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Technical Report

Life Cycle Inventories for Swiss Recycling Processes

Part Carbotech: Recycling of Cardboard, Glass, PE, PET, Tinplate

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Federal Office for the Environment FOEN

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Introduction

These inventories were elaborated on behalf of FOEN in order to be used by the ETH in their project "„Optimising the energy recovery and the sustainability of Swiss municipal solid waste management", and to be used by the public.

The reason for elaborating these inventories was, that there are only few recycling inventories in the ecoinvent database Version 3.2/3.3. The ones that are already included in the ecoinvent database are mostly out of date or refer to European conditions and are therefore only partly valid for Swiss conditions. The inventories in this report base on existing studies done by Carbotech AG and were updated if necessary.

The following waste types and recycling inventories are covered with the present inventories

- Recycling of waste cardboard: production of secondary cardboard products testliner and fluting medium
- Recycling of packaging glass : production of secondary glass and foam glass
- Recycling of PE: production of secondary polyethylene granulate and oil
- Recycling of PET: production of secondary polyethylene terephthalate granulate, food grad and non food grade
- Recycling of tin plate: production of secondary tin

1 Cardboard from waste cardboard

1.1 General Information

About 350'000 ton of cardboard per year are collected in Switzerland and further processed to recycled cardboard products such as linerboard (testliner). The recycling system is well established with a collection rate of over 90%.

1.2 Collection of waste cardboard

The local waste cardboard collection varies between the communities. It can be collected separately or together with waste paper, in some communities the waste cardboard is collected in front of the door, in others the waste cardboard has to be brought to collection facilities. After the local collection, the waste cardboard is transported by lorry or train either to sorting or recycling plants. Table 1 shows the metadata for the collection of waste cardboard. The corresponding inventory data are reported in chapter 1.5.1.

Table 1: Metadata for waste cardboard, collected {CH}

Ecoinvent v3	Meta data
Name	waste cardboard, collected {CH}
General comment	The collection of waste cardboard is valid for 1 ton of collected material which consists of 97.5 % cardboard and 2.5% impurities (plastics, strings etc.).
Activities Start	Service is starting with the disposal of waste cardboard to recycling containers or pick up places
Activities End	This module includes the local collection transports and the transportation to the recycling plant.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Estimated data for CH
Sampling procedure	Literature research and own estimation
Extrapolations	Municipal solid waste collection was used as a proxy for local collection. Further transportation is based on literature und own estimation
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

1.3 Sorting of waste cardboard

Before the collected waste cardboard can be recycled it has to be sorted. The sorting allows a reliable screening of substances in the waste cardboard and sorts the waste cardboard (and paper) according to the defined waste paper types. The existing waste paper sorting process was used as a proxy for the sorting process of cardboard assuming that the energy need, auxiliary materials and waste content were similar.

Table 2 shows the metadata for the sorting of waste cardboard. The corresponding inventory data are reported in chapter 1.5.2.

Table 2: Metadata for sorting of waste cardboard {CH}

Ecoinvent v3	Meta data
Name	Sorting of waste cardboard {CH}
General comment	The sorting of waste cardboard is valid for 1 ton of sorting waste cardboard. The process delivers 0.975 t of sorted waste cardboard
Activities Start	Service is starting with the receipt of waste cardboard. The former collection and delivery of the waste cardboard is not included.
Activities End	This module includes the sorting of the waste cardboard.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data valid for CH
Sampling procedure	Literature research and own estimation
Extrapolations	Data is extrapolated from waste paper sorting {CH}
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

1.4 Production of secondary cardboard

1.4.1 Production of secondary fibre

The process of waste cardboard recycling involves mixing used cardboard with water and chemicals to break it down. It is then chopped up and heated, which breaks it down further into strands of cellulose. The resulting pulp is strained through screens, which remove any glue or plastic that may still be in the mixture then cleaned, and mixed with water. Pulp for recovered fibre based paper for corrugated packaging does not undergo a de-inking process. The so-called rejects (non-paper materials) are separated in the course of dissolving the waste paper in the pulper. Additionally, a sophisticated sieving method cleans the waste paper, until the fibrous material is finally relieved of residues. The rejects are collected, dried and sorted and fed to the thermal utilisation system.

1.4.2 Production of secondary card board

Testliner mostly consists of two plies of paper. Depending on the type of testliner, the fibre composition of mixes of types of recovered paper can be different in each layer. In general a better grade of mix is used for the upper layer for reasons of appearance and strength. In order to increase its strength, testliner receives a surface treatment in the size press. This involves the application of a starch solution to one or both sides of the sheet.

Wellenstoff can be a one-ply or two-ply product. Usually, a size press treatment with a starch solution is applied in-line on the paper machine in order to obtain sufficient strength and stiffness properties.

The most common surface treatment of recovered fibre based corrugated board material is done by a size press. Essentially a size press comprises two revolving rubber covered rolls, pressed together, through which the paper web passes. In the nip formed by the rolls there is a starch solution. The paper absorbs some of this solution, is pressed between two rolls and goes into the “after dryer“ section of the paper machine in order to evaporate from the paper excess water absorbed from the starch solution in the size press.

After the paper machine, there is a slitter winder where the big jumbo reel from the paper machine is rewound and cut down to customer reel formats according to customer orders. Finally the reels are weighed, marked, labelled and prepared for shipment to the customer, the corrugated board industry.

1.4.3 Data sources

Data for the recycling process were derived from Model Group, Switzerland (Klumpp, 2016). Lacking data on chemicals and auxiliary materials were completed with data from the ecoinvent data set linerboard {RER} treatment of recovered paper to testliner . Data from Model Group could not be diverted between testliner and fluting medium with regard to energy and water use. It is assumed that the energy and water use is very similar. This assumption is further supported by the existing inventories in ecoinvent ("linerboard {RER} treatment of recovered paper to testliner" and "fluting medium {RER} treatment of recoivered paper to wellenstoff".

Table 3 and Table 4 show the metadata for the production of testliner and wellenstoff. The corresponding inventory data are reported in chapter 1.5.3 and 1.5.4.

Table 3: Metadata for linerboard, testliner {CH}

Ecoinvent v3	Meta data
Name	linerboard, testliner {CH}
General comment	The production of testliner is valid for 1 ton of testliner.
Activities Start	Service is starting with the receipt of bales of sorted waste cardboard.
Activities End	This module includes all processes of the production of testliner up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from one supplier
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	Chemicals and auxiliary materials were not reported. Therefore they were extrapolated from the European data set "linerboard {RER} treatment of recovered paper to testliner"
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

Table 4: Metadata for fluting medium, wellenstoff from recovered paper {CH}

Ecoinvent v3	Meta data
Name	fluting medium, wellenstoff from recovered paper {CH}
General comment	The production of wellenstoff is valid for 1 ton of wellenstoff.
Activities Start	Service is starting with the receipt of bales of sorted waste cardboard.
Activities End	This module includes all processes of the production of wellenstoff up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from one supplier
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	Chemicals and auxiliary materials were not reported. Therefore they were extrapolated from the European data set "fluting medium {RER} treatment of recovered paper to wellenstoff"
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

1.5 Inventories

1.5.1 Waste cardboard, collected {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Waste cardboard, collected {CH}| Transportation| Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Municipal waste collection service by 21 metric ton lorry {CH}| processing | Alloc Rec, U		2.510E+01	tkm	Lognormal	3.0566	(5,4,5,3,4,na)
Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Rec, U		1.000E+02	tkm	Lognormal	3.0566	(5,4,5,3,4,na)
Transport, freight train {CH}| electricity | Alloc Rec, U		5.000E+01	tkm	Lognormal	3.0566	(5,4,5,3,4,na)

1.5.2 Sorting of waste cardboard {CH}

The ecoinvent v3.3 inventory waste paper, sorted {CH} treatment of waste paper, unsorted, sorted Alloc Rec, U was used and converted form 1 ton of output to 1 ton of sorting material.

1.5.3 Linerboard, Testliner from recovered paper {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Linerboard, Testliner from recovered paper {CH}| production | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						

Waste cardboard, collected {CH}| Transportation | Alloc Rec, U - Carbotech		1.046E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Sorting of waste cardboard {CH}| Processing | Alloc Rec, U - Carbotech		1.046E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Paper mill, integrated {GLO}| market for | Alloc Rec, U		5.268E-11	p	Lognormal	3.28	(4,3,5,2,2,na)
Tap water {RER}| market group for | Alloc Rec, U		2.900E+00	kg	Lognormal	1.07	(1,3,1,1,1,na)
Potato starch {GLO}| market for | Alloc Rec, U		1.012E-02	kg	Lognormal	1.57	(5,5,2,2,2,na)
Ethoxylated alcohol (AE3) {GLO}| market for | Alloc Rec, U		1.549E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Alkylketene dimer sizing agent, for paper production {GLO}| market for | Alloc Rec, U		1.646E-03	kg	Lognormal	1.57	(5,5,2,2,2,na)
Dithiocarbamate-compound {GLO}| market for | Alloc Rec, U		6.778E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Kaolin {GLO}| market for | Alloc Rec, U		5.132E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Steel, chromium steel 18/8 {GLO}| market for | Alloc Rec, U		4.841E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Core board {GLO}| market for | Alloc Rec, U		2.372E-03	kg	Lognormal	1.57	(5,5,2,2,2,na)
Maize starch {GLO}| market for | Alloc Rec, U		2.735E-02	kg	Lognormal	1.57	(5,5,2,2,2,na)
Chemical, organic {GLO}| market for | Alloc Rec, U		6.294E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Packaging film, low density polyethylene {GLO}| market for | Alloc Rec, U		1.937E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Lubricating oil {GLO}| market for | Alloc Rec, U		2.227E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Retention aid, for paper production {GLO}| market for | Alloc Rec, U		1.365E-03	kg	Lognormal	1.57	(5,5,2,2,2,na)
Triazine-compound, unspecified {GLO}| market for | Alloc Rec, U		6.778E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Alloc Rec, U		2.130E-04	kg	Lognormal	1.57	(1,3,3,1,1,na)
Pitch despergents, in paper production {GLO}| market for | Alloc Rec, U		2.324E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		2.650E-01	kWh	Lognormal	1.07	(1,3,1,1,1,na)
Heat, district or industrial, other than natural gas {CH}| heat production, light fuel oil, at industrial furnace 1MW | Alloc Rec, U		1.100E+00	kWh	Lognormal	1.07	(1,3,1,1,1,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		2.000E-02	kg	Lognormal	1.07	(1,3,1,1,1,na)
Wastewater from soft fibreboard production {CH}| treatment of, capacity 5E9l/year | Alloc Rec, U		2.100E-03	m3	Lognormal	1.51	(1,3,1,1,4,na)

1.5.4 Fluting medium, Wellenstoff from recovered paper {CH}

Description	sub-compart-ment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Fluting medium, wellenstoff from recovered paper {CH}| production | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste cardboard, collected {CH}| Transportation | Alloc Rec, U - Carbotech		1.046E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Sorting of waste cardboard {CH}| Processing | Alloc Rec, U - Carbotech		1.046E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Tap water {RER}| market group for | Alloc Rec, U		2.900E+00	kg	Lognormal	1.07	(1,3,1,1,1,na)
Triazine-compound, unspecified {GLO}| market for | Alloc Rec, U		6.778E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Chemical, organic {GLO}| market for | Alloc Rec, U		1.937E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Potato starch {GLO}| market for | Alloc Rec, U		1.365E-02	kg	Lognormal	1.57	(5,5,2,2,2,na)
Kaolin {GLO}| market for | Alloc Rec, U		5.519E-04	kg	Lognormal	1.1198	(5,5,2,2,2,na)
Lubricating oil {GLO}| market for | Alloc Rec, U		2.227E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Packaging film, low density polyethylene {GLO}| market for | Alloc Rec, U		1.937E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Paper mill, integrated {GLO}| market for | Alloc Rec, U		5.268E-11	p	Lognormal	1.57	(5,5,2,2,2,na)
Alkylketene dimer sizing agent, for paper production {GLO}| market for | Alloc Rec, U		2.130E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
EUR-flat pallet {GLO}| market for | Alloc Rec, U		4.406E-07	p	Lognormal	1.1551	(5,5,2,2,2,na)
Maize starch {GLO}| market for | Alloc Rec, U		2.731E-02	kg	Undefined		(5,5,2,2,2,na)
Ethoxylated alcohol (AE3) {GLO}| market for | Alloc Rec, U		1.549E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Steel, chromium steel 18/8 {GLO}| market for | Alloc Rec, U		4.841E-05	kg	Lognormal	1.57	(5,5,2,2,2,na)
Pitch despergents, in paper production {GLO}| market for | Alloc Rec, U		2.324E-04	kg	Lognormal	1.1198	(5,5,2,2,2,na)
Core board {GLO}| market for | Alloc Rec, U		2.169E-03	kg	Lognormal	1.57	(5,5,2,2,2,na)
Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Alloc Rec, U		3.292E-04	kg	Lognormal	1.57	(5,5,2,2,2,na)
Retention aid, for paper production {GLO}| market for | Alloc Rec, U		1.365E-03	kg	Lognormal	1.57	(5,5,2,2,2,na)

Electricity, medium voltage {CH}| market for | Alloc Rec, U		2.650E-01	kWh	Lognormal	1.07	(1,3,1,1,1,na)
Heat, district or industrial, other than natural gas {CH}| heat production, light fuel oil, at industrial furnace 1MW | Alloc Rec, U		1.100E+00	kWh	Lognormal	1.07	(1,3,1,1,1,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, incineration | Alloc Rec, U		2.000E-02	kg	Lognormal	1.07	(1,3,1,1,1,na)
Wastewater from soft fibreboard production {CH}| treatment of, capacity 5E9l/year | Alloc Rec, U		2.100E-03	m3	Lognormal	1.51	(1,3,1,1,1,na)

2 Glass and foam glass from waste glass

2.1 General Information

About 355'000 tons of waste packaging glass per year are collected in Switzerland and further processed to recycled glass products such as bottles or foam glass. The recycling system is well established with a collection rate of over 90%. About 25% of collected glass cullet are used for CH production of green glass and about 9% for CH foam glass production (gravel). 66% of glass cullet are exported to neighbour countries.

Glass cullet can be used directly in the glass and foam glass production. They replace raw material and the release of CO_2 from carbonates and reduce the energy demand of the melting process.

2.2 Collection of packaging glass

The local collection of packaging glass is organised by the communities. Common is the glass cullet collection separated by colours. However, in some communities there is also collective collection of all glass colours together[1]. After the local collection, the glass cullet is transported by lorry or train either to sorting or glass production plant. Collection data are based on Stettler & Dinkel (2016) Table 5 shows the metadata for the collection of glass cullet. The corresponding inventory data are reported in chapter 2.7.1.

Table 5: Metadata for glass cullet, collected {CH}

Ecoinvent v3	Meta data
Name	Glass cullet, collected {CH}
General comment	The collection of glass cullet is valid for 1 kg of collected material which consists of 92.0 % glass cullet and 8% impurities (plastics, strings etc.).
Activities Start	Service is starting with the disposal of waste glass to recycling containers or pick up places
Activities End	This module includes the local collection transports and the transportation to the recycling plant in Switzerland (glass or foam glass producer).
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data valid for CH
Sampling procedure	Data collection by questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

[1] Distribution of the advanced disposal fee considering collection and further use of glass cullet. Lower values for mixed glass cullet.

2.3 Sorting of glass cullet

The collected glass cullet need to be sorted for their use in the glass or foam glass production. The sorting of cullet eliminates impurities (plastics, metals, ceramics, cullet of other colours). Table 6 shows the metadata for the sorting of waste glass cullet. The corresponding inventory data are reported in chapter 2.7.2

Table 6: Metadata for sorting of glass cullet {CH}

Ecoinvent v3	Meta data
Name	Sorting of glass cullet {CH}
General comment	The sorting of glass cullet is valid for 1 ton of sorting. The process delivers 0.94t of sorted glass cullet
Activities Start	Service is starting with the receipt of glass cullet.
Activities End	This module includes the sorting of the glass cullet. The collection and delivery of the glass cullet is excluded.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data valid for CH
Sampling procedure	Ecoinvent inventory of the sorting process in Europe adapted for Switzerland
Extrapolations	Data extrapolated from German situation
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

2.4 Production of green packaging glass

About 84 % green cullet are used in the Swiss glass production[2]. The glass cullet are used directly to replace raw materials. The use of glass cullet reduces the release of CO_2 from carbonates and leads to a lower energy consumption in the melting process (about 2 % - 3 % per 10 % of glass cullet). Limiting factors for the use of glass cullet is the desired colour quality.

After the sorting and crushing, the glass cullet are melted together with the new raw materials at temperatures of up to 1580 °C. in the melting furnace. The glowing, viscous, melted glass is first preformed and then blown with compressed air to ready-to-use glass containers. Then the bottles move into the so-called cooling furnace. Here, they are carefully cooled and then coated with a special protective spray to protect them from scratches and to increase the breaking strength. The glass packaging is then tested several times for cracks, inclusions, deformations or other defects optically, mechanically and electronically.

Data for the green glass production process were extrapolated from the existing ecoinvent inventory “packaging glass, green {DE}” assuming similar production standards for Switzerland as for Germany. Primary data from Vetroswiss was not available due to confidentiality reasons. Table 7 - Table 9 show the metadata for the production of packaging glass. Scenarios for 100% primary resource and 100% glass cullet were derived from the data set of the average CH glass production considering the impacts of glass cullet on the energy demand. The data set for the average CH glass production corresponds to 84% glass cullet and 16% primary resources,

[2] Mixed cullet can be used for green glass production but have an impact on the colour quality. There are few colour separations systems for mixed cullet in neighbour countries.

scenarios for 100 % primary resources and 100 % glass cullet are derived from the average. The corresponding inventory data are reported in chapter 2.7.2 - 2.7.5.

Table 7: Metadata for packaging glass, green, {CH}| production, extrapolated from DE

Ecoinvent v3	Meta data
Name	Packaging glass, green, {CH}| production, extrapolated from DE
General comment	The production of green packaging glass is valid for 1 ton of packaging glass
Activities Start	Service is starting with the receipt of glass cullet and other raw materials
Activities End	This module includes all processes of the production of packaging glass up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from Germany extrapolated to Swiss conditions
Sampling procedure	Literature
Extrapolations	Data were extrapolated from German conditions to Swiss conditions (choice of energy resources, electricity mix and collection system)
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

Table 8: Metadata for packaging glass, green, primary {CH}| production, extrapolated from DE

Ecoinvent v3	Meta data
Name	Packaging glass, green, primary {CH}| production, extrapolated from DE
General comment	Inventory refers to the production of 1 kg of green glass, primary resources. Energy consumption was adjusted according to 2%-3% additional energy demand per 10% of less glass cullet. Raw material input for packaging glass, green, primary are assumed to be 6.25 (1/(1-0.84) times higher than for packing glass, green (average).
Activities Start	Service is starting with the receipt of raw materials
Activities End	This module includes all processes of the production of packaging glass up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data valid for Switzerland
Sampling procedure	Extrapolation from the average glass production with 84% glass cullet to the hypothetical use of 100% primary resource use, considering the higher energy demand in the melting process and additional emissions of CO_2 from carbonates in the melting process.
Extrapolations	Data were extrapolated from German conditions to Swiss conditions (choice of energy resources, electricity mix and collection system).
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

Table 9: Metadata for packaging glass, green, secondary {CH}| production, extrapolated from DE

Ecoinvent v3	Meta data
Name	Packaging glass, green, secondary {CH}| production, extrapolated from DE
General comment	Inventory refers to the production of 1 kg of green glass, secondary resources. Energy consumption was adjusted according to 2%-3% additional energy demand per 10% of less glass cullet.

Activities Start	Service is starting with the receipt of glass cullet
Activities End	This module includes all processes of the production of packaging glass up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data valid for Switzerland
Sampling procedure	Extrapolation from the average glass production with 84% glass cullet to the hypothetical use of 100% glass cullet, considering the lower melting energy demand of cullet and the lower CO_2 from carbonates in the melting process.
Extrapolations	Data were extrapolated from German conditions to Swiss conditions
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

2.5 Production of secondary foam glass plate or gravel

Besides the recycling to packaging glass, glass cullet can also be used for the production of foam glass and foam glass gravel. Glas cullet are used for the Swiss production of foam glass gravel or exported for the production of insulation materials in neighbour countries. Mainly mixed glass cullet and green glass cullet are used for insulation materials due to the current recompensation of the advanced disposal fee. The collection and sorting of glas cullet for the production of foam glass was assumed to be similar as for the glass production.

For foam glass gravel, the sorted glass cullet are crushed and run through a multi-stage separation and comminution process. Subsequently the up to 10 mm large glass pieces are milled to the finest glass flour and minerals activators are added. Afterwards, heated continuous ovens are used for sintering and foaming of the glass flour at temperatures around 900 °C. A hot foam glass plate leaves the oven at 300 to 400 °C. The very rapid cooling causes stress cracking, which causes the plate to disintegrate into 3 to 7 cm gravel grains.

For foam glass plates, the process is similar with the exception of a controlled and slow cooling process in a drawing furnace and differences in the composition of raw materials. After cooling, a permanent negative pressure of approx. 0.5 bar is produced in the cell interior, as a result of which the thermal conductivity is additionally reduced.

Data for the foam glass gravel process were derived from an existing EPD of foam glass gravel (Institut Bauen und Umwelt e.V., 2015b), considering Swiss conditions for the standard of waste treatment, transports and electricity supply. Data for the foam glass plate process were derived from the ecoinvent inventory of foam glass considering an existing EPD of foam glass plate (Institut Bauen und Umwelt e.V., 2015a). The electricity mix was adjusted for the foam glass plates to represent the generic RER situation (no production of foam glass plates in Switzerland). Table 10 and Table 11 show the metadata for the production of foam glass gravel and plate. The corresponding inventory data are reported in chapter2.7.6 and 2.7.7.

Table 10: Metadata for foam glass gravel {CH}

Ecoinvent v3	**Meta data**
Name	Foam glass gravel {CH}
General comment	The inventory is valid for the production of 1 kg of foam glass gravel. It refers to foam glass gravel with a density of 165 kg/m3.

Activities Start	Service is starting with the receipt of glass cullet
Activities End	This module includes all processes of the production of foam glass gravel up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from one supplier
Sampling procedure	Literature
Extrapolations	Data were extrapolated from an existing EPD of foam glass gravel
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

Table 11: Metadata for foam glass plate {RER}

Ecoinvent v3	**Meta data**
Name	Foam glass plate {RER}
General comment	The inventory is valid for the production of 1 kg of foam glass plate. It refers to foam glass of a density of 115 kg/m3 and a thermal conductivity of 0.040 W/mK.
Activities Start	Service is starting with the receipt of glass cullet
Activities End	This module includes all processes of the production of foam glass plate up to the factory gate.
Geography	RER
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from one supplier
Sampling procedure	Literature
Extrapolations	Data of the existing ecoinvent inventory were adapted with newer data from an existing EPD of foam glass plate
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

2.6 Production of sand from glass cullet

Glass cullet is sometimes crushed to glass sand. Data for glass sand crushing was approximated with the process of lime stone crushing. The collection and sorting process was approximated with the cullet processing of the glass industry. Table 12 shows the metadata for the production of sand from glass cullets. The corresponding inventory data are reported in 2.7.8.

Table 12: Metadata for sand from glass cullet {CH}

Ecoinvent v3	Meta data
Name	Sand, from glass cullet {CH}
General comment	Inventory refers to the production of 1 kg of sand from glass cullet crushing
Activities Start	Service is starting with the receipt of glass cullet
Activities End	This module includes all processes of the production of glass sand up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	unknown
Sampling procedure	Literature
Extrapolations	Data were extrapolated from similar process (limestone crushing)
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

2.7 Inventories

2.7.1 Waste packaging glass, collected {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
glass cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO5 | Alloc Rec, U		1.35E+01	ton	Lognormal	2.07	(4,3,2,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Rec, U		3.60E+01	ton	Lognormal	2.07	(4,3,2,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Rec, U		6.00E+01	ton	Lognormal	2.07	(4,3,2,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		2.20E-01	ton	Lognormal	3.23	(5,1,1,1,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		1.10E-02	ton	Lognormal	3.23	(5,1,1,1,1,na)
Transport, freight train {CH}| electricity | Alloc Rec, U		7.50E+01	ton	Lognormal	2.07	(4,3,2,1,1,na)

2.7.2 Sorting of waste packaging glass {CH}

The ecoinvent v3.3 inventory glass cullet, sorted {RER} treatment of waste glass from unsorted public collection, sorting Alloc Rec, U was used and converted form 1 ton of output to 1 ton of sorting material.

2.7.3 Packaging glass, green, {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Packaging glass, green, {CH}| production, extrapolated from DE | Alloc Rec, U - Carbotech		1.00E+00	ton			
Resources						
Water, unspecified natural origin, CH		2.12E-01	m3	Lognormal	1.4926	(1,2,5,1,1,na)
Materials/fuels						
Soda ash, light, crystalline, heptahydrate {GLO}| market for | Alloc Rec, U		3.05E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Packaging glass factory {GLO}| market for | Alloc Rec, U		1.25E-07	p	Lognormal	4.0674	(5,4,5,3,4,na)
Heat, district or industrial, other than natural gas {CH}| heat production, heavy fuel oil, at industrial furnace 1MW | Alloc Rec, U		9.41E+02	MJ	Lognormal	1.51	(1,2,5,1,1,na)
Solid unbleached board {GLO}| market for | Alloc Rec, U		1.76E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace low-NOx >100kW | Alloc Rec, U		6.41E+02	kWh	Lognormal	1.51	(1,2,5,1,1,na)
Lime {GLO}| market for | Alloc Rec, U		1.99E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Silica sand {GLO}| market for | Alloc Rec, U		9.87E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
EUR-flat pallet {GLO}| market for | Alloc Rec, U		7.16E-01	p	Lognormal	1.5822	(2,4,5,2,1,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		9.13E+02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Dolomite {GLO}| market for | Alloc Rec, U		1.44E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Lubricating oil {GLO}| market for | Alloc Rec, U		2.38E-02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Graphite {GLO}| market for | Alloc Rec, U		1.25E-03	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Diesel {CH}| market for | Alloc Rec, U		1.77E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Chemical, inorganic {GLO}| market for chemicals, inorganic | Alloc Rec, U		1.14E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Feldspar {GLO}| market for | Alloc Rec, U		1.62E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		1.17E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		9.13E+02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		1.59E+02	kWh	Lognormal	1.4926	(1,2,5,1,1,na)

Emissions to air						
Carbon dioxide, fossil		3.81E+01	kg	Lognormal	1.51	(1,2,5,1,1,na)
Emissions to water						
Water, CH		1.88E-01	m3	Lognormal	1.22	(2,2,4,1,1,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		5.00E+00	kg	Lognormal	1.5822	(2,4,5,2,1,na)

2.7.4 Packaging glass, green, primary resources {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Packaging glass, green, primary {CH}| production, extrapolated from DE | Alloc Rec, U - Carbotech		1.00E+00	ton			
Resources						
Water, unspecified natural origin, CH		2.12E-01	m3	Lognormal	1.4926	(1,2,5,1,1,na)
Materials/fuels						
Soda ash, light, crystalline, heptahydrate {GLO}| market for | Alloc Rec, U		1.91E+02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Packaging glass factory {GLO}| market for | Alloc Rec, U		1.25E-07	p	Lognormal	4.0674	(5,4,5,3,4,na)
Heat, district or industrial, other than natural gas {CH}| heat production, heavy fuel oil, at industrial furnace 1MW | Alloc Rec, U		1.17E+03	MJ	Lognormal	1.51	(1,2,5,1,1,na)
Solid unbleached board {GLO}| market for | Alloc Rec, U		1.76E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace low-NOx >100kW | Alloc Rec, U		7.98E+02	kWh	Lognormal	1.51	(1,2,5,1,1,na)
Lime {GLO}| market for | Alloc Rec, U		1.24E+02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Silica sand {GLO}| market for | Alloc Rec, U		6.17E+02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
EUR-flat pallet {GLO}| market for | Alloc Rec, U		7.16E-01	p	Lognormal	1.5822	(2,4,5,2,1,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		0.00E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)

Dolomite {GLO}| market for | Alloc Rec, U		9.00E+01	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Lubricating oil {GLO}| market for | Alloc Rec, U		2.38E-02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Graphite {GLO}| market for | Alloc Rec, U		7.81E-03	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Diesel {CH}| market for | Alloc Rec, U		1.77E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Chemical, inorganic {GLO}| market for chemicals, inorganic | Alloc Rec, U		1.14E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Feldspar {GLO}| market for | Alloc Rec, U		1.01E+02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		1.17E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		0.00E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		1.79E+02	kWh	Lognormal	1.4926	(1,2,5,1,1,na)
Emissions to air						
Carbon dioxide, fossil		2.38E+02	kg	Lognormal	1.51	(1,2,5,1,1,na)
Emissions to water						
Water, CH		1.88E-01	m3	Lognormal	1.22	(2,2,4,1,1,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		5.00E+00	kg	Lognormal	1.5822	(2,4,5,2,1,na)

2.7.5 Packaging glass, green, 100 % glass cullet {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Packaging glass, green, secondary {CH}| production, extrapolated from DE | Alloc Rec, U - Carbotech		1.00E+00	ton			
Resources						
Water, unspecified natural origin, CH		2.12E-01	m3	Lognormal	1.4926	(1,2,5,1,1,na)
Materials/fuels						
Packaging glass factory {GLO}| market for | Alloc Rec, U		1.25E-07	p	Lognormal	4.0674	(5,4,5,3,4,na)

Heat, district or industrial, other than natural gas {CH}| heat production, heavy fuel oil, at industrial furnace 1MW | Alloc Rec, U		8.97E+02	MJ	Lognormal	1.51	(1,2,5,1,1,na)
Solid unbleached board {GLO}| market for | Alloc Rec, U		1.76E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace low-NOx >100kW | Alloc Rec, U		6.11E+02	kWh	Lognormal	1.51	(1,2,5,1,1,na)
EUR-flat pallet {GLO}| market for | Alloc Rec, U		7.16E-01	p	Lognormal	1.5822	(2,4,5,2,1,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		1.08E+03	kg	Lognormal	1.05	(1,1,1,1,1,na)
Lubricating oil {GLO}| market for | Alloc Rec, U		2.38E-02	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Diesel {CH}| market for | Alloc Rec, U		1.77E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Chemical, inorganic {GLO}| market for chemicals, inorganic | Alloc Rec, U		1.14E+00	kg	Lognormal	1.4926	(1,2,5,1,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		1.17E+01	kg	Lognormal	1.5822	(2,4,5,2,1,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		1.08E+03	kg	Lognormal	1.05	(1,1,1,1,1,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		1.56E+02	kWh	Lognormal	1.51	(1,2,5,1,1,na)
Emissions to water						
Water, CH		1.88E-01	m3	Lognormal	1.22	(2,2,4,1,1,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		5.00E+00	kg	Lognormal	1.5822	(2,4,5,2,1,na)

2.7.6 Foam glass plate {RER}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Foam glass plate {RER}| production | Alloc Rec, U - Carbotech		1.00E+00	ton			
Materials/fuels						
EUR-flat pallet {GLO}| market for | Alloc Rec, U		1.60E+00	p	Lognormal	1.2041	(1,3,4,2,1,na)
Sodium sulfate, anhydrite {RER}| market for | Alloc Rec, U		5.38E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Sinter, iron {GLO}| market for | Alloc Rec, U		4.00E-01	kg	Lognormal	1.2041	(1,3,4,2,1,na)

Packaging film, low density polyethylene {GLO}| market for | Alloc Rec, U		1.46E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Feldspar {GLO}| market for | Alloc Rec, U		2.58E+02	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Foam glass factory {GLO}| market for | Alloc Rec, U		5.10E-07	p	Lognormal	3.0896	(1,2,4,2,1,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		8.14E+02	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Corrugated board box {GLO}| market for corrugated board box | Alloc Rec, U		7.31E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Potassium nitrate {GLO}| market for | Alloc Rec, U		2.46E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Aluminium hydroxide {GLO}| market for | Alloc Rec, U		6.40E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Carbon black {GLO}| market for | Alloc Rec, U		6.15E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Clay {GLO}| market for | Alloc Rec, U		3.49E-01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Molybdenum {GLO}| market for | Alloc Rec, U		7.69E-02	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Manganese concentrate {GLO}| market for | Alloc Rec, U		2.62E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Steel, chromium steel 18/8, hot rolled {GLO}| market for | Alloc Rec, U		1.27E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Soda ash, light, crystalline, heptahydrate {GLO}| market for | Alloc Rec, U		4.62E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Iron ore, beneficiated, 65% Fe {GLO}| market for | Alloc Rec, U		2.77E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Tap water {Europe without Switzerland}| market for | Alloc Rec, U		0.00E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Tap water {CH}| market for | Alloc Rec, U		2.00E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		8.14E+02	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Alloc Rec, U		5.00E+02	tkm	Lognormal	2.23	(5,1,1,1,1,na)
Electricity, medium voltage {UCTE}| market group for | Alloc Rec, U		9.00E+03	MJ	Lognormal	1.07	(1,3,1,3,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace low-NOx >100kW | Alloc Rec, U		8.22E+03	MJ	Lognormal	1.07	(1,3,1,3,1,na)
Heat, district or industrial, other than natural gas {Europe without Switzerland}| heat production, light fuel oil, at industrial furnace 1MW | Alloc Rec, U		1.05E+03	MJ	Lognormal	1.07	(1,3,1,3,1,na)
Heat, central or small-scale, other than natural gas {Europe without Switzerland}| market for heat, central or small-scale, other than natural gas | Alloc Rec, U		7.16E+02	MJ	Lognormal	1.07	(1,3,1,3,1,na)
Emissions to air						
Carbon dioxide, fossil		2.94E+01	kg	Lognormal	1.2289	(3,3,4,2,1,na)
Sulfur dioxide		2.31E-01	kg	Lognormal	1.2289	(3,3,4,2,1,na)
Nitrogen oxides		1.00E+00	kg	Lognormal	1.5683	(3,3,4,2,1,na)

Particulates, < 2.5 um		4.57E-02	kg	Lognormal	3.0896	(1,2,4,2,1,na)
Water/m3		4.11E-02	m3	Lognormal	2.0569	(4,4,5,2,4,na)
Emissions to water						
Water, CH		2.51E-02	m3	Lognormal	2.0569	(4,4,5,2,4,na)
Waste to treatment						
Waste sealing sheet, polyethylene {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		1.46E+01	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Wastewater from glass production {CH}| treatment of, capacity 1.1E10l/year | Alloc Rec, U		2.08E-01	m3	Lognormal	1.1975	(1,2,4,2,1,na)
Waste paperboard {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		7.31E+00	kg	Lognormal	1.2041	(1,3,4,2,1,na)
Wood ash mixture, pure {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		4.21E+01	kg	Lognormal	1.22	(1,3,4,2,1,na)

2.7.7 Foam glass gravel {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Foam glass gravel {CH}| production | Alloc Rec, U - Carbotech		1.00E+00	ton			
Materials/fuels						
Electricity, medium voltage {CH}| market for | Alloc Rec, U		6.50E+02	kWh	Lognormal	1.21	(4,1,1,1,1,na)
Heat, central or small-scale, natural gas {CH}| heat production, natural gas, at boiler condensing modulating <100kW | Alloc Rec, U		1.26E+02	MJ	Lognormal	1.21	(4,1,1,1,1,na)
Tap water {CH}| tap water production, conventional treatment | Alloc Rec, U		3.06E+03	kg	Lognormal	1.21	(4,1,1,1,1,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		1.08E+03	kg	Lognormal	1.21	(4,1,1,1,1,na)
Soda ash, light, crystalline, heptahydrate {RER}| soda production, solvay process | Alloc Rec, U		2.00E+01	kg	Lognormal	1.52	(3,2,2,1,4,na)
Packaging glass factory {RER}| construction | Alloc Rec, U		7.52E-08	p	Lognormal	3.23	(4,1,1,1,1,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		1.08E+03	kg	Lognormal	1.21	(4,1,1,1,1,na)

Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		2.82E-03	kg	Lognormal	1.52	(3,2,2,1,4,na)
Inert waste, for final disposal {CH}| treatment of inert waste, inert material landfill | Alloc Rec, U		2.99E+01	kg	Lognormal	1.52	(3,2,2,1,4,na)
Wastewater from glass production {CH}| treatment of, capacity 1.1E10l/year | Alloc Rec, U		3.06E+00	m3	Lognormal	1.52	(3,2,2,1,4,na)

2.7.8 Sand, from glass cullet {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Sand, from glas cullet {CH}| production | Alloc Rec, U - Carbotech		1.00E+00	ton			
Resources						
Water, well, in ground, CH	in water	1.88E-01	m3	Lognormal	1.78	(5,3,1,1,4,na)
Materials/fuels						
Conveyor belt {GLO}| market for | Alloc Rec, U		2.78E-05	m	Lognormal	3.46	(5,3,1,1,4,na)
glas cullet, collected {CH} | collection | Alloc Rec, U - Carbotech		1.06E+03	kg	Lognormal	1.78	(5,3,1,1,4,na)
Industrial machine, heavy, unspecified {GLO}| market for | Alloc Rec, U		6.12E-03	kg	Lognormal	3.46	(5,3,1,1,4,na)
Sorting, glas cullets {CH} | processing | Alloc Rec, U - Carbotech		1.06E+03	kg	Undefined	1.78	(5,3,1,1,4,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		5.00E-01	kWh	Lognormal	1.78	(5,3,1,1,4,na)
Heat, central or small-scale, other than natural gas {CH}| market for | Alloc Rec, U		1.41E+00	MJ	Lognormal	1.78	(5,3,1,1,4,na)
Emissions to air						
Particulates, < 2.5 um	low. pop.	8.71E-04	kg	Lognormal	2.5442	(1,5,4,5,4,na)
Particulates, > 10 um	low. pop.	8.71E-03	kg	Lognormal	2.5442	(1,5,4,5,4,na)
Water/m3		5.47E-02	m3	Lognormal	1.5548	(2,2,4,1,1,na)
Particulates, > 2.5 um, and < 10um	low. pop.	7.84E-03	kg	Lognormal	2.5442	(1,5,4,5,4,na)

Emissions to water						
Water, CH		1.33E-01	m3	Lognormal	1.78	(5,3,1,1,4,na)

3 PE and oil from waste PE-bottles

3.1 General Information

About 5'000 to 10'000 t of PE bottles per year are collected in Switzerland by community or by retailers and further processed to non-food grade PE. 14 % of the collected material cannot be recycled again and is incinerated. There is an option for producing oil from waste PE-bottles.

3.2 Collection of PE bottles

Consumers can deposit empty PE bottles at the bigger retailers that sell PE bottles. The retro-logistic is mainly organised and integrated in the logistic process of the involved retailers. Data for the collection of PE bottles in Switzerland were based on some of the PET collection data (Würmli, 2015), as these include the same retro-logistic streams. Data for the collection of PE bottles in Europe were extrapolated from PE bottles collection in the USA (Franklin Associates, 2010). Table 13 and Table 14 show the metadata for the collection of PE bottles. The corresponding inventory data can be found in chapter 3.6.1and 3.6.2.

Table 13: Metadata for waste PE bottles, collected {CH}

Ecoinvent v3	Meta data
Name	waste PE bottles, collected {CH}
General comment	The separate collection of waste PE bottles is valid for 1 ton of collected material which consists of 86 % PE (bottles and caps), 5 % labels and 9 % impurities (low quality PE and other plastics).
Activities Start	Service is starting with the disposal of PE bottles to recycling containers
Activities End	This module includes the production of the collection containers and all transportation to the recycling plant.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from all suppliers
Sampling procedure	Data from PET collection are used as a proxy for PE bottle collection
Extrapolations	Data are extrapolated and adapted from PET collection.
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

Table 14: Metadata for waste PE bottles, collected {RER}

Ecoinvent v3	Meta data
Name	waste PE bottles, collected {RER}
General comment	The separate collection of waste PE bottles is valid for 1 ton of collected material. The composition of the collected materials is extrapolated from waste PE bottles, collected {CH} which delivers 86 % PE (bottles and caps), 5 % labels and 9 % impurities (low quality PE and other plastics).

Activities Start	Service is starting with the disposal of PE bottles to recycling containers
Activities End	This module includes the production of the collection containers and all transportation to the recycling plant.
Geography	RER
Technology	Average of present used technology
Time Period	2010
Representativeness	Data from suppliers from other region
Sampling procedure	Literature research
Extrapolations	Transportation distances are extrapolated from PE collection in USA (Franklin Associates). Further data is extrapolated from PET collection in CH for the recycling containers.
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

3.3 Sorting of PE bottles

The collected PE bottles are sorted in sorting centres in Switzerland and compressed to 200 to 300 kg heavy bales for further processing. Data were derived from involved sorting facilities (confidential). Foreign substances are sorted out and disposed of. Table 15 and Table 16 show the metadata for the sorting process of PE bottles. The corresponding inventory data are reported in chapter 3.6.3 and 3.6.4.

Table 15: Metadata for sorting of waste PE bottles {CH}

Ecoinvent v3	**Meta data**
Name	Sorting of waste PE bottles {CH}
General comment	The sorting of waste PE bottles is valid for 1 ton of sorting PE bottles. The process delivers 0.905t of sorted PE bottles (including caps and labels)
Activities Start	Service is starting with the receipt of waste PE bottles.
Activities End	This module includes the sorting of the waste PE bottles. The collection and delivery of the waste PE bottles is excluded.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from involved sorting facilities
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

Table 16: Metadata for sorting of waste PE bottles {RER}

Ecoinvent v3	**Meta data**
Name	Sorting of waste PE bottles {RER}
General comment	The sorting of waste PE bottles is valid for 1 ton of sorting PE bottles. The process delivers 0.905t of sorted PE bottles (including caps and labels)
Activities Start	Service is starting with the receipt of collected waste PE bottles.
Activities End	This module includes the sorting of the waste PE bottles. The collection and delivery of the waste PE bottles is excluded.
Geography	RER
Technology	Average of present used technology
Time Period	2014

Representativeness	Data from sorting facilities from other regions
Sampling procedure	Literature research
Extrapolations	Energy demand of sorting process was extrapolated from PE sorting in the USA. Data for the composition of the sorting material was derived from sorting of waste PE bottles {CH}
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

3.4 Production of secondary PE granulate

The plastic is further sorted and cleaned in a first step in order to remove any unwanted debris. The plastic then needs to be homogenised, so that only HDPE will be processed. If there are other plastic polymers in the batch, this can ruin the recycled end-product.
HDPE has a lower specific density than PET, meaning that these plastic polymers can be separated by using sink-float separation. However, HDPE has a similar specific density to PP. In this case, Near Infrared Radiation (NIR) techniques can be used, unless the plastic is too dark and absorbs the infrared waves.
HDPE is then shredded and melted down to further refine the polymer. The plastic is then cooled into pellets which can be used in manufacturing.
Data were derived from Innoplastics (2014). Table 17 and Table 18 show the metadata for the production of secondary PE granulate non-food grade. The corresponding inventory data are reported in chapter3.6.5 and 3.6.6.

Table 17: Metadata for polyethylene, secondary, granulate, non-food grade {CH}

Ecoinvent v3	**Meta data**
Name	polyethylene, secondary, granulate, non-food grade {CH}
General comment	The production of secondary PE granulate, non-food grade is valid for 1 ton of secondary PE granulate, non-food grade.
Activities Start	Service is starting with the receipt of bales of sorted waste PE bottles.
Activities End	This module includes all processes of the production of secondary PE granulate, non-food grade up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from only supplier
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

Table 18: Metadata for polyethylene, secondary, granulate, non-food grade {RER}

Ecoinvent v3	**Meta data**
Name	polyethylene, secondary, granulate, non-food grade {RER}
General comment	The production of secondary PE granulate, non-food grade is valid for 1 ton of secondary PE granulate, non-food grade.
Activities Start	Service is starting with the receipt of bales of sorted waste PE bottles.
Activities End	This module includes all processes of the production of secondary PE granulate, non-food grade up to the factory gate.

Geography	RER
Technology	Average of present used technology
Time Period	2010
Representativeness	Data from suppliers from other region
Sampling procedure	Literature research
Extrapolations	Energy demand and auxiliary materials of recycling process was extrapolated from PE sorting in the USA. Data for material losses was derived from polyethylene, secondary, granulate, non-food grade {CH}
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	none

3.5 Production of oil from waste PE

Plastic waste can be used for oil production. The collection and sorting is assumed to be comparable as for PE recycling. About 0.8 ton of oil is produced out of 1 t of pure PE.

The collected and sorted plastic is shredded in a first step. The grinded plastic waste undergoes so-called thermal depolymerisation, during which long molecular chains of plastics decompose into short-chain of petroleum hydrocarbons (see figure 1). This oil equals light fuel oil in terms of quality and composition. Besides the oil, gases are generated similar to natural gas. These gases are used for the process heat that is needed for melting, fracking and evaporation. Another by-product is solid residual material that can be further energetically used.

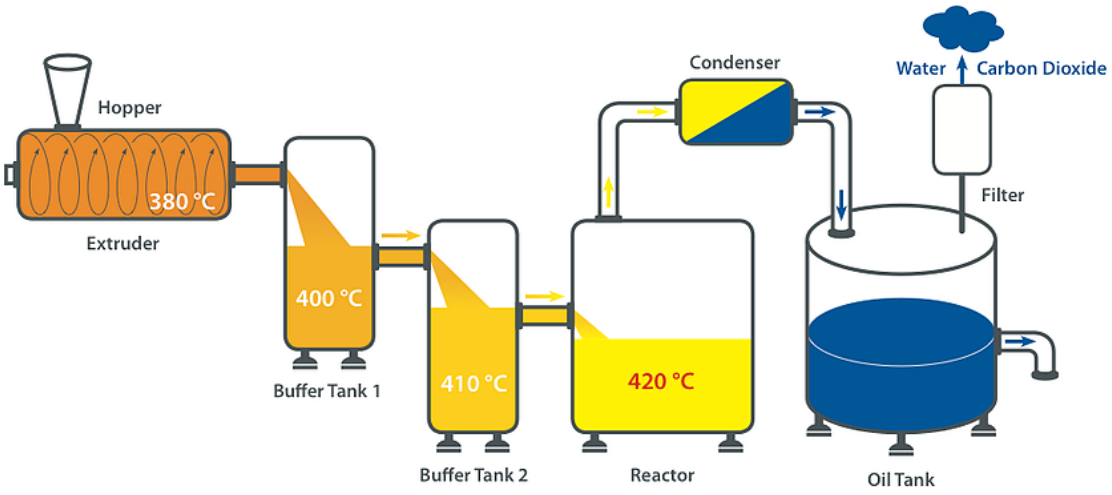

Figure 1: Plastic to oil process

Data was used from (Dinkel et al., 2012) and complemented by literature research.
Table 19 shows the metadata for the production of light fuel oil, secondary. The corresponding inventory data are reported in chapter 3.6.7.

Table 19: Metadata for light fuel oil, secondary {RER}

Ecoinvent v3	Meta data
Name	light fuel oil, secondary {CH}
General comment	The production of light fuel oil is valid for 1 ton of secondary oil. This process delivers the by-product residual material for energetic use.
Activities Start	Service is starting with the receipt of bales of sorted waste PE bottles.
Activities End	This module includes all processes of the production of light fuel oil from PE bottles up to the factory gate.
Geography	RER
Technology	Laboratory scale
Time Period	2010
Representativeness	Data from one supplier from other region
Sampling procedure	Data was used from (Dinkel et al., 2012) and complemented by literature research
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	98% allocation to light fuel oil and 2% to residual material for energetic use.

3.6 Inventories

3.6.1 Waste PE bottles, collected {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Waste PE bottles, collected {CH} | Transportation | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Transport, freight, lorry 16-32 metric ton, EURO3 {RER}| transport, freight, lorry 16-32 metric ton, EURO3 | Alloc Rec, U		9.840E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Rec, U		4.070E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Rec, U		6.116E+01	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Alloc Rec, U		3.876E+01	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight train {CH}| electricity | Alloc Rec, U		1.160E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		2.120E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		2.120E+00	kg	Lognormal	1.13	(1,1,3,2,2,na)
Polypropylene, granulate {GLO}| market for | Alloc Rec, U		1.040E-01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Polyethylene, low density, granulate {GLO}| market for | Alloc Rec, U		1.666E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Extrusion, plastic film {RER}| production | Alloc Rec, U		1.655E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Fleece, polyethylene {RER}| production | Alloc Rec, U		5.000E-06	kg	Lognormal	1.05	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		4.300E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		4.300E-02	kg	Lognormal	1.13	(1,1,3,2,2,na)
Tin plated chromium steel sheet, 2 mm {GLO}| market for | Alloc Rec, U		4.833E-02	m2	Lognormal	1.05	(1,1,3,2,2,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		3.690E+00	kWh	Lognormal	1.05	(1,1,1,1,1,na)

3.6.2 Waste PE bottles, collected {RER}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Waste PE bottles, collected {RER} | Transportation | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Alloc Rec, U		8.398E+02	tkm	Lognormal	2.29	(5,5,2,5,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		2.120E+00	kg	Lognormal	1.22	(1,5,1,4,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		2.120E+00	kg	Lognormal	1.22	(1,1,3,2,2,na)
Polypropylene, granulate {GLO}| market for | Alloc Rec, U		5.440E-01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Polyethylene, low density, granulate {GLO}| market for | Alloc Rec, U		1.666E+01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Extrusion, plastic film {RER}| production | Alloc Rec, U		1.741E+01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Fleece, polyethylene {RER}| production | Alloc Rec, U		5.000E-06	kg	Lognormal	1.22	(1,5,1,4,1,na)
Corrugated board box {RER}| production | Alloc Rec, U		4.400E-01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		3.900E-01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Injection moulding {RER}| processing | Alloc Rec, U		3.924E-01	kg	Lognormal	1.22	(1,5,1,4,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		4.300E-02	kg	Lognormal	1.22	(1,5,1,4,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		4.300E-02	kg	Lognormal	1.22	(1,5,1,4,1,na)
Tin plated chromium steel sheet, 2 mm {GLO}| market for | Alloc Rec, U		4.833E-02	m2	Lognormal	1.22	(1,5,1,4,1,na)
Electricity, low voltage {UCTE}| market for | Alloc Rec, U		3.690E+00	kWh	Lognormal	1.22	(1,5,1,4,1,na)

3.6.3 Sorting of PE bottles {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Sorting of waste PE bottles {CH} | processing | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	3.05	(4,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		5.600E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		5.600E+00	kg	Lognormal	1.21	(1,5,1,2,1,na)
Diesel, burned in building machine {GLO}| market for | Alloc Rec, U		8.022E+01	MJ	Lognormal	2.23	(1,1,1,1,4,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		3.760E+01	kWh	Lognormal	1.05	(1,1,1,1,1,na)
Heat, central or small-scale, other than natural gas {CH}| heat production, light fuel oil, at boiler 100kW, non-modulating | Alloc Rec, U		3.290E+01	MJ	Lognormal	1.21	(1,2,1,1,3,na)
Waste to treatment						
Waste plastic, mixture {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		9.500E+01	kg	Undefined		(2,1,1,1,4,na)

3.6.4 Sorting of PE bottles {RER}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Sorting of waste PE bottles {RER} | processing | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	4.01	(5,5,4,5,5,na)
Diesel, burned in building machine {GLO}| market for | Alloc Rec, U		6.229E+01	MJ	Lognormal	1.5	(1,1,1,1,4,na)
Propane, burned in building machine {GLO}| propane, burned in building machine | Alloc Rec, U		1.642E+01	MJ	Lognormal	1.3	(4,5,1,3,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		7.845E+00	kg	Lognormal	1.3	(4,5,1,3,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		7.845E+00	kg	Lognormal	1.3	(4,5,1,3,1,na)
Electricity, low voltage {RER}| market group for | Alloc Rec, U		1.573E+01	kWh	Lognormal	1.3	(4,5,1,3,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U		7.781E-02	MJ	Lognormal	1.3	(4,5,1,3,1,na)
Waste to treatment						
Waste plastic, mixture {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		9.500E+01	kg	Lognormal	1.62	(4,5,1,3,4,na)

3.6.5 Polyethylene, granulate, secondary, non-food grade {CH}

This inventory is classified as confidential. Only the calculated inventory is available. The table shows a selection of the most important resources and emissions according to the ecological scarcity method.

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Polyethylene, granulate, secondary, non-food grade {CH} production | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste PE bottles, collected {CH} | Transportation | Alloc Rec, U - Carbotech		1.170E+00	ton	Lognormal	1.06	(1,1,2,1,1,na)
Sorting of waste PE bottles {CH} | Processing | Alloc Rec, U - Carbotech		1.170E+00	ton	Lognormal	1.06	(1,1,2,1,1,na)
Chemical, inorganic {GLO}| production | Alloc Rec, U		4.240E+00	kg	Lognormal	1.51	(1,1,2,1,4,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		8.160E+02	kWh	Lognormal	1.06	(1,1,2,1,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U		7.785E+02	MJ	Lognormal	1.06	(1,1,2,1,1,na)
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	3.76	(4,1,4,1,5,na)
Tap water {CH}| market for | Alloc Rec, U		1.550E+00	ton	Lognormal	1.06	(1,1,2,1,4,na)
Waste to treatment						
Wastewater, average {CH}| treatment of, capacity 1E9l/year | Alloc Rec, U		1.550E+00	m3	Lognormal	1.06	(1,1,2,1,1,na)
Waste graphical paper {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		5.850E+01	kg	Lognormal	1.06	(1,1,2,1,1,na)
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		1.217E+01	kg	Lognormal	1.06	(1,1,2,1,1,na)

3.6.6 Polyethylene, granulate, secondary, non-food grade {RER}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Polyethylene, granulate, secondary, non-food grade {CH} production | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste PE bottles, collected {CH} | Transportation | Alloc Rec, U - Carbotech		1.170E+00	ton	Lognormal	1.32	(4,5,2,5,1,na)
Sorting of waste PE bottles {CH} | Processing | Alloc Rec, U - Carbotech		1.170E+00	ton	Lognormal	1.32	(4,5,2,5,1,na)
Chemical, inorganic {GLO}| production | Alloc Rec, U		2.920E+00	kg	Lognormal	1.32	(4,5,2,5,1,na)
Diesel, burned in building machine {GLO}| processing | Alloc Rec, U		6.478E+00	kWh	Lognormal	1.32	(4,5,2,5,1,na)
Electricity, low voltage {RER}| market group for | Alloc Rec, U		4.895E+02	MJ	Lognormal	1.32	(4,5,2,5,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U		2.765E+02	p	Lognormal	1.32	(4,5,2,5,1,na)
Propane, burned in building machine {GLO}| propane, burned in building machine | Alloc Rec, U		7.515E+00	kg	Lognormal	1.32	(4,5,2,5,1,na)
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	ton	Lognormal	4.01	(5,5,4,5,5,na)
Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Alloc Rec, U		2.700E-01	kg	Lognormal	1.32	(4,5,2,5,1,na)
Emissions to air						
Particulates, < 2.5 um		2.300E-02	kg	Lognormal	1.59	(3,5,2,5,1,na)
Particulates, > 2.5 um, and < 10um		1.500E-02	kg	Lognormal	1.59	(3,5,2,5,1,na)
Emissions to water						
BOD5, Biological Oxygen Demand		3.000E-01	kg	Lognormal	1.59	(3,5,2,5,1,na)
Suspended solids, unspecified		2.900E-01	kg	Lognormal	1.59	(3,5,2,5,1,na)
COD, Chemical Oxygen Demand		1.500E-03	kg	Lognormal	1.59	(3,5,2,5,1,na)
Organic compounds (dissolved)		9.100E-03	kg	Lognormal	1.59	(3,5,2,5,1,na)
Waste to treatment						
Wastewater, average {CH}| treatment of, capacity 1E9l/year | Alloc Rec, U		4.448E-01	m3	Lognormal	1.32	(4,5,2,5,1,na)
Waste graphical paper {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		5.850E+01	kg	Lognormal	1.32	(4,5,2,5,1,na)

Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U	1.217E+01	kg	Lognormal	1.32	(4,5,2,5,1,na)	

3.6.7 Light fuel oil, secondary {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
light fuel oil, secondary {CH} | treatment of waste PE | Alloc Rec, U - Carbotech		1.000E+00	t			Allocation factor 98%
residual material, from production of secondary light fuel oil {CH} | Alloc Rec, U - Carbotech		2.000E-02	t			Allocation factor 2%
Materials/fuels						
Waste PE bottles, collected {CH} | Transportation | Alloc Rec, U - Carbotech		1.462E+00	ton	Lognormal	1.05	(1,1,1,1,1,na)
Sorting of waste PE bottles {CH} | Processing | Alloc Rec, U - Carbotech		1.462E+00	ton	Lognormal	1.05	(1,1,1,1,1,na)
Emissions to air						
Carbon dioxide, fossil	high. pop.	3.873E+02	kg	Lognormal	1.26	(4,4,3,1,1,na)
Carbon monoxide, fossil	high. pop.	1.340E-01	kg	Lognormal	5.08	(4,4,3,1,1,na)
NMVOC, non-methane volatile organic compounds, unspecified origin	high. pop.	1.320E-01	kg	Lognormal	1.59	(4,4,3,1,1,na)
Nitrogen oxides	high. pop.	2.680E-01	kg	Lognormal	1.63	(4,4,4,1,1,na)
Waste to treatment						
Wastewater, average {CH}| treatment of, capacity 4.7E10l/year | Alloc Rec, U		1.200E-02	m3	Lognormal	1.26	(4,4,3,1,1,na)
Waste graphical paper {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		7.313E+01	kg	Lognormal	1.26	(4,4,3,1,1,na)

4 PET from waste PET bottles

4.1 General Information

About 40'000 t of PET bottles per year are collected in Switzerland and further processed to food grade (30 % recycling content) or non-food grade (50 % recycling content) PET granulate. 20 % of the PET cannot be recycled again and is incinerated. Data for the PET recycling processes were derived via PET Recycling Schweiz (PRS).

4.2 Collection of waste PET bottles

Consumers can deposit empty PET bottles at all shops that sell PET bottles or in one of the many collection containers. There are more than 45'000 collection sites with more than 100'000 collection containers available in Switzerland. Data were derived from PET Recycling Schweiz (PRS) that is responsible for the comprehensive logistic-net (Würmli, 2015). Overall, there are more than 40 subcontractors involved in the PET-bottle collection. Table 20 shows the metadata for the collection of PET bottles. The corresponding inventory data can be found in chapter 4.5.1.

Table 20: Metadata for waste PET bottles, collected {CH}

Ecoinvent v3	Meta data
Name	waste PET bottles, collected, {CH}
General comment	The collection of waste PET bottles is valid for 1 ton of collected material which consists of 78.0 % PET bottles, 9.2 % PE caps, 4.6 % labels and 8.3 % impurities.
Activities Start	Service is starting with the disposal of PET bottles to recycling containers
Activities End	This module includes the production of the collection containers and all transportation to the recycling plant.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from all suppliers
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

4.3 Sorting of waste PET bottles

The collected PET bottles are sorted by colours in one of five sorting centres in Switzerland and compressed to 200 to 300 kg heavy bales for further processing. Foreign substances are sorted out and disposed of. Data were derived from involved sorting facilities (confidential). Table 21 shows the metadata for the sorting process of PET bottles. The corresponding inventory data are reported in chapter 4.5.2.

Table 21: Metadata for sorting of waste PET bottles {CH}

Ecoinvent v3	Meta data
Name	Sorting of waste PET bottles {CH}
General comment	The sorting of waste PET bottles is valid for 1 ton of sorting PET bottles in Switzerland with the output of 0.917 t of sorted PET bottles (including caps and labels)
Activities Start	Service is starting with the receipt of collected waste PET bottles.
Activities End	This module includes the sorting of the waste PET bottles. The collection and delivery of the waste PET bottles is excluded.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from two of the five sorting facilities
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

4.4 Production of secondary PET granulate

After sorting, the pure-coloured PET bales are processed according to the United Resource Recovery Corporation (URRC)-procedure in one of two recycling plants in Switzerland. First, the wire around the PET bales is cut away and the bottles are separated again. The PET bottles pass through a metal separator which also separates aluminium-containing labels. The bottles are then shredded with knives to 12 mm size in the mill. The so-called flakes arrive from above into the air separator that separates the label residues from the PET flakes. The label residues end up in the incinerator. Purified from the labels, the flakes land in a pool of water where the bottle caps, made of PE, float on top whereas the PET flakes which are heavier than water, sink to the bottom. Thus, the PE caps can be easily separated from the PET and are transferred to the PE recycling. The PET flakes are treated with 50% sodium hydroxide and the flakes-liquor mixture is heated to approximately 200 degree. The liquor dissolves the PET surface layer. With this procedure, even the SiOx coating of the bottle-inside is removed. The purified PET flakes are washed with water and then dried. The PET flakes have now such a high quality again that they may come into contact with food again. There are two recycled PET grades produced in Switzerland: Non-food grade and food grade. For food grade, the viscosity of the recycled flakes is increased to a comparable level of primary PET by solid state polymerization (SSP). Data were derived from involved recycling facilities. Table 22 and Table 23 show the metadata for the production of secondary PET granulate non-food and food grade. The corresponding inventory data are reported in chapter 4.5.3 and 4.5.4.

Table 22: Metadata for polyethylene terephthalate, secondary, granulate, non-food grade {CH}

Ecoinvent v3	Meta data
Name	polyethylene terephthalate, secondary, granulate, non-food grade {CH}
General comment	The production of secondary PET granulate, non-food grade is valid for 1 ton of secondary PET granulate, non-food grade. This process delivers the by-product waste PE, from PET bottle recycling {CH} which is used as a raw material for PE recycling.
Activities Start	Service is starting with the receipt of bales of sorted waste PET bottles.
Activities End	This module includes all processes of the production of secondary PET granulate, non-food grade up to the factory gate.
Geography	CH

Technology	Average of present used technology
Time Period	2014
Representativeness	Data from all suppliers
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	99.5 % allocation to polyethylene terephthalate, secondary, granulate, non-food grade {CH}, 0.5 % allocation to PE, from PET bottle recycling

Table 23: Metadata for polyethylene terephthalate, secondary, granulate, food grade {CH}

Ecoinvent v3	**Meta data**
Name	polyethylene terephthalate, secondary, granulate, food grade {CH}
General comment	The production of secondary PET granulates, food grade is valid for 1 ton of secondary PET granulate, food grade. This process delivers the by-product waste PE, from PET bottle recycling {CH} which is used as a raw material for PE recycling.
Activities Start	Service is starting with the receipt of bales of sorted waste PET bottles.
Activities End	This module includes all processes of the production of secondary PET granulate, food grade up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from all suppliers
Sampling procedure	Data have been collected by data questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	99.5 % allocation to polyethylene terephthalate, secondary, granulate, food grade {CH}, 0.5 % allocation to PE, from PET bottle recycling

4.5 Inventories

4.5.1 Waste PET bottles, collected {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Waste PET bottles, collected {CH} | transportation | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Transport, freight, lorry 16-32 metric ton, EURO3 {RER}| transport, freight, lorry 16-32 metric ton, EURO3 | Alloc Rec, U		1.061E+01	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO4 {RER}| transport, freight, lorry 16-32 metric ton, EURO4 | Alloc Rec, U		4.390E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Rec, U		6.590E+01	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 16-32 metric ton, EURO6 {RER}| transport, freight, lorry 16-32 metric ton, EURO6 | Alloc Rec, U		4.177E+01	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 3.5-7.5 metric ton, EURO3 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO3 | Alloc Rec, U		2.380E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 3.5-7.5 metric ton, EURO4 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO4 | Alloc Rec, U		2.720E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 3.5-7.5 metric ton, EURO5 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO5 | Alloc Rec, U		8.640E+00	tkm	Lognormal	2	(1,1,1,1,1,na)
Transport, freight, lorry 3.5-7.5 metric ton, EURO6 {RER}| transport, freight, lorry 3.5-7.5 metric ton, EURO6 | Alloc Rec, U		4.400E-01	tkm	Lognormal	2	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		2.120E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		2.120E+00	kg	Lognormal	1.13	(1,1,3,2,2,na)
Polypropylene, granulate {GLO}| market for | Alloc Rec, U		5.440E-01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Polyethylene, low density, granulate {GLO}| market for | Alloc Rec, U		1.666E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Extrusion, plastic film {RER}| production | Alloc Rec, U		1.741E+01	kg	Undefined	1.05	(1,1,1,1,1,na)

Fleece, polyethylene {RER}| production | Alloc Rec, U		5.000E-06	kg	Lognormal	1.05	(1,1,1,1,1,na)
Corrugated board box {RER}| production | Alloc Rec, U		4.400E-01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Polyethylene, high density, granulate {GLO}| market for | Alloc Rec, U		3.900E-01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Injection moulding {RER}| processing | Alloc Rec, U		3.924E-01	kg	Undefined	1.05	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		4.300E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		4.300E-02	kg	Lognormal	1.13	(1,1,3,2,2,na)
Tin plated chromium steel sheet, 2 mm {GLO}| market for | Alloc Rec, U		4.833E-02	m2	Undefined	1.05	(1,1,1,1,1,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		3.690E+00	kWh	Lognormal	1.05	(1,1,1,1,1,na)

4.5.2 Sorting of waste PET bottles {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Sorting of waste PET bottles {CH} | processing | Alloc Rec, U - Carbotech		1.000E+00	ton			
Materials/fuels						
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	3.95	(5,1,4,1,5,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		5.596E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {GLO}| market for | Alloc Rec, U		5.596E+00	kg	Lognormal	1.21	(1,5,1,2,1,na)
Diesel, burned in building machine {GLO}| market for | Alloc Rec, U		1.068E+02	MJ	Lognormal	1.05	(1,1,1,1,4,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		4.358E+01	kWh	Lognormal	1.05	(1,1,1,1,1,na)
Heat, central or small-scale, other than natural gas {CH}| heat production, light fuel oil, at boiler 100kW, non-modulating | Alloc Rec, U		2.422E+01	MJ	Lognormal	1.21	(1,2,1,1,3,na)
Waste to treatment						
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		9.073E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)

4.5.3 Polyethylene terephthalate, secondary, granulate, non-food grade {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncer-tainty	Pedigree
Products						
Polyethylene terephthalate, secondary, granulate, non-food grade {CH} production | Alloc Rec, U - Carbotech		1.000E+00	ton			Allocation factor: 99.5%
Waste PE, from PET bottle downcycling {CH} production | Allocation Rec, U - Carbotech		1.220E-01	ton			Allocation factor: 0.5%
Resources						
Water, cooling, unspecified natural origin, CH		4.400E+00	m3	Lognormal	1.05	(1,1,1,1,1,na)
Water, unspecified natural origin, CH		1.090E-03	m3	Lognormal	1.05	(1,1,1,1,1,na)
Materials/fuels						
Waste PET bottles, collected {CH} | transportation | Alloc Rec, U - Carbotech		1.325E+00	t	Lognormal	1.05	(1,1,1,1,1,na)
Sorting of waste PET bottles {CH} | processing | Alloc Rec, U - Carbotech		1.100E+00	kg	Lognormal	2	(1,1,1,1,5,na)
Chemical, organic {GLO}| market for | Alloc Rec, U		6.240E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Extrusion, plastic film {RER}| production | Alloc Rec, U		6.240E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Polypropylene, granulate {GLO}| market for | Alloc Rec, U		1.440E-03	m3	Lognormal	1.05	(1,1,1,1,1,na)
Soap {GLO}| market for | Alloc Rec, U		2.000E-06	p	Lognormal	3.27	(4,1,1,1,4,na)
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.500E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Alloc Rec, U		3.000E-03	kg	Lognormal	1.05	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		1.100E+00	kg	Lognormal	1.05	(1,1,1,1,1,na)
Sulfuric acid {GLO}| market for | Alloc Rec, U		3.000E-03	kg	Lognormal	1.05	(1,1,1,1,1,na)
Wire drawing, steel {RER}| processing | Alloc Rec, U		1.325E+00	t	Lognormal	1.05	(1,1,1,1,1,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		4.210E+02	kWh	Lognormal	1.05	(1,1,1,1,1,na)
Heat, district or industrial, other than natural gas {CH}| heat, from municipal waste incineration to generic market for heat district or industrial, other than natural gas | Alloc Rec, U		6.932E+03	MJ	Lognormal	1.05	(1,1,1,1,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U		2.881E+02	MJ	Lognormal	1.07	(1,1,1,1,2,na)

Emissions to water						
COD, Chemical Oxygen Demand		3.370E-01	kg	Lognormal	1.5	(1,1,1,1,1,na)
Waste to treatment						
Wastewater, average {CH}| treatment of, capacity 1.1E10l/year | Alloc Rec, U		4.400E+00	m3	Lognormal	1.07	(1,1,1,1,2,na)
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		6.318E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)

4.5.4 Polyethylene terephthalate, secondary, granulate, food grade {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Polyethylene terephthalate, secondary, granulate, food grade {CH} production | Alloc Rec, U - Carbotech		1.000E+00	ton			Allocation factor: 99.5%
Waste PE, from PET bottle to bottle recycling {CH} production | Allocation Rec, U - Carbotech		1.220E-01	ton			Allocation factor: 0.5%
Resources						
Water, cooling, unspecified natural origin, CH		6.020E+00	m3	Lognormal	1.05	(1,1,1,1,1,na)
Water, unspecified natural origin, CH		3.500E-01	m3	Lognormal	1.05	(1,1,1,1,1,na)
Materials/fuels						
Waste PET bottles, collected {CH} | transportation | Alloc Rec, U - Carbotech		1.325E+00	ton	Lognormal	1.05	(1,1,1,1,1,na)
Sorting of waste PET bottles {CH} | processing | Alloc Rec, U - Carbotech		1.325E+00	ton	Lognormal	1.05	(1,1,1,1,1,na)
Chemical, organic {GLO}| market for | Alloc Rec, U		3.300E-01	kg	Lognormal	2	(1,1,1,1,5,na)
Extrusion, plastic film {RER}| production | Alloc Rec, U		1.870E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Polypropylene, granulate {GLO}| market for | Alloc Rec, U		1.870E-02	kg	Lognormal	1.05	(1,1,1,1,1,na)
Soap {GLO}| market for | Alloc Rec, U		9.000E-02	kg	Lognormal	1.2	(1,1,1,1,3,na)
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	3.27	(4,1,1,1,4,na)
Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Alloc Rec, U		3.083E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)
Steel, low-alloyed {GLO}| market for | Alloc Rec, U		9.600E-04	kg	Lognormal	1.05	(1,1,1,1,1,na)
Sulfuric acid {GLO}| market for | Alloc Rec, U		1.798E+01	kg	Lognormal	1.05	(1,1,1,1,1,na)

Wire drawing, steel {RER}| processing | Alloc Rec, U		9.600E-04	kg	Lognormal	1.05	(1,1,1,1,1,na)
Electricity, low voltage {CH}| market for | Alloc Rec, U		3.426E+02	kWh	Lognormal	1.05	(1,1,1,1,1,na)
Heat, district or industrial, other than natural gas {CH}| heat, from municipal waste incineration to generic market for heat district or industrial, other than natural gas | Alloc Rec, U		2.080E+03	MJ	Lognormal	1.05	(1,1,1,1,1,na)
Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Alloc Rec, U		4.948E+02	MJ	Lognormal	1.07	(1,1,1,1,2,na)
Emissions to water						
COD, Chemical Oxygen Demand		3.059E+00	kg	Lognormal		(1,1,1,1,1,na)
Waste to treatment						
Wastewater, average {CH}| treatment of, capacity 1.1E10l/year | Alloc Rec, U		6.370E+00	m3	Lognormal	1.07	(1,1,1,1,2,na)
Municipal solid waste {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Rec, U		1.015E+02	kg	Lognormal	1.05	(1,1,1,1,1,na)

5 Tin from steel scrap

5.1 General Information

About 13'000 t of tin plate cans per year are collected in Switzerland and further processed. Before being recycled, tin cans are de-tinned in Switzerland. The resulting tin can then be purified and be used in lieu of primary tin. Abroad it is possible the recycle tin cans directly without prior de-tinning. During this process the tin-plated steel is diluted below 0.03% tin content with additional steel scrap (weight proportion). The containing tin is lost along the way.
Most information in this chapter is taken from the report by Kägi and Zumstein (2015).

5.2 Collection of waste tin plate and aluminium

The first step to produce recycled and de-tinned material is to collect the scrap material. Table 24 shows the metadata for the inventory waste tinplate, collected {CH}. Data are based on information provided by the detinning company. The corresponding ecoinvent process data are reported in chapter 5.6.1.

Table 24: Metadata for waste tinplate and aluminium, collected, {CH}

Ecoinvent v3	Meta data
Name	waste tinplate and aluminium, collected, {CH}
General comment	Inventory is valid for 1 ton of collected material, which consists of 77% tin plate and 23% aluminium.
Activities Start	Service is starting with the disposal of tinplate/aluminium to recycling containers
Activities End	Collected and delivered material
Geography	CH
Technology	Average of present used technology
Time Period	2010-2015
Representativeness	Data valid for CH
Sampling procedure	Data collection by questionnaire
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

5.3 Sorting of waste tin plate and aluminium

Before being de-tinned and recycled, the collected waste tinplate has to be sorted because the collected material consists of 77 % waste tin plate and of 23 % waste aluminium. Data for the sorting process could not be deducted from the existing data. Therefore, the inventory iron scrap, sorted and pressed {RER}was used as a proxy for the sorting process. Table 25 shows the metadata for the inventory sorting of waste tin plate an aluminium {CH}. The corresponding ecoinvent process data are reported in chapter 5.6.2.

Table 25: Metadata for sorting of waste tinplate and aluminium {CH}

Ecoinvent v3	Meta data
Name	Sorting of waste tinplate and aluminium {CH} | processing

General comment	The sorting of waste tinplate and aluminium is valid for 1 ton of sorted material (either waste tin plate or waste aluminium).
Activities Start	Service is starting with the input of unsorted material and energy
Activities End	This module includes all activities up to the sorting and pressing to blocks.
Geography	CH
Technology	Average of present used technology
Time Period	2010-2014
Representativeness	Data valid for CH
Sampling procedure	Literature and own estimations
Extrapolations	Data are extrapolated from iron scrap, sorted and pressed {RER
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

5.4 De-tinning of waste tin plate

Data for de-tinning was collected from Elektrozinn AG in Oberrüti, the only existing de-tinning plant in Switzerland. The de-tinning process is performed by means of electrolysis, where tin cake (tin content 85%) and black plate (tin content < 0.03%) can be recovered from steel. Additionally, the process delivers sludge as well as plastic and paper waste, which is burned in cement or municipal incineration plants. Table 26 and Table 27 show the metadata for tin, 85%, secondary {CH} and black plate, after de-tinning, {CH}. The corresponding ecoinvent process data are reported in chapter 5.6.3 and 5.6.4.

Table 26: Metadata for tin, 85%, secondary, {CH} | production

Ecoinvent v3	Meta data
Name	tin, 85%, secondary, {CH} | production
General comment	The manufacturing is based on confidential production data and is therefore only available as calculated inventory process (S-process). The inventory is valid for 1 kg of tin 85%
Activities Start	Service is starting with the input of raw materials from collection and energy
Activities End	This module includes all processes of the production of secondary tin up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2010-2015
Representativeness	Data from all suppliers
Sampling procedure	Data have been collected by data questionnaire and from literature
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	Economic allocation is used between tin 85% and black plate, after de-tinning. Values of allocation are confidential

Table 27: Metadata for black plate, after de-tinning, {CH}

Ecoinvent v3	Meta data
Name	black plate, after de-tinning, {CH}
General comment	The manufacturing is based on confidential production data and is therefore only available as calculated inventory process (S-process). The inventory is valid for 1 kg of detinned black plate
Activities Start	Service is starting with the input of raw materials from collection and energy

Activities End	This module includes all processes of the production of black plate after de-tinning up to the factory gate.
Geography	CH
Technology	Average of present used technology
Time Period	2010-2015
Representativeness	Data from all suppliers
Sampling procedure	Data have been collected by data questionnaire and from literature
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	Economic allocation is used between tin 85% and black plate, after de-tinning

5.5 Production of secondary tin

The tin cake is transported to a recycling plant and further processed together with tin and lead containing sludge from copper recycling. The lead contents are removed by vacuum distillation and high-grade tin (99.9%) is produced. Due to lack of data, the energy demand to produce 1 ton of pure tin was estimated with literature values ((Grimes et al., 2008), 20 MJ from 50 % electricity and fuel oil respectively). These values seem rather high, as they are valid for the processes „roasting, reduction & refining“. But data for the refining only are not reported. Table 28 shows the metadata for tin, 99.9%, secondary, {RER}. The corresponding ecoinvent process data are reported in chapter 0.

Table 28: Metadata for tin, 99.9%, secondary, {RER}

Ecoinvent v3	**Meta data**
Name	tin, 99.9%, secondary, {RER}
General comment	This inventory is valid for 1kg of tin 99.9%
Activities Start	Service is starting with the input of tin cake (85% tin content) and energy
Activities End	This module includes treatment to high-grade tin (99-9%).
Geography	RER
Technology	Average of present used technology
Time Period	2010-2015
Representativeness	unknown
Sampling procedure	Data have been collected from literature
Extrapolations	none
Data treatment	Uncertainty estimation according to the pedigree matrix
Allocation rules	no allocation used

5.6 Inventories

5.6.1 Waste tinplate and aluminium, collected, {CH} | transportation

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
waste tinplate and aluminium, collected, {CH} | transportation | Alloc Rec U - Carbotech		1.000E+00	ton			
Materials/fuels						
Transport, freight train {CH}| electricity | Alloc Rec, U		1.154E+02	tkm	Lognormal	2	(1,2,2,2,1,na)
Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Alloc Rec, U		4.945E+01	tkm	Lognormal	2	(1,2,2,2,1,na)

5.6.2 Sorting of waste tin plate and aluminium, {CH}| processing

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Sorting of waste tin plate and aluminium, {CH}| processing | Alloc Rec, U - Carbotech		1	t			
Materials/fuels						
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-06	p	Lognormal	5.2663	(1,1,5,1,1,na)
Electricity, medium voltage {CH}| market for | Alloc Rec, U		1.000E+01	kWh	Lognormal	5.2663	(1,1,5,1,1,na)
Diesel, burned in building machine {GLO}| market for | Alloc Rec, U		1.728E+01	MJ	Lognormal	5.2663	(1,1,5,1,1,na)

5.6.3 Tin, 85%, secondary, {CH} | production

This inventory is classified as confidential. Only the calculated inventory is available. The table shows a selection of the most important resources and emissions according to the ecological scarcity method.

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
tin, 85%, secondary, {CH} | production | Alloc Rec S - Carbotech		1	ton			
Resources and emissions						
Gravel	Raw	2.391E+03	kg	n/a	n/a	n/a
Indium	Raw	7.636E-04	kg	n/a	n/a	n/a
Occupation, industrial area	Raw	5.333E+02	kg	n/a	n/a	n/a
Oil, crude	Raw	9.222E+02	kg	n/a	n/a	n/a
Uranium	Raw	8.142E-02	kg	n/a	n/a	n/a
Cadmium	Air	4.582E-02	kg	n/a	n/a	n/a
Carbon dioxide, fossil	Air	9.022E+02	kg	n/a	n/a	n/a
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	1.306E-09	kg	n/a	n/a	n/a
Lead	Air	7.636E-01	kg	n/a	n/a	n/a
Methane, fossil	Air	2.035E-01	m2a	n/a	n/a	n/a
Nitrogen oxides	Air	4.958E+00	kg	n/a	n/a	n/a
Particulates, < 2.5 um	Air	3.710E-01	kg	n/a	n/a	n/a
Particulates, > 2.5 um, and < 10um	Air	3.812E-01	kg	n/a	n/a	n/a
Sulfur dioxide	Air	8.473E-01	kg	n/a	n/a	n/a
Zinc	Air	1.375E+00	kg	n/a	n/a	n/a
Chromium VI	Water	1.483E-07	kg	n/a	n/a	n/a

5.6.4 Black plate, after de-tinning, {CH}

This inventory is classified as confidential. Only the calculated inventory is available. The table shows a selection of the most important resources and emissions according to the ecological scarcity method.

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
black plate, after detinning, {CH} | production | Alloc Rec S - Carbotech		1	ton			
Resources and emissions						
Gravel	Raw	5.727E-04	kg	n/a	n/a	n/a
Indium	Raw	1.128E+01	kg	n/a	n/a	n/a
Occupation, industrial area	Raw	1.854E-09	m2a	n/a	n/a	n/a
Oil, crude	Raw	1.632E-11	kg	n/a	n/a	n/a
Uranium	Raw	2.989E+01	kg	n/a	n/a	n/a
Volume occupied, final repository for radioactive waste	Raw	9.545E-06	m3	n/a	n/a	n/a
Cadmium	Air	9.545E-03	kg	n/a	n/a	n/a
Carbon dioxide, fossil	Air	2.543E-03	kg	n/a	n/a	n/a
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	6.198E-02	kg	n/a	n/a	n/a
Lead	Air	6.667E+00	kg	n/a	n/a	n/a
Methane, fossil	Air	1.153E+01	kg	n/a	n/a	n/a
Nitrogen oxides	Air	2.023E-04	kg	n/a	n/a	n/a
Particulates, < 2.5 um	Air	4.638E-03	kg	n/a	n/a	n/a
Particulates, > 2.5 um, and < 10um	Air	4.765E-03	kg	n/a	n/a	n/a
Sulfur dioxide	Air	1.059E-02	kg	n/a	n/a	n/a
Zinc	Air	1.018E-03	kg	n/a	n/a	n/a
Chromium VI	Water	3.158E-07	kg	n/a	n/a	n/a
Oils, unspecified	Water	1.719E-02	kg	n/a	n/a	n/a

5.6.5 Tin, 99.9%, secondary, {RER} | production

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
tin, 99.9%, secondary, {RER} | production | Alloc Rec U - Carbotech		1.000E+00	kg			
Materials/fuels						
tin, 85%, secondary, {CH} | production | Alloc Rec S - Carbotech		1.176E+00	kg	Lognormal	1.09	(2,1,1,1,2,na)
Transport, freight, lorry >32 metric ton, EURO4 {RER}| transport, freight, lorry >32 metric ton, EURO4 | Alloc Rec, U		8.850E-01	tkm	Lognormal	2.11	(4,4,2,4,3,na)
Electricity, medium voltage {UCTE}| market for | Alloc Rec, U - Carbotech		1.000E+01	MJ	Lognormal	1.78	(5,2,2,2,4,na)
Heat, district or industrial, other than natural gas {Europe without Switzerland}| heat production, light fuel oil, at industrial furnace 1MW | Alloc Rec, U		1.000E+01	MJ	Lognormal	1.79	(5,2,3,2,4,na)
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		2.000E-09	p	Lognormal	3.06	(3,5,2,4,1,na)
Waste to treatment						
Sludge, NaCl electrolysis {CH}| treatment of sludge, NaCl electrolysis, residual material landfill | Alloc Rec, U		1.800E-01	kg	Lognormal	1.8	(5,3,3,4,4,na)

6 Waste preparation facility {CH}

6.1 Construction of waste preparation facility

In order to include the infrastructure of scrap sorting and preparation facilities in Switzerland, a new infrastructure inventory was created. It is based on the already existing ecoinvent inventory "scrap preparation facility {RER}" but without the administration building of 50x50x10 m3 which seems highly overestimated (size of half a soccer field, place for about 200 persons) for a production plant with a capacity of 10'000 t per year. The lifespan of the building is estimated to be 50 years.
Table 29 shows the metadata for the scrap preparation facility. The corresponding inventory data are reported in chapter 6.2.1.

Table 29: Metadata for polyethylene terephthalate, secondary, granulate, non-food grade {CH}

Ecoinvent v3	Meta data
Name	Waste preparation facility {CH}
General comment	The inventory is valid for 1 facility with an estimated lifespan of 50 years and a production volume of 10'000 t per year. This inventory is a very rough estimation and should be used carefully. It should not be used if the building itself is in focus of the LCA
Activities Start	Service is starting with the components used for the building
Activities End	This module includes all processes of the production of the facility and its disposal.
Geography	CH
Technology	Average of present used technology
Time Period	2014
Representativeness	Data from one supplier
Sampling procedure	Data have been copied and altered based on an existing inventory (scrap preparation facility {RER})
Extrapolations	Extrapolated and adapted based on existing inventory (scrap preparation facility {RER})
Data treatment	High uncertainty. Uncertainty estimation according to the pedigree matrix
Allocation rules	None

6.2 Inventory

6.2.1 Waste preparation facility {CH}

Description	sub-compartment	amount	unit	uncertainty distribution	value uncertainty	Pedigree
Products						
Waste preparation facility {CH}| construction | Alloc Rec, U - Carbotech		1.000E+00	p			
Resources						
Transformation, to industrial area	land	3.751E+04	m2	Lognormal	3.0999	(5,5,5,5,5,na)
Transformation, from unknown	land	3.750E+04	m2	Lognormal	3.0999	(5,5,5,5,5,na)
Occupation, industrial area	land	1.875E+06	m2a	Lognormal	2.6639	(5,5,5,5,5,na)
Materials/fuels						
Building, hall {GLO}| market for | Alloc Rec, U		1.670E+03	m2	Lognormal	4.1133	(5,5,5,5,5,na)
Concrete, sole plate and foundation {CH}| market for | Alloc Rec, U		6.700E+01	m3	Lognormal	4.1133	(5,5,5,5,5,na)
Industrial machine, heavy, unspecified {GLO}| market for | Alloc Rec, U		1.540E+05	kg	Lognormal	4.1133	(5,5,5,5,5,na)
Concrete, normal {CH}| market for | Alloc Rec, U		1.910E+01	m3	Lognormal	4.1133	(5,5,5,5,5,na)
Reinforcing steel {GLO}| market for | Alloc Rec, U		1.320E+04	kg	Lognormal	4.1133	(5,5,5,5,5,na)
Conveyor belt {GLO}| market for | Alloc Rec, U		2.000E+02	m	Lognormal	4.1133	(5,5,5,5,5,na)
Waste to treatment						
Waste reinforced concrete {GLO}| market for | Alloc Rec, U		5.530E+04	kg	Lognormal	4.1133	(5,5,5,5,5,na)
Waste concrete, not reinforced {GLO}| market for | Alloc Rec, U		1.540E+05	kg	Lognormal	4.1133	(5,5,5,5,5,na)

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