worldsteel ASSOCIATION

LCI DATA FOR STEEL PRODUCTS

Report produced for:

Jude Medard Singarayar

William Hare UAE LLC

Data provided by:

Ping Yang

World Steel Association

16-11-2020

worldsteel contact:

Clare Broadbent

Head of Sustainability

broadbent@worldsteel.org

T: 32. 2 702 89 32

2019 LCI data release

worldsteel.org

1 Introduction

The following data is provided in this report:

- 1kg of global steel plate, cradle-to-gate,
- 1kg of global steel sections, cradle-to-gate,

- 1kg of global steel plate, cradle-to-gate, including end-of-life recycling (85% recycling rate)
- 1kg of global steel sections, cradle-to-gate, including end-of-life recycling (85% recycling rate)

Chapter 4 shows the cradle to gate LCI.
Chapter 5 shows the cradle to gate including net credits for recycling.
Chapter 6 shows the net credits for recycling (i.e. the difference between chapters 4 and 5)
Chapter 9 shows the LCI for steel scrap that is used to represent the burden of scrap inputs and credit for the amount of steel that is recycled at the end-of-life.

The data provided has been generated based on the worldsteel data collection and LCI methodology report, published in 2017. Full details are available in the World Steel Association Life Cycle Inventory for Steel Products report. This data was published in December 2019. The study report accompanying this data will be published shortly.

2 Data description

A description of the steel products provided in this report:

Product	**Technical purpose of product or process**
Plate	A flat steel sheet rolled on a hot rolling mill. It can be found on the market in sheets and is further processed into finished products by the manufacturers. Heavy plate is used in a large number of sectors: structural steels, shipbuilding, pipes, pressure vessels, boilers, heavy metal structures, offshore structures etc. Typical thickness between 2 to 20 mm. The maximum width is 1860 mm.
Sections	A steel section rolled on a hot rolling mill. Steel Sections include I-beams, H-beams, wide-flange beams, and sheet piling. It can be found on the market for direct use. This product is used in construction, multi-story buildings, industrial buildings, bridge trusses, vertical highway supports, and riverbank reinforcement.

The data provided is cradle to gate data. Data can also be provided to show the net benefits of recycling steel from the product at the end of its life, in other words it includes the benefits of recycling. This means that a burden is given for the steel scrap that is used as an input to the steel making process, and a credit for the end-of-life (EoL) steel that is recycled. More details about this are given in the section on methodology.

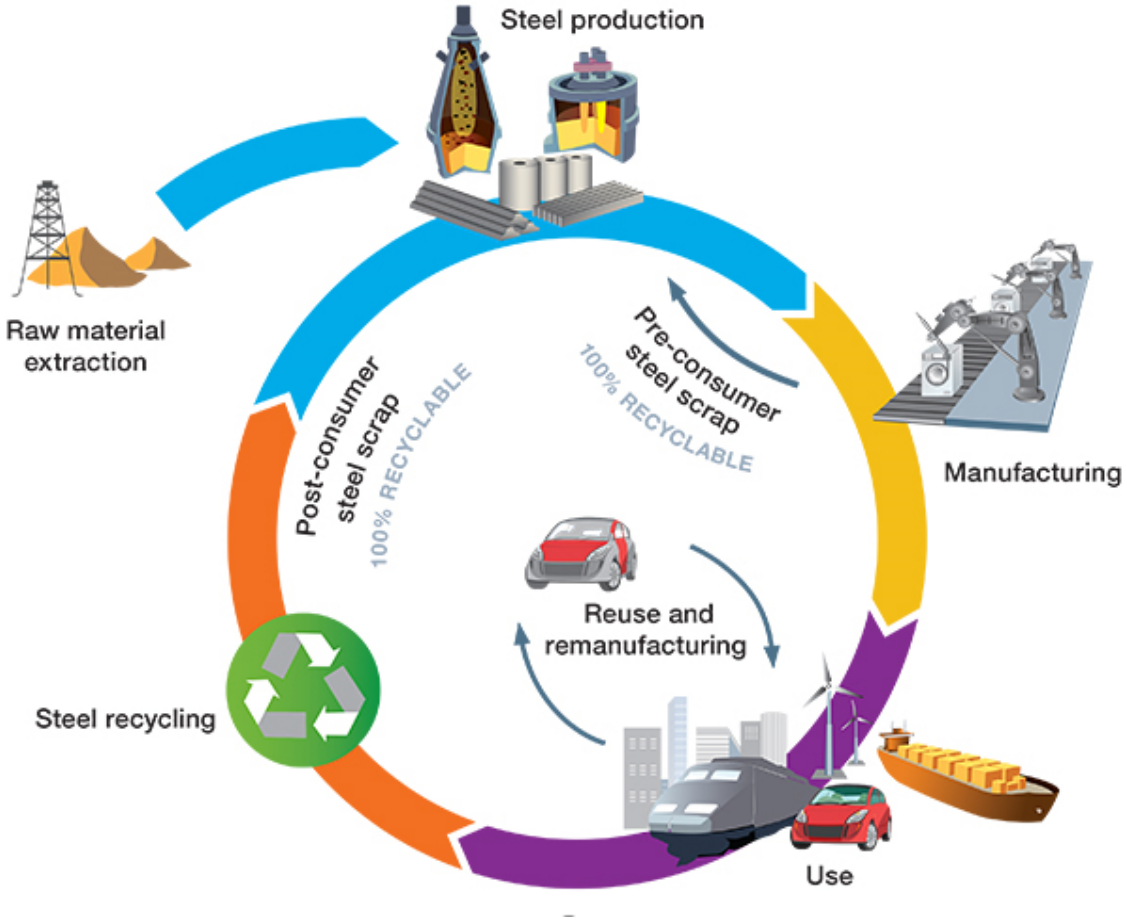
For each of the products given in this report, the recycling rates are specified with the data.

The data was published in 2019 and represents steel production from 2014 to 2018, with the majority being from 2015.

The flow list includes the main inputs and outputs of the steelmaking process. Please note that, when using the data, the inputs are expressed in **kg** and the outputs in **grams**.

3 Methodology

The methodology used to develop this data is detailed in worldsteel's World Steel Life Cycle Inventory report, 2017, which is provided with this data or can be requested via the worldsteel website www.worldsteel.org.



3.1 Summary of methodology

The quality and relevance of LCA/LCI results, and the extent to which they can be applied and interpreted, depends critically upon the methodology used. It is therefore important that methodology is transparent and well documented. ISO standards have been developed to provide guidance on methodological choices and to set down rules for transparency and reporting. The relevant ISO standards are:

- ISO 14040: 2006 - Environmental management – Life cycle assessment – Principles and framework
- ISO 14044: 2006 - Environmental management – Life cycle assessment – Requirements and guidelines

The goal of collecting and developing worldsteel LCI datasets is to facilitate the range of emerging impact assessment methods in future studies.

The worldsteel LCI study has been undertaken in accordance with ISO 14040 and ISO 14044. The previous three data collections and methodology reports underwent a critical review from an independent Critical Review Panel of LCA specialists. This approach improved the integrity of the study and can help guide methodology. The full CRP Report is included in the reports. The new data collection, released in December 2019, is based on the same methodology, except that now a weighted average approach is

taken to determine product specific LCIs. This methodology has undergone a critical review by an external expert and is available from worldsteel.

The study is a cradle-to-gate LCI study, including recycling. That is, it covers all of the production steps from raw materials 'in the earth' (i.e. the cradle) to finished products ready to be shipped from the steelworks (i.e. the gate). It can also include the credits associated with recycling the steel from the product at the end of its life. It does not include the manufacture of downstream products or their use.

The steel product manufacturing system encompasses the activities of the steel sites and all major upstream processes, including the production and transportation of raw materials, energy sources and consumables used on the steelworks. In addition the recovery and use of steel industry by-products outside of the steelworks are taken into account using in most cases the method of system expansion.

The data includes steel production from both the integrated route (Blast Furnace / Basic Oxygen Furnace) and the Electric Arc Furnace route.

3.2 Recycling methodology

Steel is one of the most recyclable materials in the world and therefore it is important to consider recycling in life cycle assessment studies involving steel, namely the steel scrap that is recycled from a product at the end of its life. In addition, steel is a vital input to the steel making process, and this input of steel scrap should also be considered in LCA studies.

The worldsteel methodology therefore considers both of these factors in the methodology (full details available in the methodology report).

The general life cycle equation for the “closed material loop recycling methodology” is applied as shown by the equation below:

LCI for 1 kg of steel product including recycling = X – (RR – S) × Y(Xpr – Xre)

where:

X is the cradle to gate LCI of the product

(RR – S) is the net amount of scrap:
RR is the end of life recycling rate of the steel product
S is the scrap input to the steelmaking process

Y(Xpr - Xre) is the value of scrap:
Y is the process yield of the EAF (i.e. >1kg scrap is required to produce 1kg steel)
Xpr = the LCI for 100% primary metal production This is a theoretical value of steel slab made in the BF/BOF route, assuming 0% scrap input.
Xre = the LCI for 100% secondary metal production from scrap in the EAF (assuming scrap = 100%)

4 LCI Results: Cradle to Gate excluding Recycling for 1kg steel

The data does not consider a burden for scrap input or a credit for the EoL recycling.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Bauxite	0.0086493	0.0030303
Crude oil (resource)	0.0054276	0.01573
Dolomite	0.066179	0.030159
Hard coal (resource)	0.89393	0.48019
Lignite (resource)	0.014444	0.0461
Limestone (calcium carbonate)	-0.058944	0.035172
Natural gas (resource)	0.040198	0.067463
Uranium (resource)	5.279E-007	1.4197E-006

	1kg of global plate	1kg of global sections
Total freshwater consumption (including rainwater) 1 [kg]	10.13	0.78
Blue water consumption 2 [kg]	8.64	-1.87

[1] The total fresh water consumption is the net amount of freshwater, lake water, river water and rain water that is consumed. It excludes sea water.
[2] Blue water is Ground water + surface water. This is what is used for water footprint calculation. Please note the blue water is from the water footprint network and is for information only.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Chromium	0.001222	0.00073716
Copper	8.0227E-005	-5.4853E-005
Iron	1.0564	0.45249
Lead	5.49E-006	-7.0483E-005
Nickel	8.9E-005	4.8501E-005
Tin	-3.16E-015	-8.12E-016
Titanium	4.3113E-008	-4.5298E-007
Vanadium	4.53E-005	0.00010535
Zinc	5.2906E-006	-0.0039329

	1kg of global plate	1kg of global sections
Steel and Iron scrap [kg]	0.15613	0.64406

Emissions to air (mass, g)

	1kg of global plate	1kg of global sections
Carbon dioxide	2368	1498
Carbon monoxide	29.08	17.88
Hydrogen chloride	0.01925	0.0282
Hydrogen sulphide	0.005266	0.01265
Nitrogen dioxide	-0.0007293	-0.000512
Nitrogen oxides	3.387	2.297
Nitrous oxide (laughing gas)	0.01185	0.01489
Sulphur dioxide	2.939	2.043
Dioxins (unspec.)	5.87E-008	1.61E-008
NMVOC (unspecified)	0.1043	0.09445
Methane	5.275	3.328
Particles to air	1.741	1.213

Emissions to fresh water (mass, g)

	1kg of global plate	1kg of global sections
Biological oxygen demand (BOD)	0.00872	0.005004
Chemical oxygen demand (COD)	0.1916	0.2983
Nitrogenous Matter (unspecified, as N)	0.0764	0.0245
Solids (dissolved)	-0.0502	-0.0633
Iron	0.1601	0.1262
Phosphate	0.0008177	0.001609
Phosphorus	0.0009494	0.0004544

Environmental Indicators – for information only

	1kg of global plate	1kg of global sections
CML2001 - Jan. 2016, Acidification Potential (AP) [kg SO2 eq.]	0.00526	0.00366
CML2001 - Jan. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	0.000466	0.000328
CML2001 - Jan. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	2.52	1.6
CML2001 - Jan. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	0.00109	0.0007
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	26.6	18.9

5 LCI Results: Cradle to Gate including Recycling for 1kg steel

The data considers a burden for scrap input and a credit for the EoL recycling. The EoL recycling rate is 85%.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Bauxite	0.0062786	0.0023267
Crude oil (resource)	0.02943	0.022854
Dolomite	0.023974	0.017632
Hard coal (resource)	0.39417	0.33186
Lignite (resource)	0.038634	0.053279
Limestone (calcium carbonate)	0.0044122	0.053976
Natural gas (resource)	0.064427	0.074654
Uranium (resource)	1.517E-006	1.7132E-006

	1kg of global plate	1kg of global sections
Total freshwater consumption (including rainwater) 1 [kg]	6.10	-0.41
Blue water consumption 2 [kg]	3.45	-3.41

[1] The total fresh water consumption is the net amount of freshwater, lake water, river water and rain water that is consumed. It excludes sea water.
[2] Blue water is Ground water + surface water. This is what is used for water footprint calculation. Please note the blue water is from the water footprint network and is for information only.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Chromium	0.0011732	0.00072267
Copper	-7.9178E-005	-0.00010216
Iron	0.37774	0.25107
Lead	-9.3442E-005	-9.9846E-005
Nickel	7.6584E-005	4.4815E-005
Tin	-2.1666E-015	-5.1716E-016
Titanium	-5.3391E-007	-6.2424E-007
Vanadium	0.00014592	0.00013521
Zinc	-0.0051526	-0.0054637

Emissions to air (mass, g)

	1kg of global plate	1kg of global sections
Carbon dioxide	1314	1185
Carbon monoxide	11.54	12.68
Hydrogen chloride	0.03351	0.03243
Hydrogen sulphide	0.01683	0.01608
Nitrogen dioxide	0.0003244	-0.0001993
Nitrogen oxides	2.665	2.083
Nitrous oxide (laughing gas)	0.01385	0.01548
Sulphur dioxide	1.735	1.686
Dioxins (unspec.)	5.727E-008	1.568E-008
NMVOC (unspecified)	0.122	0.09972
Methane	2.695	2.562
Particles to air	0.7218	0.9104

Emissions to fresh water (mass, g)

	1kg of global plate	1kg of global sections
Biological oxygen demand (BOD)	0.002443	0.003141
Chemical oxygen demand (COD)	0.3986	0.3597
Nitrogenous Matter (unspecified, as N)	0.04943	0.0165
Solids (dissolved)	2.243	0.6174
Iron	0.1475	0.1225
Phosphate	0.001689	0.001867
Phosphorus	0.0004293	0.0003001

Environmental Indicators – for information only

	1kg of global plate	1kg of global sections
CML2001 - Jan. 2016, Acidification Potential (AP) [kg SO2 eq.]	0.00348	0.00313
CML2001 - Jan. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	0.000373	0.0003
CML2001 - Jan. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.4	1.26
CML2001 - Jan. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	0.000525	0.000534
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	17.3	16.2

6 LCI Results: Net credit of Recycling

The data show the net credit of recycling per product and per Recycling Rate selected.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Bauxite	-0.0023708	-0.00070364
Crude oil (resource)	0.024002	0.0071239
Dolomite	-0.042205	-0.012526
Hard coal (resource)	-0.49976	-0.14833
Lignite (resource)	0.02419	0.0071795
Limestone (calcium carbonate)	0.063356	0.018804
Natural gas (resource)	0.024229	0.0071911
Uranium (resource)	9.8912E-007	2.9357E-007

	1kg of global plate	1kg of global sections
Total freshwater consumption (including rainwater) 1 [kg]	-4.03	-1.20
Blue water consumption 2 [kg]	-5.18	-1.54

[1] The total fresh water consumption is the net amount of freshwater, lake water, river water and rain water that is consumed. It excludes sea water.
[2] Blue water is Ground water + surface water. This is what is used for water footprint calculation. Please note the blue water is from the water footprint network and is for information only.

Inputs (mass, kg)

	1kg of global plate	1kg of global sections
Chromium	-4.8832E-005	-1.4493E-005
Copper	-0.0001594	-4.7311E-005
Iron	-0.67865	-0.20142
Lead	-9.8932E-005	-2.9363E-005
Nickel	-1.2417E-005	-3.6853E-006
Tin	9.9341E-016	2.9484E-016
Titanium	-5.7702E-007	-1.7126E-007
Vanadium	0.00010062	2.9864E-005
Zinc	-0.0051579	-0.0015308

Emissions to air (mass, g)

	1kg of global plate	1kg of global sections
Carbon dioxide	-1054	-312.9
Carbon monoxide	-17.54	-5.205
Hydrogen chloride	0.01425	0.00423
Hydrogen sulphide	0.01156	0.003431
Nitrogen dioxide	0.001054	0.0003127
Nitrogen oxides	-0.7216	-0.2142
Nitrous oxide (laughing gas)	0.001995	0.0005921
Sulphur dioxide	-1.204	-0.3573
Dioxins (unspec.)	-1.427E-009	-4.236E-010
NMVOC (unspecified)	0.01775	0.00527
Methane	-2.581	-0.766
Particles to air	-1.02	-0.3026

Emissions to fresh water (mass, g)

	1kg of global plate	1kg of global sections
Biological oxygen demand (BOD)	-0.006276	-0.001863
Chemical oxygen demand (COD)	0.2071	0.06146
Nitrogenous Matter (unspecified, as N)	-0.02697	-0.008006
Solids (dissolved)	2.294	0.6807
Iron	-0.01258	-0.003733
Phosphate	0.0008713	0.0002586
Phosphorus	-0.0005201	-0.0001544

Environmental Indicators – for information only

	1kg of global plate	1kg of global sections
CML2001 - Jan. 2016, Acidification Potential (AP) [kg SO2 eq.]	-0.00177	-0.000526
CML2001 - Jan. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	-9.28E-005	-2.76E-005
CML2001 - Jan. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	-1.13	-0.335
CML2001 - Jan. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	-0.000561	-0.000166
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	-9.3	-2.76

7 Data usage

A life cycle inventory (LCI) study has been carried out by the World Steel Association (worldsteel) to quantify resource use, energy and environmental emissions associated with the processing of 16 steel industry products, from the extraction of raw materials in the ground through to the steel factory gate and including end-of-life recycling.

LCI data were calculated for products derived via the blast furnace/basic oxygen furnace route (based on iron ore and steel scrap) and the electric arc furnace route (mainly based on steel scrap).

The 16 products included in the study are the main finished products of the steel industry. They include hot rolled coil (with and without pickling), cold rolled coil (with and without finishing), hot dip and electrically galvanised sheet, painted sheet, tinplate and tin-free sheet, welded pipe, seamless tube, sections, plate, rebar, engineering steel and wire rod. The products are of general relevance to a wide range of downstream applications including those in the construction, automotive and packaging sectors.

A key goal of worldsteel is to provide support on the environmental credentials of steel to customers and users of steel, with the intention that those that specify and use materials in applications have access to relevant data to facilitate their own informed decision-making. In this regard, worldsteel is keen to support the implementation of this data in LCA software and LCA tools. It therefore currently has been made available to the GaBi software and SimaPro software.

worldsteel establishes agreement with LCA database vendors or consultants or advanced users to encourage broad use of the data in the interests of good LCA practice. The data is fully based on the worldsteel methodology.

By using the data, you agree with the following points:

- The worldsteel LCI data is provided free of charge and may not be sold to other parties.
- When the worldsteel data is included in a database for different products, it shall be supplied with the main database of the software (or tool), i.e. at no extra cost for the buyer, nor as an extra library.
- The data shall include a reference source (i.e. www.worldsteel.org)
- The worldsteel LCI Methodology Report shall be provided on request to users of the data.
- Version updates will be available following data improvements and extra LCI information supplied by companies around the world. Please accept these updates (e.g. version changes), and update the database system as required.
-
- The data is supplied only for the purpose of the study for which it was requested. Should they be required for any another purpose, worldsteel must be contacted beforehand.
- The user shall not provide the data on public websites or communicate the full inventories externally without worldsteel agreement.
- The user shall not tamper with the worldsteel data in any way.
- worldsteel accepts no responsibility for the use or misuse of the data.

Clare Broadbent
Head of Sustainability
World Steel Association,
Avenue de Tervueren 270, 1150 Brussels, Belgium
Tel: +32 (0)2 702 89 32 Fax: +32 (0)2 702 88 99
email: broadbent@worldsteel.org / lca@worldsteel.org
worldsteel web site: http://www.worldsteel.org

8 FAQ

1. What is the system boundary of the data?

The data is cradle to gate data and is also provided including recycling at end-of-life. This can also be seen as cradle to grave, excluding the product manufacture (e.g. building, car etc.) and use phase. Upstream processes e.g. production of raw materials, are included. The net credits are also provided separately. The end of life recycling rate is determined by the user of the data.

2. Are you not double accounting by including a credit for the end-of-life recycling?

No. By considering the end of life of the product, we are taking a full life cycle approach: cradle to grave. We give a credit for the scrap that is recycled at the end of the products life, based on avoiding the production of steel from virgin material, but also a burden for any scrap that has been used to make that product: thus, each product has an overall net scrap credit or burden.

3. Is the EAF route better than the BOF route?

Both EAF and BOF routes provide essential capacity for scrap recycling and the impacts of converting scrap to steel are similar for each route. At current levels of demand, there is insufficient scrap supply. Therefore there is a need to produce steel from virgin material. In life cycle terms, the two production routes are equivalent: specifying EAF steel has no net benefit to the earth. What is essential is that steel recycling is optimised so that the use of virgin material resources can be reduced and this makes the two routes complementary.

9 LCI for 1kg Steel Scrap

LCI for 1kg steel scrap - Global value

Inputs (mass, kg)

	Steel Scrap LCI (2019)
Bauxite	0.0034167
Crude oil (resource)	-0.034592
Dolomite	0.060826
Hard coal (resource)	0.72025
Lignite (resource)	-0.034862
Limestone (calcium carbonate)	-0.091308
Natural gas (resource)	-0.034918
Uranium (resource)	-1.4255E-006

	Steel Scrap LCI (2019)
Total freshwater consumption (including rainwater) 1 [kg]	5.81
Blue water consumption 2 [kg]	7.47

[1] The total fresh water consumption is the net amount of freshwater, lake water, river water and rain water that is consumed. It excludes sea water.
[2] Blue water is Ground water + surface water. This is what is used for water footprint calculation. Please note the blue water is from the water footprint network and is for information only.

Inputs (mass, kg)

	Steel Scrap LCI (2019)
Chromium	7.0377E-005
Copper	0.00022973
Iron	0.97806
Lead	0.00014258
Nickel	1.7895E-005
Tin	-1.4317E-015
Titanium	8.316E-007
Vanadium	-0.00014501
Zinc	0.0074335

Emissions to air (mass, g)

	Steel Scrap LCI (2019)
Carbon dioxide	1520
Carbon monoxide	25.28
Hydrogen chloride	-0.02054
Hydrogen sulphide	-0.01666
Nitrogen dioxide	-0.001518
Nitrogen oxides	1.04
Nitrous oxide (laughing gas)	-0.002875
Sulphur dioxide	1.735
Dioxins (unspec.)	2.057E-009
NMVOC (unspecified)	-0.02559
Methane	3.719
Particles to air	1.47

Emissions to fresh water (mass, g)

	Steel Scrap LCI (2019)
Biological oxygen demand (BOD)	0.009046
Chemical oxygen demand (COD)	-0.2984
Nitrogenous Matter (unspecified, as N)	0.03887
Solids (dissolved)	-3.306
Iron	0.01813
Phosphate	-0.001256
Phosphorus	0.0007496

Environmental Indicators – for information only Environmental Indicators

	Steel Scrap LCI (2019)
CML2001 - Jan. 2016, Acidification Potential (AP) [kg SO2 eq.]	0.00255647
CML2001 - Jan. 2016, Eutrophication Potential (EP) [kg Phosphate eq.]	0.0001337993
CML2001 - Jan. 2016, Global Warming Potential (GWP 100 years) [kg CO2 eq.]	1.6246
CML2001 - Jan. 2016, Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	0.0008080354
Primary energy demand from ren. and non ren. resources (net cal. value) [MJ]	13.40479