AP; IN-GJ; IN-KA; IN-MH; IN-MP; IN-RJ; IN-TN	2000-2015	electricity, high voltage	kWh	N
heat and power co-generation, wood chips, 6667 kW	IN-AP; IN-BR; IN-CT; IN-GA; IN-GJ; IN-HR; IN-KA; IN-MH; IN-MP; IN-OR; IN-PB; IN-RJ; IN-UP; IN-UT; IN-WB, IN-TN	2010-2015	electricity, high voltage	kWh	N
electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted	IN-AS; IN-BR; IN-CH; IN-DD; IN-DN; IN-HP; IN-MN; IN-TR	2005-2015	electricity, low voltage	kWh	N
treatment of bagasse, from sugarcane, in heat and power co-generation unit, 6400kW thermal	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2000-2001	electricity, high voltage	kWh	N

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity production, hard coal	IN-AS	1980-2015	electricity, high voltage	kWh	N
electricity production, hydro, reservoir, alpine region	IN-JK	1945-2015	electricity, high voltage	kWh	N
electricity production, hydro, reservoir, non-alpine region	IN-AP; IN-AS; IN-CT; IN-GJ; IN-HP; IN-JH; IN-KA; IN-KL; IN-MH; IN-ML; IN-MP; IN-MZ; IN-NL; IN-OR; IN-PB; IN-RJ; IN-TN; IN-UP; IN-UT; IN-WB	1945-2015	electricity, high voltage	kWh	N
electricity production, hydro, run-of-river	IN-BR; IN-CT; IN-HR; IN-JH; IN-MN; IN-MZ; IN-OR; IN-TR, IN-NL	1945-2015	electricity, high voltage	kWh	N
electricity production, lignite	IN-AP; IN-BR; IN-CT; IN-KA; IN-MH; IN-MP; IN-OR; IN-PB; IN-UP; IN-WB, IN-HR	1980-2015	electricity, high voltage	kWh	N
electricity production, natural gas, combined cycle power plant	IN-KA, IN-PB, IN-UT	2000-2015	electricity, high voltage	kWh	N
electricity production, natural gas, conventional power plant	IN-DN, IN-KA, IN-MP	1990-2015	electricity, high voltage	kWh	N
electricity voltage transformation from high to medium voltage	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2012-2012	electricity, medium voltage	kWh	U
electricity voltage transformation from medium to low voltage	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2012-2012	electricity, low voltage	kWh	U
market for electricity, high voltage	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2012-2015	electricity, high voltage	kWh	U
market for electricity, low voltage	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2012-2015	electricity, low voltage	kWh	U
market for electricity, medium voltage	IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IN-Eastern grid	2012-2015	electricity, medium voltage	kWh	U

7.3.3 Brazil

The Brazilian electricity markets were updated based on data from national statistics of the year 2020. The market shares were collected and compiled by ACV Brasil (https://acvbrasil.com). The following data sources were used for the update:

- Generation data: Energy Research Enterprise - EPE (2021). National Energy Balance. Available at: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/BEN-Series-Historicas-Completas. Datasheets used: Capítulo 8 (Dados Estaduais): 8.1 part 3 / TABLE 8.1.e- Electric Generation by Source; Capítulo 2 (Oferta e Demanda de Energia por Fonte) 1970-2020: Table 2.28 – Electricity
- Total transmission and distribution losses: EMPRESA, D.P.E.E., 2021. Anuário Estatístico de Energia Elétrica 2021 ano base 2020. Rio de Janeiro: EPE.. Available: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-160/topico-168/Anu%C3%A1rio_2021.pdf#page=1&zoom=auto,-248,653

- National subsystem import data: Electric System Operator (ONS), Data can be obtained either through an interactive dashboard (available on http://www.ons.org.br/Paginas/resultados- da-operacao/historico-da-operacao/intercambios_energia.aspx) or the raw data can be downloaded on https://dados.ons.org.br/dataset/intercambio-nacional.
- Energy import from neighbouring countries: Energy Information System (SIE) portal (available on https://www.mme.gov.br/SIEBRASIL). The information can be accessed by selecting: Brazil > Energy Supply and Demand >Energy Import by Country.

The distribution of transmission losses among the voltage levels of the electricity markets was performed in accordance with all other electricity markets and based on Itten (2014).

The updated and added electricity market mixes, transformation datasets, import datasets as well as several new electricity production datasets required for the update are listed in Table 61. As described in Section 7.1.1 the two regions "BR-South-eastern grid" and "BR-Mid-western grid" were merged to "BR-South-eastern/Mid-western grid".

Table 61. New and updated datasets for the Brazilian electricity markets. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity production, hard coal	BR-Northern grid	2014-2017	electricity, high voltage	kWh	N
electricity production, hydro, reservoir, tropical region	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
electricity production, natural gas, combined cycle power plant	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
electricity production, natural gas, conventional power plant	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
electricity production, nuclear, pressure water reactor	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
electricity production, oil	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted	BR-South-eastern/Mid-western grid; BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2005-2015	electricity, low voltage	kWh	N
electricity, high voltage, import from BR-North-eastern grid	BR-South-eastern/Mid-western grid; BR-Northern grid	2020-2020	electricity, high voltage	kWh	N
electricity, high voltage, import from BR-Northern grid	BR-South-eastern/Mid-western grid	2020-2020	electricity, high voltage	kWh	N
electricity, high voltage, import from BR-South-eastern/Mid-western grid	BR-Southern grid	2014-2017	electricity, high voltage	kWh	N
electricity, high voltage, import from PY	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N
heat and power co-generation, diesel, 200kW electrical, SCR-NOx reduction	BR-South-eastern/Mid-western grid; BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2000-2000	electricity, high voltage	kWh	N
heat and power co-generation, wood chips, 6667 kW	BR-South-eastern/Mid-western grid; BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2010-2015	electricity, high voltage	kWh	N
treatment of bagasse, from sugarcane, in heat and power	BR-South-eastern/Mid-western grid	2014-2017	electricity, high voltage	kWh	N

Activity Name	Geography	Time Period	Product name	Unit	v3.9
co-generation unit, 6400kW thermal					
electricity voltage transformation from high to medium voltage	BR-South-eastern/Mid-western grid	2020-2020	electricity, medium voltage	kWh	N
electricity voltage transformation from medium to low voltage	BR-South-eastern/Mid-western grid	2020-2020	electricity, low voltage	kWh	N
market for electricity, high voltage	BR-South-eastern/Mid-western grid	2020-2020	electricity, high voltage	kWh	N
market for electricity, low voltage	BR-South-eastern/Mid-western grid	2020-2020	electricity, low voltage	kWh	N
market for electricity, medium voltage	BR-South-eastern/Mid-western grid	2020-2020	electricity, medium voltage	kWh	N
electricity voltage transformation from high to medium voltage	BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2014-2017	electricity, medium voltage	kWh	U
electricity voltage transformation from medium to low voltage	BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2014-2017	electricity, low voltage	kWh	U
market for electricity, high voltage	BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2014-2017	electricity, high voltage	kWh	U
market for electricity, low voltage	BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2014-2017	electricity, low voltage	kWh	U
market for electricity, medium voltage	BR-North-eastern grid; BR-Northern grid; BR-Southern grid	2014-2017	electricity, medium voltage	kWh	U
electricity production, hydro, reservoir, tropical region	BR-Mid-western grid; BR-South-eastern grid	2014-2014	electricity, high voltage	kWh	D
electricity production, natural gas, combined cycle power plant	BR-Mid-western grid; BR-South-eastern grid	2017-2020	electricity, high voltage	kWh	D
electricity production, natural gas, conventional power plant	BR-Mid-western grid; BR-South-eastern grid	2014-2014	electricity, high voltage	kWh	D
electricity production, nuclear, pressure water reactor	BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity production, oil	BR-Mid-western grid; BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity voltage transformation from high to medium voltage	BR-Mid-western grid; BR-South-eastern grid	2014-2017	electricity, medium voltage	kWh	D
electricity voltage transformation from medium to low voltage	BR-Mid-western grid; BR-South-eastern grid	2014-2017	electricity, low voltage	kWh	D
electricity, high voltage, import from BR-Mid-western grid	BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity, high voltage, import from BR-North-eastern grid	BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity, high voltage, import from BR-Northern grid	BR-North-eastern grid; BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity, high voltage, import from BR-South-eastern grid	BR-North-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity, high voltage, import from BR-Southern grid	BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
electricity, high voltage, import from VE	BR-Northern grid; BR-Southern grid	2014-2017	electricity, high voltage	kWh	D
market for electricity, high voltage	BR-Mid-western grid; BR-South-eastern grid	2014-2017	electricity, high voltage	kWh	D
market for electricity, low voltage	BR-Mid-western grid; BR-South-eastern grid	2014-2017	electricity, low voltage	kWh	D
market for electricity, medium voltage	BR-Mid-western grid; BR-South-eastern grid	2017-2020	electricity, medium voltage	kWh	D
sulfate pulp production, from eucalyptus, bleached	BR-North-eastern grid; BR-Southern grid	2014-2017	electricity, high voltage	kWh	D

Activity Name	Geography	Time Period	Product name	Unit	v3.9
treatment of bagasse, from sugarcane, in heat and power co-generation unit, 6400kW thermal	BR-Mid-western grid; BR-South-eastern grid	2014-2014	electricity, high voltage	kWh	D

7.4 Transmission & distribution

7.4.1 Transmission infrastructure of high voltage electricity markets

In v3.9 the transmission infrastructure for all high voltage electricity markets was updated. For all datasets (except CH, see section 7.4.2) the transmission infrastructure inputs of “transmission network, electricity, high voltage” and “transmission network, long-distance” are replaced by new datasets on high voltage transmission lines (Table 62.). These datasets were provided by the University of Pforzheim based on Jorge (2012).

Table 62. New datasets for high voltage electricity transmission. If several geographies of the same activity with the same time period exist, all of them are listed in the “Geography” column. In the column v3.9, “N” stands for “New Activity”.

Activity Name	Geography	Time Period	Product name	Unit	v3.9
maintenance, transmission network, electricity, high voltage direct current aerial line	GLO; RER	1998-2012	maintenance, transmission network, electricity, high voltage direct current aerial line	km*year	N
maintenance, transmission network, electricity, high voltage direct current land cable	GLO; RER	1998-2012	maintenance, transmission network, electricity, high voltage direct current land cable	km*year	N
maintenance, transmission network, electricity, high voltage direct current subsea cable	GLO; RER	1998-2012	maintenance, transmission network, electricity, high voltage direct current subsea cable	km*year	N
market for maintenance, transmission network, electricity, high voltage direct current aerial line	GLO	1998-2012	maintenance, transmission network, electricity, high voltage direct current aerial line	km*year	N
market for maintenance, transmission network, electricity, high voltage direct current land cable	GLO	1998-2012	maintenance, transmission network, electricity, high voltage direct current land cable	km*year	N
market for maintenance, transmission network, electricity, high voltage direct current subsea cable	GLO	1998-2012	maintenance, transmission network, electricity, high voltage direct current subsea cable	km*year	N
market for transmission network, electricity, high voltage direct current aerial line	GLO	1998-2012	transmission network, electricity, high voltage direct current aerial line	km	N
market for transmission network, electricity, high voltage direct current land cable	GLO	1998-2012	transmission network, electricity, high voltage direct current land cable	km	N

Activity Name	Geography	Time Period	Product name	Unit	v3.9
market for transmission network, electricity, high voltage direct current subsea cable	GLO	1998-2012	transmission network, electricity, high voltage direct current subsea cable	km	N
transmission network construction, electricity, high voltage direct current aerial line	GLO; RER	1998-2012	transmission network, electricity, high voltage direct current aerial line	km	N
transmission network construction, electricity, high voltage direct current land cable	GLO; RER	1998-2012	transmission network, electricity, high voltage direct current land cable	km	N

With these new datasets, aerial, underground and subsea transmission cables are represented in separately. Based on information from Global Transmission Report (2022) country-specific amounts for transmission infrastructure were implemented where they were available. For electricity markets where no specific information was available, an average of surrounding countries was used. The electricity markets for which the transmission inputs were updated are listed in Table 63.

Table 63. High voltage electricity markets updated with new transmission datasets. If several geographies of the same activity with the same time period exist, all of them are listed in the “Geography” column. In the column v3.9, “U” stands for “Updated Activity.

Activity Name	Geography	Time Period	Product name	Unit	v3.9
market for electricity, high voltage	AE; AL; AM; AO; AR; AT; AU; AZ; BA; BD; BE; BG; BH; BJ; BN; BO; BW; BY; CA-AB; CA-BC; CA-MB; CA-NB; CA-NF; CA-NS; CA-NT; CA-NU; CA-ON; CA-PE; CA-SK; CA-YK; CD; CG; CI; CL; CM; CN-CCG; CN-ECGC; CN-NCGC; CN-NECG; CN-NWG; CN-SWG; CO; CR; CU; CW; CY; CZ; DE; DK; DO; DZ; EC; EE; EG; ER; ES; ET; FI; FR; GA; GB; GE; GH; GI; GLO; GR; GT; HK; HN; HR; HT; HU; ID; IE; IL; IN-Eastern grid; IN-North-eastern grid; IN-Northern grid; IN-Southern grid; IN-Western grid; IQ; IR; IS; IT; JM; JO; JP; KE; KG; KH; KP; KR; KW; KZ; LB; LK; LT; LU; LV; LY; MA; MD; ME; MK; MM; MN; MT; MU; MX; MY; MZ; NA; NE; NG; NI; NL; NO; NP; NZ; OM; PA; PE; PH; PK; PL; PT; PY; QA; RO; RS; RU; SA; SD; SE; SG; SI; SK; SN; SS; SV; SY; TG; TH; TJ; TM; TN; TR; TT; TW; TZ; UA; US-ASCC; US-FRCC; US-HICC; US-MRO; US-NPCC; US-PR; US-RFC; US-SERC; US-TRE; US-WECC; UY; UZ; VE; VN; XK; YE; ZA; ZM; ZW	2014-2017	electricity, high voltage	kWh	U
market for electricity, high voltage, aluminium industry	CA; CN; GLO; UN-OCEANIA	2015-2015	electricity, high voltage	kWh	U

Activity Name	Geography	Time Period	Product name	Unit	v3.9
market for electricity, high voltage, aluminium industry, IAI Area	Africa; EU27 & EFTA; Gulf Cooperation Council; Russia & RER w/o EU27 & EFTA; South America	2015-2015	electricity, high voltage	kWh	U
market for electricity, high voltage, cobalt industry	GLO	2012-2012	electricity, high voltage	kWh	U
market for electricity, high voltage, for internal use in coal mining	GLO	2012-2015	electricity, high voltage	kWh	U

7.4.2 Transmission infrastructure in Switzerland

For Switzerland the datasets for transmission infrastructure datasets (Table 64) were retained, however their inventory was updated based on data from Itten et al. (2014).

Table 64. Updated transmission infrastructure datasets for Switzerland. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity.

Activity Name	Geography	Time Period	Product name	Unit	v3.9
transmission network construction, electricity, high voltage	CH	1988-2014	transmission network, electricity, high voltage	km	U
transmission network construction, electricity, medium voltage	CH	1988-2020	transmission network, electricity, medium voltage	km	U
distribution network construction, electricity, low voltage	CH	1988-2020	distribution network, electricity, low voltage	km	U

7.5 Residual electricity mixes for Europe

For v3.9, datasets on residual mixes are added to the ecoinvent database. The residual mix is a virtual mix. It represents the energy mix of untracked consumption, i.e., electricity consumption that is not explicitly tracked through mechanisms such as Guarantees of Origin (GO). The shares of the residual mixes implemented in the ecoinvent database have been calculated based on statistics from AIB (2022) following the methodology of grexel (2020). The calculation area considered for the calculation of the residual mixes covers all members of EU28, Iceland, Norway, Serbia and Switzerland. The composition of the implemented residual mixes is valid for 2021.

The residual mixes have been modelled, following the same structure as the electricity markets in the database, delivering electricity on high, medium and low voltage levels, which are connected with transforming activities. The European Attribute Mix (EAM) has been modelled as separate datasets for clearer representation and is linked to the residual mixes of all deficit countries. For countries importing electricity outside of the calculation area (not covered by tracking mechanisms), these imports are represented through activity links directly in the residual mix datasets. Please refer to grexel (2020) for detailed methodology on residual mixes and their calculation.

Table 65. New datasets on residual mixes and European attribute mix. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity.

Activity Name	Geography	Time Period	Product name	Unit	v3.9
electricity, high voltage, european attribute mix	RER	2021-2021	electricity, high voltage	kWh	N
electricity, medium voltage, european attribute mix	RER	2021-2021	electricity, medium voltage	kWh	N
electricity, low voltage, european attribute mix	RER	2021-2021	electricity, low voltage	kWh	N
electricity, high voltage, residual mix	BA; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LT; LU; LV; ME; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK	2021-2021	electricity, high voltage	kWh	N
electricity, medium voltage, residual mix	BA; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LT; LU; LV; ME; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK	2021-2021	electricity, medium voltage	kWh	N
electricity, low voltage, residual mix	BA; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LT; LU; LV; ME; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK	2021-2021	electricity, low voltage	kWh	N
electricity voltage transformation, residual mix, from high to medium voltage	BA; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LT; LU; LV; ME; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK	2021-2021	electricity, medium voltage	kWh	N
electricity voltage transformation, residual mix, from medium to low voltage	BA; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR; HR; HU; IE; IS; IT; LT; LU; LV; ME; MT; NL; NO; PL; PT; RO; RS; SE; SI; SK	2021-2021	electricity, low voltage	kWh	N

7.6 Cadmium telluride (CdTe) photovoltaics

Updated datasets for "photovoltaic laminate production, CdTe" are included in v3.9 of ecoinvent. The data has been provided by First Solar (https://firstsolar.com). New production datasets were added for Vietnam (VN) and Malaysia (MY) and the dataset for the US has been updated. The production of CdTE laminate in Germany (DE) has seized, thus this dataset was deleted. Additions, changes and deletions are summarized in Table 66.

Table 66. New and updated datasets for CdTe laminate production. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity", "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name	Geography	Time Period	Product name	Unit	v3.9
photovoltaic laminate production, CdTe	MY; VN	2020-2020	photovoltaic laminate, CdTe	m2	N
photovoltaic laminate production, CdTe	GLO; US	2020-2020	photovoltaic laminate, CdTe	m2	U
photovoltaic laminate production, CdTe	DE	2004-2005	photovoltaic laminate, CdTe	m2	D

7.7 Corrections in compressed air energy storage

The lifetime of the gas turbines used for compressed air energy storage was revised to 30 years (Kelly et al., 2014). The datasets of Table 67 were modified to integrate this change.

Table 67. Updated datasets for the lifetime of the gas turbines in compressed air energy storage.. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product name	Unit	v3.9
compressed air energy storage plant construction, adiabatic, 150 MW electrical	GLO; RER	2015-2015	compressed air energy storage plant, adiabatic, 150 MW electrical	unit	U
gas turbine construction, 80MW electrical, for compressed air energy storage	GLO	2011-2015	gas turbine, 80MW, for compressed air energy storage	unit	U

8 Metals

8.1 Scarce and critical metals

New and updated datasets were provided by the Swiss Federal Laboratories for Materials Science and Technology, EMPA (sponsored by the Swiss Federal Office for the Environment, BAFU).

One of the updates concerns the production of antimony, which has been adapted to better represent the ore grade and recovery rates observed in China. In addition, the data for mining and production of calcium borates and sodium borates have been updated based on more recent literature data.

The new data covers the production of nuclear-grade zirconium sponge and hafnium sponge. Both metal sponges are commonly used in the production of components used in nuclear reactors.

The new and updated datasets are shown in Table 68.

Table 68. New and updated datasets for scarce and critical metals. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity", "U" stands for "Updated Activity" and "D" stands for "Deleted Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
antimony production	CN; GLO	1994-2021	antimony	kg	U
calcium borates production	GLO; TR	2000-2000	calcium borates	kg	D
chlorine, for reuse in zirconium and hafnium tetrachloride production, to generic market for chlorine	FR; GLO; US	2021-2021	chlorine, liquid	kg	N
colemanite mine operation and beneficiation	GLO; TR	2008-2013	calcium borates	kg	N
electrolysis of magnesium chloride, from hafnium sponge production	FR; GLO; US	2020-2024	magnesium chloride, from hafnium sponge production	kg	N
electrolysis of magnesium chloride, from zirconium sponge production	FR; GLO; US	2020-2024	magnesium chloride, from zirconium sponge production	kg	N
hafnium sponge production, from hafnium tetrachloride	FR; GLO; US	2020-2024	hafnium sponge	kg	N
magnesium, for reuse in hafnium sponge production, to generic market for magnesium	FR; GLO; US	2021-2021	magnesium	kg	N
magnesium, for reuse in zirconium sponge production, to generic market for magnesium	FR; GLO; US	2021-2021	magnesium	kg	N
market for antimony slag, desulfurised	GLO	2017-2018	antimony slag, desulfurised	kg	N
market for antimony slag, water-quenched	GLO	2017-2018	antimony slag, water-quenched	kg	N
market for chlorine, for reuse in zirconium and hafnium tetrachloride production	FR; GLO; US	2021-2021	chlorine, for reuse in zirconium and hafnium tetrachloride production	kg	N
market for hafnium sponge	GLO	2020-2024	hafnium sponge	kg	N

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
market for hafnium tetrachloride	GLO	2020-2024	hafnium tetrachloride	kg	N
market for magnesium chloride, from hafnium sponge production	GLO	2021-2021	magnesium chloride, from hafnium sponge production	kg	N
market for magnesium chloride, from zirconium sponge production	GLO	2021-2021	magnesium chloride, from zirconium sponge production	kg	N
market for magnesium, for reuse in hafnium sponge production	FR; GLO; US	2021-2021	magnesium, for reuse in hafnium sponge production	kg	N
market for magnesium, for reuse in zirconium sponge production	FR; GLO; US	2021-2021	magnesium, for reuse in zirconium sponge production	kg	N
market for zirconium sponge, nuclear-grade	GLO	2020-2024	zirconium sponge, nuclear-grade	kg	N
market for zirconium tetrachloride	GLO	2020-2024	zirconium tetrachloride	kg	N
sodium borate mine operation and beneficiation	GLO; US	2005-2013	sodium borates	kg	N
sodium borates production	GLO; US	2000-2000	sodium borates	kg	D
stibnite mine operation and beneficiation	CA-QC; CN; GLO	1994-2020	stibnite concentrate	kg	U
treatment of antimony slag, desulfurised, residual material landfill	GLO	2017-2018	antimony slag, desulfurised	kg	N
treatment of antimony slag, water-quenched, residual material landfill	GLO	2017-2018	antimony slag, water-quenched	kg	N
zirconium and hafnium tetrachloride production, from zircon	FR; GLO; US	2020-2024	hafnium tetrachloride; zirconium tetrachloride	kg; kg	N
zirconium sponge production, from zirconium tetrachloride	FR; GLO; US	2020-2024	zirconium sponge, nuclear-grade	kg	N

8.2 Replacement of long-term emissions

Some datasets modelling the mining and production of metals contained emissions to air with the subcompartment “low population density, long-term”. This subcompartment was considered inadequate for modelling the emissions in those activities. The exchanges with that subcompartment were therefore replaced with the equivalent exchange with the subcompartment “non-urban air or from high stacks”. The datasets concerned by this change are listed in Table 69.

Table 69. Datasets in which the emissions with the subcompartment “low population density, long-term” were replaced. If several geographies of the same activity with the same time period exist, all of them are listed in the “Geography” column.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
electrolysis of magnesium chloride, from titanium sponge production	CN; GLO; JP	2020-2024	magnesium chloride, from titanium sponge production	kg
ferroniobium production, from pyrochlore concentrate, 66% Nb	BR; GLO	2019-2023	ferroniobium, 66% Nb	kg

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
rare earth oxides production, from rare earth carbonate concentrate	CN-FJ	2017-2018	cerium oxide; europium oxide; lanthanum oxide; neodymium oxide; samarium oxide; ytterbium oxide; yttrium oxide	kg; kg; kg; kg; kg; kg; kg
rare earth oxides production, from rare earth oxide concentrate, 50% REO	CN-NM	2017-2018	cerium oxide; lanthanum oxide; neodymium oxide; samarium-europium-gadolinium oxide	kg; kg; kg; kg
rare earth oxides production, from rare earth oxide concentrate, 70% REO	CN-SC	2017-2018	cerium oxide; europium oxide; lanthanum oxide; lanthanum-cerium oxide; praseodymium-neodymium oxide; samarium oxide; yttrium oxide	kg; kg; kg; kg; kg; kg; kg
smelting and refining of nickel concentrate, 7% Ni	CN	2017-2018	nickel, class 1	kg
titanium tetrachloride production	CN; GLO; JP	2020-2024	titanium tetrachloride	kg
electrolysis of magnesium chloride, from titanium sponge production	CN; GLO; JP	2020-2024	magnesium chloride, from titanium sponge production	kg

8.3 Correction of Tellurium extraction in copper mining

The amount of the elementary exchange "Tellurium", in ground, in the activities "copper mine operation and beneficiation, sulfide ore" (all geographies) was identified as being overestimated. It was therefore corrected in order to be aligned with the mass flow analysis described in Turner & Hischier (2020). The list of datasets affected by this correction is given in Table 70.

Table 70. Datasets in which the amount of "Tellurium", in ground, was updated. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column.

Activity Name in v3.9	Geography	Time Period	Product Name	Unit
copper mine operation and beneficiation, sulfide ore	AU; CA; CL; CN; GLO; ID; KZ; RU; US; ZM	1994-2021	copper concentrate, sulfide ore	kg

8.4 Update of transport in markets

The transport inputs in markets for certain concentrates and metals were changed in order to harmonize the transport modes and distances for markets of similar products and to add transport for products that previously did not have any transport. The list of market activities that were updated in the metals sector is provided in Table 71.

Table 71. Market activities in the metals sector for which transport inputs were added or updated. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column "v3.9, "A" stands for "Added", "U" stands for "Updated".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
market for copper concentrate, sulfide ore	GLO	2011-2011	copper concentrate, sulfide ore	kg	A
market for copper telluride cement	GLO	2011-2011	copper telluride cement	kg	A
market for copper, cathode	GLO	2011-2011	copper, cathode	kg	A
market for rutile, 95% titanium dioxide	GLO	2000-2015	rutile, 95% titanium dioxide	kg	A
market for titania slag, 85% titanium dioxide	GLO	2015-2015	titania slag, 85% titanium dioxide	kg	U
market for titanium	GLO	2022-2022	titanium	kg	A
market for titanium sponge	GLO	2020-2024	titanium sponge	kg	U
market for titanium tetrachloride	GLO	2022-2022	titanium tetrachloride	kg	A
market for titanium, triple-melt	GLO	2022-2022	titanium, triple-melt	kg	A

9 Pulp and paper

9.1 Sulfate pulp

Data for sulfate pulp production were updated based on data which was provided by the European Pulp Industry Sector Association AISBL (EPIS). In addition to the update of existing datasets, new datasets are available for the production of unbeached softwood pulp in the region of Latin America and the Caribbean and sulfate pulp production from eucalyptus for the region of Europe. New and updated datasets are shown in Table 72.

Table 72. New and updated activities related to sulfate pulp production. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. The unit of all reference products is kg. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product Name	v3.9
sulfate pulp production, from eucalyptus, bleached	RER	2020 - 2022	sulfate pulp, bleached	N
sulfate pulp production, from eucalyptus, bleached	GLO; RLA	2020 - 2022	sulfate pulp, bleached	U
sulfate pulp production, from hardwood, bleached	RER	2020 - 2022	sulfate pulp, bleached	U
sulfate pulp production, from hardwood, bleached	GLO	2011-2022	sulfate pulp, bleached	U
sulfate pulp production, from softwood, bleached	GLO; RER	2020 - 2022	sulfate pulp, bleached	U
sulfate pulp production, from softwood, unbleached	GLO; RER	2020 - 2022	sulfate pulp, unbleached	U
sulfate pulp production, from softwood, unbleached	RLA	2020 - 2022	sulfate pulp, unbleached	N

9.2 Containerboard

Data for European containerboard and corrugate board box production were updated based on the 2018 European Database for Corrugated Board Life Cycle Studies issued by the European Federation of Corrugated Board Manufacturer and Cepi ContainerBoard (FFECO, 2018). The update was performed in collaboration with RISE Research Institutes of Sweden.

In addition, new data for containerboard production and corrugate board box production for the region US have been added. The US data were provided by National Council for Air and Stream Improvement, Inc. (NCASI) and are based on a LCA study conducted by NCASI (2014). The new activity "containerboard production, unspecified" produces the reference product "containerboard, unspecified" representing an US-average containerboard.

New and updated datasets related to containerboard production are shown in Table 73.

Table 73. New and updated activities related to containerboard production. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. The unit of all reference products is kg. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	Product Name	v3.9
containerboard production, fluting medium, semichemical	GLO; RER	2018 - 2022	containerboard, fluting medium	U
containerboard production, fluting medium, recycled	GLO; RER	2018 - 2022	containerboard, fluting medium	U
containerboard production, linerboard, kraftliner	CA-QC; GLO; RER	2018 - 2022	containerboard, linerboard	U
containerboard production, linerboard, testliner	GLO	2007-2022	containerboard, linerboard	U
containerboard production, linerboard, testliner	RER	2018 - 2022	containerboard, linerboard	U
containerboard production, unspecified	US	2014 - 2022	containerboard, unspecified	N
market for containerboard, unspecified	US	2014 - 2022	containerboard, unspecified	N
corrugated board box production	CA-QC	2008 - 2008	corrugated board box	U
corrugated board box production	RER	2018-2022	corrugated board box	U
corrugated board box production	GLO	2008 - 2022	corrugated board box	U
corrugated board box production	US	2014-2022	corrugated board box	N
market for corrugated board box	US	2014-2022	corrugated board box	N

9.3 Kraft paper

The activities for kraft paper production were updated based on a study by CEPI Eurokraft in 2020. Data were collected specifically for sack kraft paper production but are also considered as representative for other kraft packaging papers. The update was performed in collaboration with RISE Research Institutes of Sweden. The updated datasets are shown in Table 74.

Table 74. Updated activities related to kraft paper. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. The unit of all reference products is kg. In the column v3.9, "U" stands for "Updated Activity".

Activity Name	Geography	Time Period	v3.9
kraft paper production	GLO; RER	2018 - 2022	U

9.4 Liquid packaging board

Data for liquid packaging board production were updated based on industry data collected by The Alliance for Beverage Cartons and the Environment (ACE) which commissioned the Institut für Energie- und Umweltforschung Heidelberg (ifeu) with the provision of the data to the ecoinvent database. In the context of this update, a new dataset for “liquid packaging board production” in Europe has been added. New and updated datasets related to liquid packaging board production are listed in Table 75.

Table 75. New and updated activities related to liquid packaging board. The unit of all reference products is kg. In the column v3.9, “N” stands for “New Activity” and “U” stands for “Updated Activity”.

Activity Name	Geography	Time Period	Product Name	v3.9
liquid packaging board production	RER	2018 - 2018	liquid packaging board	N
liquid packaging board production	GLO	2018 - 2018	liquid packaging board	U
market for liquid packaging board	GLO	2018 - 2018	liquid packaging board	U
market for liquid packaging board	RER	2018 - 2018	liquid packaging board	N
lime, from liquid packaging board production to generic market for soil pH raising agent	GLO	2022 - 2022	soil pH raising agent, as CaCO3	N
market for lime, from liquid packaging board production	GLO	2022 - 2022	lime, from liquid packaging board production	N

9.5 Other updates

Minor updates were made to other activities in relation to the pulp and paper sector which are listed in Table 76. These changes include updates of exchanges and properties.

Table 76. Other activities updated related to the Pulp and Paper sector. The unit of all reference products is kg.

Activity Name	Geography	Time Period	Product Name
offset printing, per kg printed paper	CH; GLO	2007 - 2011	offset printing, per kg printed paper
containerboard production, fluting medium, semichemical, 40% recycled content	CA-QC; GLO	2009 - 2009	containerboard, fluting medium
tall oil refinery operation	GLO	2010 - 2020	rosin size, for paper production
treatment of waste paper to pulp, wet lap, totally chlorine free bleached	CA-QC; GLO	2007-2007	waste paper, unsorted

10 Waste

Version 3.9 introduces several updates and methodological changes to the waste sector.

10.1 Waste disaggregation

The waste sector in the ecoinvent database comprises of more than 1600 datasets, covering the management of wastes and wastewaters from a wide variety of sectors producing them. The sector can be subdivided into solid waste management (SWM) and wastewater treatment (WWT).

When a waste is generated, it naturally passes several treatment steps and potentially more wastes (out of this waste) are generated until the original waste finally disposed. For example, municipal solid waste that is treated in a waste incineration is generating several other wastes such as bottom ass and other incineration residues which in turn need to be treated.

Up to and including version 3.8, a treatment dataset in the ecoivnent database handles in one single dataset, the treatment of a waste and all treatment steps for wastes generated by this waste. Consequently, a waste treatment process is an aggregation of treatments.

In v.3.9 the disaggregation of treatments is introduced for the first time in the database and in the wastewater sector. Meaning all wastewater treatment activities are now disaggregated into the different treatment steps for wastes generated during the wastewater treatment.

10.1.1 Updates

All wastewater treatment datasets have been disaggregated and have been updated. The core modelling methodology remains unaltered: burdens are calculated based on waste (in this case wastewater) specific elemental composition (composition). It is important to report here that the update refers mostly to the methodological change of introducing the disaggregation. The wastewater composition of the wastewaters used remains unaltered compared to older versions.

10.1.2 Naming convention

In v.3.9 a new naming convention is introduced in the sector for the updated and the new datasets. The naming convention is implemented now to new and updated datasets but it will eventually be applied in all datasets in the future versions. It refers to activity names and waste or wastewater names.

10.1.2.1 Activity names

All new treatment activity names have three elements,

a) the term introducing that this activity is a treatment

b) the name of the waste or wastewater (details also in section Waste or wastewater names)

c) and a suffix that clearly defines the treatment process

For example, “treatment of wastewater, average, wastewater treatment”

The naming convention allows users to efficiently look for

a) all available treatment options for a specific waste or wastewater by searching using the name of the waste or wastewater (wastewater, average)

b) all wastes or wastewaters treated by a specific treatment by searching using the term of the treatment (wastewater treatment)

c) all treatment activities by searching using the term of the treatment (treatment of)

10.1.2.2 Waste or wastewater names

The disaggregation inevitably generates new wastes within the database and their names are designed in a manner to reflect the waste treatment chain.

The new names of the waste or wastewater generated due to disaggregation have three elements

a) The name of the waste itself

b) The treatment chain this waste was generated from. Here only the treatments are reported in capital letters separated with a dash (-)

c) The original waste or wastewater name in the beginning of the treatment chain

For example: “residues, MSWI-WWT, WW, average” where

a= residues, b= MSWI-WWT, and c= WW, average

List of abbreviations in treatment chains, within the waste name

- MSWI: Municipal solid waste incineration
- MSWI[F]: Municipal solid waste incineration, with fly ash extraction
- WWT: Wastewater treatment
- WWT[U]: Wastewater treatment, urban
- WWT[R]: Wastewater treatment, rural
- WW: Wastewater

10.1.3 Wastewater treatments and new datasets

Wastewater treatment processes now generate sludge as the main by-product; the composition and the water content of the sludge are related to the treatment of the sludge that will follow (the wastewater treatment) with potential options being, landfill (sanitary or unsanitary), municipal incineration and landfarming. A prime example of compositional difference is between the sludge for landfarming and the sludge for incineration. The latter one is drier (70% water) whereas the former is more wet (97% water). Based on each geography, the wastewater treatment dataset is a weighted average treatment based on a national level. The weighting keys are the possible sludge fates of the different wastewater plants. The wastewater treatments therefore represent a weighted average dataset with the national shares of the sludge fate as weighting keys.

New wastes (introduced due to the waste disaggregation) are shown in the table below. The wastes are generated in treatments and where those wastes are further treated can also be seen in the table below. Finally, when the market transporting a wastewater has losses it is also shown.

Table 77. New and updated wastes and wastewaters in version 3.9. SC: Slag compartment, RML: Residual material landfill, MI: Municipal incineration, SLF: Sanitary landfill, LF: Landfarming, WWT: Wastewater treatment. T, G, and Y stand for treated, generated and yes respectively.

Waste	SC	RML	MI	SLF	LF	WWT	L	N
bottom ash, MSWI[F]-WWT, condensate from light oil boiler	T		G					Y
bottom ash, MSWI[F]-WWT, heat carrier liquid, 40% C3H8O2	T		G					Y
bottom ash, MSWI[F]-WWT, rainwater mineral oil storage	T		G					Y
bottom ash, MSWI[F]-WWT, WW from black chrome coating	T		G					Y
bottom ash, MSWI[F]-WWT, WW from ceramic production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from concrete production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from CRT production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from glass production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from grass refinery	T		G					Y
bottom ash, MSWI[F]-WWT, WW from LCD backlight production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from LCD production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from liquid crystal production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from maize starch production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from pig iron production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from plywood production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from potato starch production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from PV cell production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from soft fibreboard production	T		G					Y

Waste	SC	RML	MI	SLF	LF	WWT	L	N
bottom ash, MSWI[F]-WWT, WW from tube collector production	T		G					Y
bottom ash, MSWI[F]-WWT, WW from wafer fabrication	T		G					Y
bottom ash, MSWI[F]-WWT, WW, average	T		G					Y
bottom ash, MSWI[F]-WWT[R], WW from anaerobic digestion of whey	T		G					Y
bottom ash, MSWI[F]-WWT[U], WW from lorry production	T		G					Y
bottom ash, MSWI-WWT, condensate from light oil boiler	T		G					Y
bottom ash, MSWI-WWT, heat carrier liquid, 40% C3H8O2	T		G					Y
bottom ash, MSWI-WWT, rainwater mineral oil storage	T		G					Y
bottom ash, MSWI-WWT, WW from ammonium paratungstate production	T		G					Y
bottom ash, MSWI-WWT, WW from black chrome coating	T		G					Y
bottom ash, MSWI-WWT, WW from ceramic production	T		G					Y
bottom ash, MSWI-WWT, WW from concrete production	T		G					Y
bottom ash, MSWI-WWT, WW from CRT production	T		G					Y
bottom ash, MSWI-WWT, WW from GGBFS production	T		G					Y
bottom ash, MSWI-WWT, WW from glass production	T		G					Y
bottom ash, MSWI-WWT, WW from grass refinery	T		G					Y
bottom ash, MSWI-WWT, WW from hard fibreboard production	T		G					Y
bottom ash, MSWI-WWT, WW from LCD backlight production	T		G					Y
bottom ash, MSWI-WWT, WW from LCD production	T		G					Y
bottom ash, MSWI-WWT, WW from liquid crystal production	T		G					Y
bottom ash, MSWI-WWT, WW from maize starch production	T		G					Y
bottom ash, MSWI-WWT, WW from medium density board production	T		G					Y
bottom ash, MSWI-WWT, WW from particle board production	T		G					Y
bottom ash, MSWI-WWT, WW from pig iron production	T		G					Y
bottom ash, MSWI-WWT, WW from plywood production	T		G					Y
bottom ash, MSWI-WWT, WW from potato starch production	T		G					Y
bottom ash, MSWI-WWT, WW from PV cell production	T		G					Y
bottom ash, MSWI-WWT, WW from soft fibreboard production	T		G					Y
bottom ash, MSWI-WWT, WW from tube collector production	T		G					Y
bottom ash, MSWI-WWT, WW from vegetable oil refinery	T		G					Y
bottom ash, MSWI-WWT, WW from wafer fabrication	T		G					Y
bottom ash, MSWI-WWT, WW, average	T		G					Y
bottom ash, MSWI-WWT[R], WW from anaerobic digestion of whey	T		G					Y
bottom ash, MSWI-WWT[U], WW from lorry production	T		G					Y
condensate from light oil boiler						T	Y	Y
heat carrier liquid, 40% C3H8O2						T	Y	Y

Waste	SC	RML	MI	SLF	LF	WWT	L	N
rainwater mineral oil storage						T	Y	Y
residues, MSWI[F]-WWT, condensate from light oil boiler		T	G					Y
residues, MSWI[F]-WWT, heat carrier liquid, 40% C3H8O2		T	G					Y
residues, MSWI[F]-WWT, rainwater mineral oil storage		T	G					Y
residues, MSWI[F]-WWT, WW from black chrome coating		T	G					Y
residues, MSWI[F]-WWT, WW from ceramic production		T	G					Y
residues, MSWI[F]-WWT, WW from concrete production		T	G					Y
residues, MSWI[F]-WWT, WW from CRT production		T	G					Y
residues, MSWI[F]-WWT, WW from glass production		T	G					Y
residues, MSWI[F]-WWT, WW from grass refinery		T	G					Y
residues, MSWI[F]-WWT, WW from LCD backlight production		T	G					Y
residues, MSWI[F]-WWT, WW from LCD production		T	G					Y
residues, MSWI[F]-WWT, WW from liquid crystal production		T	G					Y
residues, MSWI[F]-WWT, WW from maize starch production		T	G					Y
residues, MSWI[F]-WWT, WW from pig iron production		T	G					Y
residues, MSWI[F]-WWT, WW from plywood production		T	G					Y
residues, MSWI[F]-WWT, WW from potato starch production		T	G					Y
residues, MSWI[F]-WWT, WW from PV cell production		T	G					Y
residues, MSWI[F]-WWT, WW from soft fibreboard production		T	G					Y
residues, MSWI[F]-WWT, WW from tube collector production		T	G					Y
residues, MSWI[F]-WWT, WW from wafer fabrication		T	G					Y
residues, MSWI[F]-WWT, WW, average		T	G					Y
residues, MSWI[F]-WWT[R], WW from anaerobic digestion of whey		T	G					Y
residues, MSWI[F]-WWT[U], WW from lorry production		T	G					Y
residues, MSWI-WWT, condensate from light oil boiler		T	G					Y
residues, MSWI-WWT, heat carrier liquid, 40% C3H8O2		T	G					Y
residues, MSWI-WWT, rainwater mineral oil storage		T	G					Y
residues, MSWI-WWT, WW from ammonium paratungstate production		T	G					Y
residues, MSWI-WWT, WW from black chrome coating		T	G					Y
residues, MSWI-WWT, WW from ceramic production		T	G					Y
residues, MSWI-WWT, WW from concrete production		T	G					Y
residues, MSWI-WWT, WW from CRT production		T	G					Y
residues, MSWI-WWT, WW from GGBFS production		T	G					Y
residues, MSWI-WWT, WW from glass production		T	G					Y
residues, MSWI-WWT, WW from grass refinery		T	G					Y
residues, MSWI-WWT, WW from hard fibreboard production		T	G					Y
residues, MSWI-WWT, WW from LCD backlight production		T	G					Y
residues, MSWI-WWT, WW from LCD production		T	G					Y

Waste	SC	RML	MI	SLF	LF	WWT	L	N
residues, MSWI-WWT, WW from liquid crystal production		T	G					Y
residues, MSWI-WWT, WW from maize starch production		T	G					Y
residues, MSWI-WWT, WW from medium density board production		T	G					Y
residues, MSWI-WWT, WW from particle board production		T	G					Y
residues, MSWI-WWT, WW from pig iron production		T	G					Y
residues, MSWI-WWT, WW from plywood production		T	G					Y
residues, MSWI-WWT, WW from potato starch production		T	G					Y
residues, MSWI-WWT, WW from PV cell production		T	G					Y
residues, MSWI-WWT, WW from soft fibreboard production		T	G					Y
residues, MSWI-WWT, WW from tube collector production		T	G					Y
residues, MSWI-WWT, WW from vegetable oil refinery		T	G					Y
residues, MSWI-WWT, WW from wafer fabrication		T	G					Y
residues, MSWI-WWT, WW, average		T	G					Y
residues, MSWI-WWT[R], WW from anaerobic digestion of whey		T	G					Y
residues, MSWI-WWT[U], WW from lorry production		T	G					Y
sewage sludge, 70% water, WWT, condensate from light oil boiler			T			G		Y
sewage sludge, 70% water, WWT, heat carrier liquid, 40% C3H8O2			T			G		Y
sewage sludge, 70% water, WWT, rainwater mineral oil storage			T			G		Y
sewage sludge, 70% water, WWT, WW from ammonium paratungstate production			T			G		Y
sewage sludge, 70% water, WWT, WW from black chrome coating			T			G		Y
sewage sludge, 70% water, WWT, WW from ceramic production			T			G		Y
sewage sludge, 70% water, WWT, WW from concrete production			T			G		Y
sewage sludge, 70% water, WWT, WW from CRT production			T			G		Y
sewage sludge, 70% water, WWT, WW from GGBFS production			T			G		Y
sewage sludge, 70% water, WWT, WW from glass production			T			G		Y
sewage sludge, 70% water, WWT, WW from grass refinery			T			G		Y
sewage sludge, 70% water, WWT, WW from hard fibreboard production			T			G		Y
sewage sludge, 70% water, WWT, WW from LCD backlight production			T			G		Y
sewage sludge, 70% water, WWT, WW from LCD production			T			G		Y
sewage sludge, 70% water, WWT, WW from liquid crystal production			T			G		Y
sewage sludge, 70% water, WWT, WW from maize starch production			T			G		Y
sewage sludge, 70% water, WWT, WW from medium density board production			T			G		Y
sewage sludge, 70% water, WWT, WW from particle board production			T			G		Y

Waste	SC	RML	MI	SLF	LF	WWT	L	N
sewage sludge, 70% water, WWT, WW from pig iron production			T			G		Y
sewage sludge, 70% water, WWT, WW from plywood production			T			G		Y
sewage sludge, 70% water, WWT, WW from potato starch production			T			G		Y
sewage sludge, 70% water, WWT, WW from PV cell production			T			G		Y
sewage sludge, 70% water, WWT, WW from soft fibreboard production			T			G		Y
sewage sludge, 70% water, WWT, WW from tube collector production			T			G		Y
sewage sludge, 70% water, WWT, WW from vegetable oil refinery			T			G		Y
sewage sludge, 70% water, WWT, WW from wafer fabrication			T			G		Y
sewage sludge, 70% water, WWT, WW, average			T			G		Y
sewage sludge, 70% water, WWT[R], WW from anaerobic digestion of whey			T			G		Y
sewage sludge, 70% water, WWT[U], WW from lorry production			T			G		Y
sewage sludge, 75% water, WWT, condensate from light oil boiler				T		G		Y
sewage sludge, 75% water, WWT, heat carrier liquid, 40% C3H8O2				T		G		Y
sewage sludge, 75% water, WWT, rainwater mineral oil storage				T		G		Y
sewage sludge, 75% water, WWT, WW from ammonium paratungstate production				T		G		Y
sewage sludge, 75% water, WWT, WW from black chrome coating				T		G		Y
sewage sludge, 75% water, WWT, WW from ceramic production				T		G		Y
sewage sludge, 75% water, WWT, WW from concrete production				T		G		Y
sewage sludge, 75% water, WWT, WW from CRT production				T		G		Y
sewage sludge, 75% water, WWT, WW from GGBFS production				T		G		Y
sewage sludge, 75% water, WWT, WW from glass production				T		G		Y
sewage sludge, 75% water, WWT, WW from grass refinery				T		G		Y
sewage sludge, 75% water, WWT, WW from hard fibreboard production				T		G		Y
sewage sludge, 75% water, WWT, WW from LCD backlight production				T		G		Y
sewage sludge, 75% water, WWT, WW from LCD production				T		G		Y
sewage sludge, 75% water, WWT, WW from liquid crystal production				T		G		Y
sewage sludge, 75% water, WWT, WW from maize starch production				T		G		Y
sewage sludge, 75% water, WWT, WW from medium density board production				T		G		Y
sewage sludge, 75% water, WWT, WW from particle board production				T		G		Y
sewage sludge, 75% water, WWT, WW from pig iron production				T		G		Y
sewage sludge, 75% water, WWT, WW from plywood production				T		G		Y

Waste	SC	RML	MI	SLF	LF	WWT	L	N
sewage sludge, 75% water, WWT, WW from potato starch production				T		G		Y
sewage sludge, 75% water, WWT, WW from PV cell production				T		G		Y
sewage sludge, 75% water, WWT, WW from soft fibreboard production				T		G		Y
sewage sludge, 75% water, WWT, WW from tube collector production				T		G		Y
sewage sludge, 75% water, WWT, WW from vegetable oil refinery				T		G		Y
sewage sludge, 75% water, WWT, WW from wafer fabrication				T		G		Y
sewage sludge, 75% water, WWT, WW, average				T		G		Y
sewage sludge, 75% water, WWT[R], WW from anaerobic digestion of whey				T		G		Y
sewage sludge, 75% water, WWT[U], WW from lorry production				T		G		Y
sewage sludge, 97% water, WWT, condensate from light oil boiler					T	G		Y
sewage sludge, 97% water, WWT, heat carrier liquid, 40% C3H8O2					T	G		Y
sewage sludge, 97% water, WWT, rainwater mineral oil storage					T	G		Y
sewage sludge, 97% water, WWT, WW from ammonium paratungstate production					T	G		Y
sewage sludge, 97% water, WWT, WW from black chrome coating					T	G		Y
sewage sludge, 97% water, WWT, WW from ceramic production					T	G		Y
sewage sludge, 97% water, WWT, WW from concrete production					T	G		Y
sewage sludge, 97% water, WWT, WW from CRT production					T	G		Y
sewage sludge, 97% water, WWT, WW from GGBFS production					T	G		Y
sewage sludge, 97% water, WWT, WW from glass production					T	G		Y
sewage sludge, 97% water, WWT, WW from grass refinery					T	G		Y
sewage sludge, 97% water, WWT, WW from hard fibreboard production					T	G		Y
sewage sludge, 97% water, WWT, WW from LCD backlight production					T	G		Y
sewage sludge, 97% water, WWT, WW from LCD production					T	G		Y
sewage sludge, 97% water, WWT, WW from liquid crystal production					T	G		Y
sewage sludge, 97% water, WWT, WW from maize starch production					T	G		Y
sewage sludge, 97% water, WWT, WW from medium density board production					T	G		Y
sewage sludge, 97% water, WWT, WW from particle board production					T	G		Y
sewage sludge, 97% water, WWT, WW from pig iron production					T	G		Y
sewage sludge, 97% water, WWT, WW from plywood production					T	G		Y
sewage sludge, 97% water, WWT, WW from potato starch production					T	G		Y
sewage sludge, 97% water, WWT, WW from PV cell production					T	G		Y

Waste	**SC**	**RML**	**MI**	**SLF**	**LF**	**WWT**	**L**	**N**
sewage sludge, 97% water, WWT, WW from soft fibreboard production					T	G		Y
sewage sludge, 97% water, WWT, WW from tube collector production					T	G		Y
sewage sludge, 97% water, WWT, WW from vegetable oil refinery					T	G		Y
sewage sludge, 97% water, WWT, WW from wafer fabrication					T	G		Y
sewage sludge, 97% water, WWT, WW, average					T	G		Y
sewage sludge, 97% water, WWT[R], WW from anaerobic digestion of whey					T	G		Y
sewage sludge, 97% water, WWT[U], WW from lorry production					T	G		Y
wastewater from ammonium paratungstate production						T	Y	
wastewater from anaerobic digestion of whey						T	Y	
wastewater from black chrome coating						T	Y	
wastewater from cathode ray tube production						T	Y	
wastewater from ceramic production						T	Y	
wastewater from concrete production						T	Y	
wastewater from glass production						T	Y	
wastewater from grass refinery						T	Y	
wastewater from ground granulated blast furnace slag production						T	Y	
wastewater from hard fibreboard production						T	Y	
wastewater from liquid crystal display backlight production						T	Y	
wastewater from liquid crystal display production						T	Y	
wastewater from liquid crystal production						T	Y	
wastewater from lorry production						T	Y	
wastewater from maize starch production						T	Y	
wastewater from medium density board production						T	Y	
wastewater from particle board production						T	Y	
wastewater from pig iron production						T	Y	
wastewater from plywood production						T	Y	
wastewater from potato starch production						T	Y	
wastewater from PV cell production						T	Y	
wastewater from soft fibreboard production						T	Y	
wastewater from textile production						T	Y	
wastewater from tube collector production						T	Y	
wastewater from vegetable oil refinery						T	Y	
wastewater from wafer fabrication						T	Y	
wastewater, average						T	Y	
wastewater, unpolluted						T	Y	

10.1.4 New elementary exchanges in waste treatment datasets

New datasets feature three new elementary exchanges that help calculate LCIA scores for a specific method (Ecological Scarcity 2021), category (waste disposal) and indicator (waste, non radioactive) or specific system models (EN 15804).

10.1.4.1 Waste hazardousness

For EN 15804, a new elementary exchange is added in new and updated treatment datasets for the hazardousness of the waste. “Non-hazardous waste disposed” or “Hazardous waste disposed”. This information is extracted by the available treatments that a waste receives within the database. Below there is a list of potential treatments and the characterisation the wastes receive. For example, a new “municipal incineration” dataset will have the elementary exchange of “Non-hazardous waste disposed” with an amount that equals the waste treated.

Table 78. Treatment categories and their suitability for treating wastes

Treatment tag	Hazardous characterization
anaerobic digestion	FALSE
dismantling	FALSE
home composting	FALSE
industrial composting	FALSE
inert material landfill	FALSE
landfarming	FALSE
municipal incineration	FALSE
open burning	FALSE
open dump	FALSE
sanitary landfill	FALSE
shredding	FALSE
unsanitary landfill	FALSE
residual material landfill	TRUE
conditioning	TRUE
final repository	TRUE
hazardous waste incineration	TRUE
impoundment	TRUE
interim storage	TRUE
opencast refill	TRUE
plasma torch incineration	TRUE
reprocessing	TRUE
surface or trench deposit	TRUE
tailings impoundment	TRUE
underground deposit	TRUE

A waste can be treated in treatments that treat both types of wastes. For example, “waste emulsion paint” can be treated by both “hazardous waste incineration” and “municipal incineration”. In the former case, the dataset will have the elementary exchange of “Hazardous waste disposed” whilst in the latter one the elementary exchange of “Non-hazardous waste disposed”. The datasets that generate this waste (waste emulsion paint) will in end receive a mixed LCIA for the indicator in discussion.

10.1.5 Eco scarcity indicators

Two unique elementary exchanges have been added to new datasets that support calculations for specific ecoscarcity indicators (). Those are the following: “Waste mass, total, placed in landfill” and “Organic carbon, placed in landfill”. Both are “FromEnvironment” with compartment “inventory indicator” and sub compartment “waste”. Both exchanges are found in new landfill datasets such as new slag compartment, residual material landfill and sanitary landfill datasets.

“Waste mass, total, placed in landfill” is measured in wet mass units (kg) and represents the amount of a waste that is disposed (eternal deposition) in a landfill of any sort (sanitary landfills, residual material landfill and slag compartments).

“Organic carbon, placed in landfill” is measured in mass units (kg) and represents the amount of organic carbon that is disposed in sanitary landfills, residual material landfill and slag compartments. The method ensures that ensures that the anticipated chemical reactions, landfill gas and leachate formation are appropriately taken into account in the life cycle assessment.

More information about the two elementary exchanges described above can be found in FOEN 2021.

10.1.6 Wastewater not treated – losses

In almost every part of the world, all the wastewater that enters the wastewater treatment plant is not fully treated and the wastewater is thus directly emitted to the environment. Further, not all wastewater produced is finally reaching the wastewater treatment plant. In v.3.9 this is for the first time modelled in the wastewater market in the form of wastewater losses. The elemental composition of the wastewater is matched with elementary exchanges of emissions to the environment. The amount of emissions is dependent on the amount of wastewater that is not treated on an average situation in a country.

10.1.7 Rural and Urban wastewater treatments

An urban or rural setting for wastewater treatment is defined. When information on the location of the treatment is known then this setting is used, otherwise and when not mentioned, all wastewater treatment datasets refer to a country average mix of the two possibilities. The size of the plant also affects the infrastructure employed by the treatment. Detailed modelling parameters related to infrastructure can be found in Doka G. 2021.

11 Other sectors

11.1 Forestry and Wood

Minor updates were made to other activities in relation to the Forestry and Wood Sector which are listed in Table 79. These changes include updates of exchanges, properties, and production Volumes.

Table 79. Other activities updated related to the Forestry and Wood sector. In the column v3.9, "U" stands for "Updated Activity", "D" stands for "Deleted Activity", and "PV" indicates that the only quantitative change was an update to the production volume of the output(s).

Activity Name	Geography	Time Period	Product Name	Unit	v3.9
debarking, hardwood, azobe	GLO; RER	2000 - 2005	sawlog and veneer log, azobe, debarked, measured as solid wood	m3	PV
debarking, hardwood, meranti	GLO; MY	2000 - 2005	sawlog and veneer log, meranti, debarked, measured as solid wood	m3	PV
glued laminated timber production, average glue mix	CA-QC	2009 - 2001	glued laminated timber, average glue mix	m3	U
market for sawlog and veneer log, azobe, measured as solid wood under bark	CM; GLO	2019-2019	sawlog and veneer log, azobe, measured as solid wood under bark	m3	D
oriented strand board production	CA-QC	2005 - 2006	oriented strand board	m3	U
sawing and planing, azobe, air dried	GLO; RER	2000 - 2005	sawnwood, azobe, dried (u=15%), planed	m3	PV
wood cladding production, softwood	CA-QC; GLO	2012-2012	wood cladding, softwood	m2	U
wood preservation, hot/cold dipping, creosote, outdoor use, ground contact	GLO; RER	2008-2008	wood preservation, hot/cold dipping, creosote, outdoor use, ground contact	kg	U

11.2 Lithium iron phosphate batteries

For ecoinvent v3.9 new datasets for Lithium Iron Phosphate (LFP) batteries are included in the ecoinvent database. These datasets were created by the Swiss Federal Laboratories for Materials Science and Technology (EMPA), based on a publication of Dai et al. (2018) and include battery components (cathode, cell, battery) specifically for this type of battery as well as datasets covering the production of lithium iron phosphate through hydrothermal and solid state process adapted from Dunn et al. (2014). Complementary, the datasets for battery separator (Yin, 2019) and electrolyte (Dai, 2019) were updated. The added and adapted datasets are summarized in Table 80.

Table 80. New datasets in the battery sector. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "N" stands for "New Activity" and "U" stands for "Updated Activity.

Activity Name	Geography	Time Period	Product name	Unit	v3.9
battery production, Li-ion, LFP, rechargeable, prismatic	GLO; CN	2018-2025	battery, Li-ion, LFP, rechargeable, prismatic	kg	N
battery cell production, Li-ion, LFP	GLO; CN	2018-2025	battery cell, Li-ion, LFP	kg	N
cathode production, LFP, for Li-ion battery	GLO; CN	2018-2025	cathode, LFP, for Li-ion battery	kg	N
market for battery, Li-ion, LFP, rechargeable, prismatic	GLO	2022-2025	battery, Li-ion, LFP, rechargeable, prismatic	kg	N
market for battery cell, Li-ion, LFP	GLO	2022-2025	battery cell, Li-ion, LFP	kg	N
market for cathode, LFP, for Li-ion battery	GLO; CN	2022-2025	cathode, LFP, for Li-ion battery	kg	N
lithium iron phosphate production, hydrothermal process	GLO; CN	2014-2025	lithium iron phosphate	kg	N
lithium iron phosphate production, solid state process	GLO; CN	2014-2025	lithium iron phosphate	kg	N
market for lithium iron phosphate	GLO; CN	2022-2025	lithium iron phosphate	kg	N
market for lithium sulfate	GLO	2022-2025	lithium sulfate	kg	N
lithium sulfate production	GLO	2020-2020	lithium sulfate	kg	N
electrolyte production, for Li-ion battery	GLO	2019-2020	electrolyte, for Li-ion battery	kg	U
battery separator production	GLO; CN	2017-2020	battery separator	kg	U

11.3 Transport sector

The marginal supplier for the different regional markets for unspecified lorry transport in the consequential system model have been updated. In v3.9 only the latest technology (EURO class), in the selected geography responds to an increase in demand. The shares of contribution of the regional markets to the RoW market and the GLO market group are set equal to those reflected in the other system models.

The contribution to the market for cooling and freezing with refrigeration machine have also been updated to match those set in the other system models.

Table 81. Datasets affects by updated marginal suppliers and production volumes. If several geographies of the same activity with the same time period exist, all of them are listed in the "Geography" column. In the column v3.9, "U" stands for "Updated Activity".

Activity Name in v3.9	Geography	Time Period	Product Name	Unit	v3.9
market for transport, freight, lorry with refrigeration machine, cooling	GLO	2010-2022	transport, freight, lorry with refrigeration machine, cooling	metric ton*km	U
market for transport, freight, lorry with refrigeration machine, freezing	GLO	2010-2022	transport, freight, lorry with refrigeration machine, freezing	metric ton*km	U
market for transport, freight, lorry, unspecified	BR	2019-2022	transport, freight, lorry, unspecified	metric ton*km	U
market for transport, freight, lorry, unspecified	RoW; RER	2012-2022	transport, freight, lorry, unspecified	metric ton*km	U
market for transport, freight, lorry, unspecified	ZA	2019-2022	transport, freight, lorry, unspecified	metric ton*km	U

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13 Annex to 'Crude petroleum oil and natural gas supply' – activity correspondence

The integration of the LCI data in Meili et al. (2022a,b) and Bussa et al. (2022) into the ecoinvent database for the release of version 3.9 required a number of adaptions to the original datasets[6] to adhere to the nomenclature and system modelling of ecoinvent version 3. The original inventories in Meili et al. and Bussa et al. essentially adhere to the modelling principles, data quality guidelines and nomenclature of ecoinvent version 2. Including this data for the update of these activities for version 3.9 mainly meant to map flows (both elementary and intermediate exchanges) as well as activity names. In a next step, the original datasets were categorized as either representing *transforming* or *market activities*, following the Data Quality Guidelines for version 3 [Weidema et al. – *ref needed?*]. A complete overview of the correspondence between the original datasets and the activities and products found in ecoinvent 3.9 is provided in Table 82 and Table 83 for the main supply chain activities and auxiliary processes (including infrastructure), respectively.

The datasets 'natural gas, at production' and 'crude oil, at production', used by Meili et al. (2022a) to establish the country-specific shares of crude oil and natural gas from offshore and onshore production were omitted. These proportions are instead reflected directly in the demanding activities. The consumption mixes provided in Meili et al. (2022b) already contained the supply modelling, product losses, and transport requirements for crude petroleum oil for four geographies. The scope of the datasets 'crude oil, market mix, at long distance transport' in Meili et al. (2022b) hence matches that of the activity 'market for petroleum' in ecoinvent version 3 without further modifications. The updated supply chains for 'petroleum' in ecoinvent 3.9 therefore consist of market activities linked directly to the producing activities (Figure 3).

The database implementation of the natural gas supply chain is more complex than that of petroleum. An important aspect is internal energy requirements for the various steps along the chain, where a fraction of the natural gas is consumed in the process itself. This includes, for example, to provide energy for the liquefaction process, or to fuel compressor stations along gas pipelines and for gas storage facilities. The gas input required to run these activities ideally reflects the origin of the gas being transported or processed, for this supply to also carry the appropriate environmental burden. Following the general structure described in Bussa et al. (2022), the implementation of this supply chain into the ecoinvent database is illustrated in Figure 4.

As described in more detail in section 6, Bussa et al. (2022) provide country-specific consumption mixes and regional distribution efforts for twelve geographies as well as the regional mixes in Europe (RER) and North America (RNA), and for the global (GLO) supply situation in 2019, based on BP (2020). For the integration into ecoinvent v3.9, these mixes (referred to as 'natural gas, at long-distance pipeline', in [Nm3], in Bussa et al.) and inventories for regional gas distribution ('natural gas, high pressure, at consumer', in [MJ]; scaled to [m3]) were combined into the corresponding 'market for natural gas, high pressure' (in [m3]). Further adaptations for the integration into ecoinvent 3.9 include the

[6] Earlier versions are available from ESU-services Ltd.: https://esu-services.ch/data/public-lci-reports/

insertion of pressure reduction activities between the markets for natural gas at high and low pressure, as well as addition of import activities to model supply from consumption mixes (rather than directly from production) in neighbouring countries where exports exceed own (domestic) production.

Table 82. Correspondence of activity names, reference products, and units between the original study by ESU (2022) and as implemented in ecoinvent v3.9. Main activities in crude petroleum oil and natural gas supply. Two-letter country codes included in the names of datasets/activities or reference products are indicated by [XX.] *Datasets representing ”import” from XX to XX in ESU (2022) were renamed by changing the ending of the activity names to “[…], domestic supply with seasonal storage”.

ESU (2022)			ecoinvent 3.9		
Dataset	**Reference product**	**Unit**	**Activity name**	**Reference product**	**Unit**
combined gas and oil production offshore	crude oil, at production offshore	kg	petroleum and gas production, offshore	petroleum	kg
	natural gas, at production offshore	Nm3		natural gas, high pressure	m3
combined gas and oil production onshore	crude oil, at production onshore	kg	petroleum and gas production, onshore	petroleum	kg
	natural gas, at production onshore	Nm3		natural gas, high pressure	m3
crude oil, at production offshore	crude oil, at production offshore	kg	(not included)		
crude oil, at production onshore	crude oil, at production onshore	kg	(not included)		
crude oil, at production	crude oil, at production	kg	(not included)		
crude oil, market mix, at long distance transport	crude oil, market mix, at long distance transport	kg	market for petroleum	petroleum	kg
natural gas, at production offshore	natural gas, at production offshore	Nm3	(not included)		
natural gas, at production onshore	natural gas, at production onshore	Nm3	(not included)		
natural gas, at production	natural gas, at production	Nm3	(not included)		
natural gas, burned in gas turbine	natural gas, burned in gas turbine	MJ	natural gas, burned in gas turbine	natural gas, burned in gas turbine	MJ
natural gas, liquefied, at liquefaction plant	natural gas, liquefied, at liquefaction plant	Nm3	natural gas production, liquefied	natural gas, liquefied	m3
natural gas, liquefied, production [XX], at harbour	natural gas, liquefied, production [XX], at harbour	Nm3	natural gas, liquefied, import from [XX]	natural gas, liquefied	m3
natural gas, production [XX], at evaporation plant	natural gas, production [XX], at evaporation plant	Nm3	evaporation of natural gas, import from [XX]	natural gas, high pressure	m3
natural gas, production [XX], at long-distance pipeline	natural gas, production [XX], at long-distance pipeline	Nm3	natural gas, high pressure, import from [XX]*	natural gas, high pressure	m3
			natural gas, high pressure, domestic supply with seasonal storage*	natural gas, high pressure	m3
natural gas, at long-distance pipeline	natural gas, at long-distance pipeline	Nm3	market for natural gas, high pressure	natural gas, high pressure	m3
natural gas, high pressure, at consumer	natural gas, high pressure, at consumer	MJ			

ESU (2022)			ecoinvent 3.9		
Dataset	**Reference product**	**Unit**	**Activity name**	**Reference product**	**Unit**
natural gas, low pressure, at consumer	natural gas, low pressure, at consumer	MJ	market for natural gas, low pressure	natural gas, low pressure	m3

Table 83. Correspondence of activity names, reference products, and units between the original study by ESU (2022) and as implemented in ecoinvent v3.9. Further activities in crude petroleum oil and natural gas supply. Two-letter country codes included in the names of datasets/activities or reference products are indicated by [XX]. Rows shaded grey indicate that the corresponding activities in ecoinvent remained unchanged over v3.8.

ESU (2022)			ecoinvent 3.9		
Dataset	**Reference product**	**Unit**	**Activity name**	**Reference product**	**Unit**
Diesel, burned in diesel-electric generating set, at extraction site	Diesel, burned in diesel-electric generating set, at extraction site	MJ	diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction	diesel, burned in diesel-electric generating set, 10MW, for oil and gas extraction	MJ
discharge, produced water, offshore	discharge, produced water, offshore	kg	treatment of water discharge from petroleum extraction, offshore	water discharge from petroleum extraction, offshore	kg
discharge, produced water, onshore	discharge, produced water, onshore	kg	treatment of water discharge from petroleum/natural gas extraction, onshore	water discharge from petroleum/natural gas extraction, onshore	kg
natural gas, sweet, burned in production flare	natural gas, sweet, burned in production flare	Nm3	treatment of waste natural gas, sweet, burned in production flare	waste natural gas, sweet	MJ
natural gas, vented	natural gas, vented	Nm3	natural gas venting from petroleum/natural gas production	natural gas, vented	m3
pipeline, crude oil, offshore	pipeline, crude oil, offshore	km	pipeline construction, petroleum, offshore	pipeline, petroleum, offshore	km
pipeline, crude oil, onshore	pipeline, crude oil, onshore	km	pipeline construction, petroleum	pipeline, petroleum	km
pipeline, natural gas, high pressure distribution network	pipeline, natural gas, high pressure distribution network	km	pipeline construction, natural gas, high pressure distribution network	pipeline, natural gas, high pressure distribution network	km
pipeline, natural gas, long distance, high capacity, offshore	pipeline, natural gas, long distance, high capacity, offshore	km	pipeline construction, natural gas, long distance, high capacity, offshore	pipeline, natural gas, long distance, high capacity, offshore	km
pipeline, natural gas, long distance, high capacity, onshore	pipeline, natural gas, long distance, high capacity, onshore	km	pipeline construction, natural gas, long distance,	pipeline, natural gas, long distance,	km

ESU (2022)			ecoinvent 3.9		
Dataset	**Reference product**	**Unit**	**Activity name**	**Reference product**	**Unit**
			high capacity, onshore	high capacity, onshore	
pipeline, natural gas, long distance, low capacity, onshore	pipeline, natural gas, long distance, low capacity, onshore	km	pipeline construction, natural gas, long distance, low capacity, onshore	pipeline, natural gas, long distance, low capacity, onshore	km
pipeline, natural gas, low pressure distribution network	pipeline, natural gas, low pressure distribution network	km	pipeline construction, natural gas, low pressure distribution network	pipeline, natural gas, low pressure distribution network	km
plant offshore, natural gas, production	plant offshore, natural gas, production	unit	offshore platform production, natural gas	offshore platform, natural gas	unit
plant onshore natural gas, production	plant onshore natural gas, production	unit	onshore natural gas field infrastructure production	onshore natural gas field infrastructure	unit
platform, crude oil, offshore	platform, crude oil, offshore	unit	offshore platform production, petroleum	offshore platform, petroleum	unit
production plant crude oil, onshore	production plant crude oil, onshore	unit	onshore petroleum field infrastructure construction	onshore petroleum field infrastructure	unit
sweet gas, burned in gas turbine, production	sweet gas, burned in gas turbine, production	MJ	sweet gas, burned in gas turbine	sweet gas, burned in gas turbine	MJ
transport, crude oil pipeline, offshore	transport, crude oil pipeline, offshore	tkm	transport, pipeline, offshore, petroleum	transport, pipeline, offshore, petroleum	metric ton*km
transport, crude oil pipeline, onshore	transport, crude oil pipeline, onshore	tkm	transport, pipeline, onshore, petroleum	transport, pipeline, onshore, petroleum	metric ton*km
transport, liquefied natural gas [XX], freight ship	transport, liquefied natural gas [XX], freight ship	tkm	transport, freight, sea, tanker for liquefied natural gas	transport, freight, sea, tanker for liquefied natural gas	metric ton*km
transport, natural gas, offshore pipeline, long distance	transport, natural gas, onshore pipeline, long distance	tkm	transport, pipeline, offshore, long distance, natural gas	transport, pipeline, offshore, long distance, natural gas	metric ton*km
transport, natural gas, onshore pipeline, long distance	transport, natural gas, offshore pipeline, long distance	tkm	transport, pipeline, onshore, long distance, natural gas	transport, pipeline, onshore, long distance, natural gas	metric ton*km
transport, transoceanic tanker	transport, transoceanic tanker	tkm	transport, freight, sea, tanker for petroleum	transport, freight, sea, tanker for petroleum	metric ton*km
well for exploration and production, offshore	well for exploration and production, offshore	m	offshore well production, oil/gas	offshore well, oil/gas	m
well for exploration and production, onshore	well for exploration and production, onshore	m	onshore well production, oil/gas	onshore well, oil/gas	m