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Life Cycle Assessment of Two Wheel Vehicles

Implemented in ecoinvent data v2.2 (2010)

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Report

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Summary

Bicycles and scooters are effective means of transport for short distance travel. Especially for daily commuter travel, electric bicycles and scooters become more and more popular. The aim of this report is to provide up-to-date LCI data on transport by two wheel vehicles.

The life cycle inventories of two wheel vehicles expand the existing data sets on transport life cycle inventories. Existing ecoinvent data (Spielmann et al. 2007) is adapted to two wheel vehicle manufacture and operation. The life cycle inventories of bicycles and electric bicycles manufacture are established from literature on bicycle manufacture, whereas the life cycle inventories of scooter and electric scooter manufacture are extrapolated from passenger car manufacture.

The cumulative LCI results show, that the manufacture of two wheel vehicles has a main influence on the environmental performance of transport by bicycles or scooters.

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Abbreviations and Glossary

BEV Battery electric vehicle

CED Cumulative energy demand

LiIo Lithium-ion

Contents

1 Two wheel vehicles

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1.1 Introduction

Bicycles and scooters are an effective means of transport for short distance travel. In the last decade, electric bicycles and electric scooters have become more affordable, which makes them attractive for commuter travel on short distances. The market for electric bicycles is currently growing at annual rates of 100 % and more (velosuisse 2008). Thanks to newer generation of battery packs, mainly Lithium-ion (LiIo) batteries, the operating distance of electric vehicles have attained an operation range, which is suitable for daily short and medium distance operation.

The life cycle inventories cover both the conventional transport by bicycles or scooters and the electrically powered alternative. In order to assess the influence of electricity generation on the overall environmental impact of bicycle transport, the data sets are established for electricity consumption from the Swiss grid (supply mix) and from certified electricity in Switzerland.

The data set of transport by two wheel vehicles is composed of the following input data:

- vehicle operation
- vehicle manufacture
- vehicle maintenance
- vehicle disposal
- use of road infrastructure

1.2 Characterisation of bicycles and electric bicycles

The construction of an average electric bicycle basically is comparable to normal bicycles. However, there are two categories of electric bicycles available. The first category contains bicycles, whose speed is limited to 25 km/h. They can be driven without special permit or license plate. Bicycles with a speed limit up to 45 km/h belong into the second category and need to be registered according to Swiss regulations as motor-assisted bicycle/moped (Bundesversammlung 1995). This study focuses on electric bicycles of the first category. An electric bicycle usually offers four different levels of assistance. The more assistance is provided by the electric motor, the lower is the operating distance of the electric bicycle. We assume an average electricity consumption of 1 kWh per 100 km (Biketech 2009).

The product leader in Switzerland is Biketech AG, who produces the electric bicycles of the label “Flyer”. Flyer bicycles are equipped with an electric motor at the wheel hub and a battery pack mounted on the back of the frame. The weight of a Flyer ranges from 21 to 25 kg. The electric motor contributes 4.4 kg and the battery pack 2.6 kg to the total weight. A comparable bicycle has an overall weight of 17 kg, which is a standard value for so-called citybikes (bicycles for daily use in an urban environment).

Only a small percentage of the bicycles sold in Switzerland are produced or assembled in Switzerland (less than 10%)[1]. We therefore include manufacture and transport to Switzerland from Far East Asia.

[1] Personal communication: Mr. Reto Meier, Tour de Suisse Velos, Kreuzlingen, 2009-08-31

Tab. 1.1: Overview of data sets for bicycles and electric bicycles

Components/activities	Data set
Bicycle, produced in the Far East, sold in Switzerland	bicycle, at regional storage, CH [unit]
Electric bicycle, produced in Far East, assembled and sold in Switzerland	electric bicycle, at regional storage, CH [unit]
Maintenance of a bicycle over the lifetime	maintenance, bicycle, CH [unit]
Maintenance of an electric bicycle over the lifetime	maintenance, electric bicycle, CH [unit]
End-of-life of a bicycle	disposal, bicycle, CH [unit]
End-of-life of an electric bicycle	disposal, electric bicycle, CH [unit]
Operation of bicycle	operation, bicycle, CH [km]
Operation of an electric bicycle charged with Swiss supply mix	operation, electric bicycle, CH [km]
Operation of an electric bicycle charged with certified electricity	operation, electric bicycle, certified electricity, CH [km]
Transport of one person on one kilometre by bicycle	transport, bicycle, CH [pkm]
Transport of one person on one kilometre by electric bicycle charged with Swiss supply mix	transport, electric bicycle, CH [pkm]
Transport of one person on one kilometre by electric bicycle charged with certified electricity	transport, electric bicycle, certified electricity, CH [pkm]

1.3 Characterisation of scooters and electric scooters

The market for electric scooters is evolving and the number of vehicles in circulation is still small. There are three main producers in Switzerland: i.o. e-Scooter, Vespino and Vectrix, which offer various models differing in size and power. Conventional scooters are available in two main categories, 50cc and 125cc. Currently, the majority of the electric scooters sold is comparable to the 50cc class, as their speed limit is at 60-70 km/h (NewRide 2009). We therefore establish the data sets for scooters and electric scooters with engines limited to this speed.

Tab. 1.2: Overview of data sets for scooters and electric scooters

Components/activities	Data set
Scooter, produced in the Far East, sold in Switzerland	scooter, at regional storage, CH [unit]
Electric scooter, produced in Far East, assembled and sold in Switzerland	electric scooter, at regional storage, CH [unit]
Maintenance of a scooter over the lifetime	maintenance, scooter, CH [unit]
Maintenance of an electric scooter over the lifetime	maintenance, electric scooter, CH [unit]
End-of-life of a scooter	disposal, scooter, CH [unit]
End-of-life of an electric scooter	disposal, electric scooter, CH [unit]
Operation of scooter	operation, scooter, CH [km]
Operation of an electric scooter charged with Swiss supply mix	operation, electric scooter, CH [km]
Operation of an electric scooter charged with certified electricity	operation, electric scooter, certified electricity, CH [km]
Transport of one person on one kilometre by scooter	transport, scooter, CH [pkm]
Transport of one person on one kilometre by electric scooter charged with Swiss supply mix	transport, electric scooter, CH [pkm]
Transport of one person on one kilometre by electric scooter charged with certified electricity	transport, electric scooter, certified electricity, CH [pkm]

1.4 System characterisation

The following sections describe the life cycle inventories of electric bicycles and scooters. To be able to compare the different vehicle types, not only the inventory of electric bicycle is established, but also the inventory of a conventional bicycle and a petrol fuelled scooter. Furthermore, the operation of electric bicycles and scooters are considered using different electricity mixes for battery charging. All data sets represent the most commonly used type of vehicle in Switzerland with respect to vehicle weight, battery type and other materials applied.

Some data are extrapolated from passenger car manufacturing and operation using the weight ratio as extrapolation factor (see Tab. 1.3). Whenever the weight ratio is used as extrapolation factor the following values are applied:

Tab. 1.3: weight ratios applied for extrapolation from passenger car data sets

	weights	weight ratio
bicycle : passenger car	17 kg : 1320 kg	0.013
electric bicycle : passenger car	24 kg : 1320 kg	0.018
electric scooter : passenger car	144 kg : 1320 kg	0.109
scooter : passenger car	90 kg : 1320 kg	0.068

1.5 Life cycle inventories of transport by two-wheel vehicles

The transport data sets combine the inventories of vehicle production, operation, maintenance, road infrastructure use and disposal. The comparison of the different vehicle types is carried out on the level of transport services in person kilometres. This comparison requires information from transport statistics, which is outlined in the following section. Furthermore, the vehicle types and the corresponding unit process raw data of the transport data sets are outlined.

1.5.1 Road infrastructure

According to the ecoinvent report no.14 (Spielmann et al. 2007), the allocation factor for road use and disposal is defined by calculating the share of the gross transport performance. The gross transport performance is calculated using the gross vehicle weight, including passengers. Assuming that an average person riding a bicycle weights 75 kg, the gross vehicle weight is 0.092 t. Multiplying the gross vehicle weight with the vehicle kilometres (BfS 2007) results in a gross transport performance of 1.26E+8 Gtkm. This is a share of 0.001% of the total Swiss gross transport performance. Applied to 71600 km road network in Switzerland, where two wheel vehicles of these categories are admitted, the specific road demand per person kilometre is 4.92E-5 m*a.

Electric bicycles and electric scooters account for approximately 2.5% of all bicycles[2] or scooters registered in Switzerland. The total kilometres ridden by electric bicycles or scooters are therefore 2.5% of the conventional bicycles or scooters respectively. The road network demand is calculated identically to calculations carried out for bicycles or scooters (Tab. 1.4).

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[2] Personal communication: Mr. Roland Fuchs, Schweizerische Fachstelle für Zweiradfragen, Solothurn, 2009-08-31

Tab. 1.4: Calculation of demand factors of bicycle transport using Gtkm as allocation factor

Road use and disposal	unit	bicycles	eBikes	Scooters	eScooters	source
length road network	km	71600	71600	71600	71600	ecoinvent report No. 14
total kilometers by vehicle type	vkm	1.37E+09	1.39E+07	2.26E+09	2.28E+07	Bike: BFS Mikrozensus 2005, motorcycle: ecoinvent
net-transport performance	pkm	1.37E+09	1.39E+07	2.48E+09	2.51E+07	BFS, Mikrozensus Verkehrsverhalten 2005
net vehicle weight	t	1.70E-02	2.40E-02	9.00E-02	1.43E-01	own calculation, see in Overview
average load	t	7.50E-02	7.50E-02	8.25E-02	8.25E-02	estimation: average person: 75kg
average gross vehicle weight	t	9.20E-02	9.90E-02	1.73E-01	2.26E-01	sum of vehicle and load weight
Gross transport performance vehicle	Gtkm	1.26E+08	1.37E+06	3.89E+08	5.14E+06	share of gross transport performance
Gross transport performance total (CH)	Gtkm	1.34E+11	1.34E+11	1.34E+11	1.34E+11	ecoinvent report No. 14
Demand of total network	%	0.094%	0.00102%	0.29057%	0.00384%	own calculation from share of road network
Specific road demand per pkm	m*a/p	4.92E-05	5.29E-05	8.38E-05	1.10E-04	own calculation from total network demand

Road maintenance mainly includes snow clearance and pavement repair on motorways, to which bicycles and small scooters are not admitted. Therefore, no share of road maintenance is attributed to transport by the two-wheelers.

1.5.2 Capacity utilization

The average occupation of the vehicle is needed to calculate the person kilometres (pkm). In contrast to bicycles, which have a transport capacity of one person, scooters usually have a pillion's seat. The ecoinvent report (Spielmann et al. 2007) states an average occupation of 1.1 persons for motorcycles. These two values are used to calculate the bicycle or scooter manufacture input, maintenance (if applicable) and disposal per pkm.

Tab. 1.5: Occupation of bicycles and scooters

operation	persons/vehicle	source
bicycle	1.00	defined by laws and physics
e-bicycle	1.00	defined by laws and physics
e-scooter	1.10	ecoinvent report Nr.14
scooter	1.10	ecoinvent report Nr.14

1.5.3 Transport

The data set of bicycle transport refers to an average, not weight optimized, all-round bicycle designed for the use on paved roads in an urban environment (citybike). It contains some additional equipment such as a rear rack, mudguards and lights and has a total weight of 17 kg. The same data is used for electric bicycles, which are additionally equipped with an electric motor (4.4 kg) and a rechargeable lithium-ion battery pack (2.6 kg). The total weight of the electric bicycle is 24 kg, which corresponds to current standards. Bicycles can be used as regular means of transport, e.g. for the daily travel to work or shopping, and as a sport equipment. This inventory focuses on the use of bicycles as means of transport with an average operation range of 1000 km per year. Bicycles used as sport equipment usually have a higher operation range than 1000 km per year. An average bicycle is used for 10'000 to 15'000 kilometers[3].

The scooter data set is established for a 50cc scooter with a maximum speed of 70-80 km/h. Even though there are electric scooters with more powerful motors, the majority of the electric scooter on Swiss roads has a maximal speed limit of 60-70 km/h[4]. Further specification of the vehicle types are outlined in the section on the manufacture data sets (see Section 1.8).

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[3] Personal communication: Mr. Roland Fuchs, Schweizerische Fachstelle für Zweiradfragen, Solothurn, 2009-08-31

[4] Personal communication: Mr. Wirth, i.o. eScooter, Schöftland, 2009-07-06

The manufacture, maintenance and disposal are accounted for based on the life expectancy of the vehicle. Bicycles[5] have an estimated life time of 15000 km and the life time of scooters[6] is set to 50000 km.

Tab. 1.6: Life expectancies of bicycles and scooters

Life expectancy	unit	value	source
bicycle	km	15000	personal communication
e-bicycle	km	15000	personal communication
e-scooter	km	50000	personal communication
scooter	km	50000	personal communication

Tab. 1.7: Unit process raw data for transport by bicycles and scooters

	Name	Location	InfrastructureProcess	Unit	transport, electric bicycle	transport, electric bicycle, certified electricity	transport, electric scooter	transport, electric scooter, certified electricity	transport, bicycle	transport, scooter	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH	CH	CH	CH			
	InfrastructureProcess				0	0	0	0	0	0			
	Unit				pkm	pkm	pkm	pkm	pkm	pkm			
product	transport, electric bicycle	CH	0	pkm	1	0	0	0	0	0			
	transport, electric bicycle, certified electricity	CH	0	pkm	0	1	0	0	0	0			
	transport, electric scooter	CH	0	pkm	0	0	1	0	0	0			
	transport, electric scooter, certified electricity	CH	0	pkm	0	0	0	1	0	0			
	transport, bicycle	CH	0	pkm	0	0	0	0	1	0			
	transport, scooter	CH	0	pkm	0	0	0	0	0	1			
technosphere	bicycle, at regional storage	RER	1	unit					6.67E-5		1	3.02	(2,1,1,1,1,4); Estimation: Bike 15'000km
	electric bicycle, at regional storage	RER	1	unit	6.67E-5	6.67E-5					1	3.02	(2,1,1,1,1,4); Estimation: eBike 15'000km
	electric scooter, at regional storage	RER	1	unit			1.82E-5	1.82E-5			1	3.02	(2,1,1,1,1,4); Estimation: eScooter 50'000km
	scooter, ICE, at regional storage	RER	1	unit						1.82E-5	1	3.02	(2,1,1,1,1,4); Estimation: Scooter 50'000km
	operation, electric bicycle	CH	0	km	1.00E+0						1	2.00	(1,1,1,1,1,1); defined by laws and physics
	operation, electric bicycle, certified electricity	CH	0	km		1.00E+0					1	2.00	(1,1,1,1,1,1); defined by laws and physics
	operation, electric scooter	CH	0	km			9.09E-1				1	2.00	(1,1,2,1,1,3); ecoinvent report Nr.14
	operation, electric scooter, certified electricity	CH	0	km				9.09E-1			1	2.00	(1,1,2,1,1,3); ecoinvent report Nr.14
	operation, scooter	CH	0	km						9.09E-1	1	2.00	(1,1,2,1,1,3); ecoinvent report Nr.14
	road	CH	1	ma	5.29E-5	5.29E-5	1.10E-4	1.10E-4	4.92E-5	8.38E-5	1	3.28	(4,1,2,1,4,4); allocation of road use according to gross ton kilometre performance
	maintenance, bicycle	CH	1	unit					6.67E-5		1	3.02	(2,1,1,1,1,4); Estimation: Bike 15'000km
	maintenance, electric bicycle	CH	1	unit	6.67E-5	6.67E-5					1	3.02	(2,1,1,1,1,4); Estimation: eBike 15'000km
	maintenance, electric scooter	CH	1	unit			1.82E-5	1.82E-5			1	3.02	(2,1,1,1,1,4); Estimation: eScooter 50'000km
	maintenance, scooter	CH	1	unit						1.82E-5	1	3.02	(2,1,1,1,1,4); Estimation: Scooter 50'000km
	disposal, road	RER	1	ma	5.29E-5	5.29E-5	1.10E-4	1.10E-4	4.92E-5	8.38E-5	1	3.28	(4,1,2,1,4,4); allocation of road use according to gross ton kilometre performance
	disposal, bicycle	CH	1	unit					6.67E-5		1	3.02	(2,1,1,1,1,4); Estimation: Bike 15'000km
	disposal, electric bicycle	CH	1	unit	6.67E-5	6.67E-5					1	3.02	(2,1,1,1,1,4); Estimation: eBike 15'000km
	disposal, electric scooter	CH	1	unit			1.82E-5	1.82E-5			1	3.02	(2,1,1,1,1,4); Estimation: eScooter 50'000km
	disposal, scooter	CH	1	unit						1.82E-5	1	3.02	(2,1,1,1,1,4); Estimation: Scooter 50'000km

1.6 Life cycle inventories of two-wheel vehicle operation

1.6.1 Bicycles and electric bicycles

For the assessment of vehicle operation, two main aspects have to be considered. Firstly, the electricity consumption is of interest: the electricity consumption per kilometre varies depending on the grade of motor powered support. Assuming an average support factor, the electricity consumption is 1 kWh per 100 km (Biketech 2009). Two electricity mixes for battery charging are taken into account: certified electricity and Swiss supply mix.

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5 Personal communication: Mr. M. Kofmehl, Biketec AG, Huttwil, 2009-08-31

6 Personal communication: Mr. Moser, 2-Rad-Center Hofer, Meilen, 2009-09-07

Secondly, vehicle operation leads to particle emissions e.g. due to tyre wear. For heavy and fast vehicles, this is an important point to consider. However, bicycles weigh 1 % of a passenger car and are relatively slow. Consequently, the particle emissions are negligible and therefore are omitted (see Tab. 1.10).

1.6.2 Scooters and electric scooters

Electric scooters have an electricity consumption of 2 to 4 kWh per 100 km (i.o. E-Scooter 2009). An electricity demand of 3 kWh per 100 km is used for these data sets. The particle emissions of electric scooters are approximated using 10 % of the emissions of a battery electric vehicle (BEV), which represents the approximate weight ratio of BEV and electric scooters (see Tab. 1.10).

The majority of conventional scooters (50cc) have an average consumption of 3.5 litres of 2-stroke petrol per 100 km. Newer scooters contain a 4-stroke engine.[7] The data set of scooter operation refers to 45 % 2-stroke and 55 % 4-stroke engines because the statistical data available for this class of motorcycles refer to these shares. The emissions originating from the combustion engine are derived from the HBEFA v2.1 (BUWAL & INFRAS 2004) for 50-150cc motorcycles (see Tab. 1.8) and extrapolated from the average fuel consumption of these categories. The provided data refers to average emissions of all motorcycles within this engine-power class. It includes, for instance, the actual share of two-stroke motorcycle (4 %) with very high NMVOC emissions as well as newest 4-stroke engines (17 %) with rather low NMVOC emissions. The air emissions not monitored by the HBEFA are proportionally extrapolated from passenger car emissions according to the petrol consumption of the scooter. Emissions into soil and surface water are extrapolated using the weight ratio between scooter and passenger car as extrapolation factor (see Tab. 1.11).

Tab. 1.8: Emission factors from 50-150cc motorcycles according to HBEFA v2.1, shares of emission categories indicated

	Unit	2stroke <Euro1	2stroke Euro1	2stroke Euro2	2stroke Euro3	average 2stroke	4stroke <Euro1	4stroke Euro1	4stroke Euro2	4stroke Euro3	average 4stroke	average overall
Share	%	4.04%	19.91%	7.53%	13.74%	45.22%	0.00%	28.05%	9.71%	17.01%	54.78%	100.00%
HC	g/km	1.88E+01	4.77E+00	2.54E+00	1.59E+00	4.69E+00	7.84E-01	7.84E-01	4.32E-01	2.71E-01	5.62E-01	2.43E+00
CO	g/km	2.44E+01	2.10E+01	1.66E+01	9.11E+00	1.70E+01	1.28E+01	4.51E+00	7.65E+00	4.20E+00	4.97E+00	1.04E+01
NOx	g/km	1.20E-01	9.54E-02	2.23E-01	1.17E-01	1.26E-01	2.31E-01	4.95E-01	2.23E-01	1.43E-01	3.37E-01	2.42E-01
Part	g/km	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	g/km	1.66E+02	1.13E+02	9.60E+01	8.13E+01	1.05E+02	6.60E+01	6.86E+01	7.23E+01	6.46E+01	6.80E+01	8.48E+01
CH4	g/km	1.32E+00	3.34E-01	5.68E-01	3.56E-01	4.68E-01	2.64E-02	2.64E-02	3.62E-02	2.27E-02	2.70E-02	2.26E-01
NMHC	g/km	1.75E+01	4.44E+00	1.97E+00	1.23E+00	4.23E+00	7.57E-01	7.57E-01	3.95E-01	2.48E-01	5.35E-01	2.20E+00
Pb	g/km	7.10E-05	4.83E-05	4.12E-05	3.49E-05	4.51E-05	2.83E-05	2.94E-05	3.10E-05	2.77E-05	2.92E-05	3.64E-05
SO2	g/km	8.43E-04	5.74E-04	4.89E-04	4.14E-04	5.35E-04	3.36E-04	3.49E-04	3.68E-04	3.29E-04	3.46E-04	4.32E-04
N2O	g/km	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
NH3	g/km	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03	2.00E-03
Benzene	g/km	9.42E-01	2.39E-01	1.27E-01	7.95E-02	2.35E-01	3.43E-02	3.43E-02	5.58E-02	3.50E-02	3.83E-02	1.27E-01
Toluene	g/km	2.28E+00	5.78E-01	3.07E-01	1.92E-01	5.68E-01	8.23E-02	8.23E-02	4.01E-02	2.52E-02	5.71E-02	2.88E-01
Xylene	g/km	2.07E+00	5.25E-01	2.79E-01	1.75E-01	5.16E-01	6.66E-02	6.66E-02	3.32E-02	2.08E-02	4.65E-02	2.59E-01
Fuel input	g/km	5.27E+01	3.59E+01	3.06E+01	2.59E+01	3.35E+01	2.10E+01	2.18E+01	2.30E+01	2.06E+01	2.17E+01	2.70E+01

[7] Personal communication Mr. Roland Fuchs, Fachstelle für Zweiradfragen, Solothurn, 2009-10-30

Tab. 1.9: Calculation of emissions from scooter operation

Substances	To	Unit	Emissions from passenger car average fleet (ecoinvent)	Extrapolated emissions from passenger car	Emissions extrapolated from HBEFA v2.1
Carbon dioxide, fossil	air	kg/km	1.91E-01		7.91E-02
Sulfur dioxide	air	kg/km	6.03E-06		4.03E-07
Cadmium	air	kg/km	7.30E-10	4.58E-10	
Copper	air	kg/km	4.88E-07	3.06E-07	
Chromium	air	kg/km	8.39E-09	5.27E-09	
Nickel	air	kg/km	8.05E-09	5.06E-09	
Zinc	air	kg/km	2.04E-07	1.28E-07	
Lead	air	kg/km	2.46E-08		3.40E-08
Selenium	air	kg/km	6.03E-10	3.79E-10	
Mercury	air	kg/km	1.21E-12	7.58E-13	
Chromium VI	air	kg/km	6.03E-12	3.79E-12	
Carbon monoxide, fossil	air	kg/km	1.15E-03		9.70E-03
Nitrogen oxides	air	kg/km	5.32E-04		2.26E-04
Particulates, < 2.5 um	air	kg/km	2.54E-05	1.60E-05	
Particulates, > 10 um	air	kg/km	1.19E-05	7.49E-06	
Particulates, > 2.5 um, and < 10um	air	kg/km	1.35E-05	8.45E-06	
NMVOC, non-methane volatile organic compound	air	kg/km	1.94E-04		2.37E-03
Methane, fossil	air	kg/km	8.89E-06		2.11E-04
Benzene	air	kg/km	2.92E-05		1.21E-04
Toluene	air	kg/km	1.51E-05		2.78E-04
Xylene	air	kg/km	2.05E-05		2.45E-04
Formaldehyde	air	kg/km	5.85E-06	3.67E-06	
Acetaldehyde	air	kg/km	2.71E-06	1.70E-06	
Ammonia	air	kg/km	2.03E-05		1.87E-06
Dinitrogen monoxide	air	kg/km	1.03E-05		9.34E-07
PAH, polycyclic aromatic hydrocarbons	air	kg/km	6.01E-10	3.77E-10	
Heat, waste	air	kg/km	9.11E-01	5.72E-01	
Zinc, ion	water	kg/km	2.70E-07	1.69E-07	
Copper, ion	water	kg/km	6.39E-09	4.01E-09	
Cadmium, ion	water	kg/km	9.55E-11	6.00E-11	
Chromium, ion	water	kg/km	4.55E-10	2.86E-10	
Nickel, ion	water	kg/km	1.23E-09	7.75E-10	
Lead	water	kg/km	3.93E-09	2.47E-09	
Zinc	soil	kg/km	2.70E-07	1.69E-07	
Copper	soil	kg/km	6.39E-09	4.01E-09	
Cadmium	soil	kg/km	9.55E-11	6.00E-11	
Chromium	soil	kg/km	4.55E-10	2.86E-10	
Nickel	soil	kg/km	1.23E-09	7.75E-10	
Lead	soil	kg/km	3.93E-09	2.47E-09	

Tab. 1.10: Unit process raw data of the operation of electric bicycles and e-scooters

	Name	Location	InfrastructureP	Unit	operation, electric bicycle	operation, electric bicycle, certified electricity	operation, electric scooter	operation, electric scooter, certified electricity	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH	CH			
	InfrastructureProcess				0	0	0	0			
	Unit				km	km	km	km			
product	operation, electric bicycle	CH	0	km	1	0	0	0			
	operation, electric bicycle, certified electricity	CH	0	km	0	1	0	0			
	operation, electric scooter	CH	0	km	0	0	1	0			
	operation, electric scooter, certified electricity	CH	0	km	0	0	0	1			
technosphere	electricity, low voltage, consumer mix, at grid	CH	0	kWh	1.00E-2		3.00E-2		1	1.11	(1,1,1,1,1,4); Company information: e-bike: 1kWh/100km, i.o.-scooter: 3 kWh/100km
	electricity, low voltage, certified, at grid	CH	0	kWh		1.00E-2		3.00E-2	1	1.11	(1,1,1,1,1,4); Company information: e-bike: 1kWh/100km, i.o.-scooter: 3 kWh/100km
emission air, unspecified	Cadmium	-	-	kg			1.27E-11	1.27E-11	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Copper	-	-	kg			1.74E-8	1.74E-8	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Chromium	-	-	kg			7.99E-10	7.99E-10	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Nickel	-	-	kg			7.85E-10	7.85E-10	2	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Zinc	-	-	kg			2.02E-8	2.02E-8	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Lead	-	-	kg			2.46E-9	2.46E-9	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Particulates, < 2.5 um	-	-	kg			7.80E-7	7.80E-7	1	3.06	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Particulates, > 10 um	-	-	kg			1.20E-6	1.20E-6	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Particulates, > 2.5 um, and < 10um	-	-	kg			1.35E-6	1.35E-6	1	2.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission air, high population density	Heat, waste	-	-	MJ			2.76E-1	2.76E-1	1	1.25	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission water, unspecified	Zinc, ion	-	-	kg			2.70E-8	2.70E-8	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Copper, ion	-	-	kg			6.39E-10	6.39E-10	1	3.06	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Cadmium, ion	-	-	kg			9.55E-12	9.55E-12	1	3.06	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Chromium, ion	-	-	kg			4.55E-11	4.55E-11	1	3.06	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Nickel, ion	-	-	kg			1.23E-10	1.23E-10	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
	Lead	-	-	kg			3.93E-10	3.93E-10	1	5.07	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, unspecified	Zinc	-	-	kg			2.70E-8	2.70E-8	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, agricultural	Copper	-	-	kg			6.39E-10	6.39E-10	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, unspecified	Cadmium	-	-	kg			9.55E-12	9.55E-12	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, unspecified	Chromium	-	-	kg			4.55E-11	4.55E-11	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, unspecified	Nickel	-	-	kg			1.23E-10	1.23E-10	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV
emission soil, unspecified	Lead	-	-	kg			3.93E-10	3.93E-10	1	1.58	(2,2,2,1,3,4); Bicycles: no emissions, eScooters abrasion emissions: 10% of BEV

Tab. 1.11: Unit process raw data of scooter operation

	Name	Location	InfrastructureProcess	Unit	operation, scooter	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH			
	InfrastructureProcess				0			
	Unit				km			
product	operation, scooter	CH	0	km	1			
technosphere	petrol, low-sulphur, at regional storage	CH	0	kg	1.39E-2	1	1.12	(1,3,1,1,1,4); Literature: 3.5 liters/100km, 55% 4-stroke
technosphere	petrol, two-stroke blend, at regional storage	CH	0	kg	1.13E-2	1	1.12	(1,3,1,1,1,4); Literature: 3.5 liters/100km, 45% 2-stroke
emission air, unspecified	Carbon dioxide, fossil	-	-	kg	7.91E-2	1	1.23	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Sulfur dioxide	-	-	kg	4.03E-7	1	1.23	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Cadmium	-	-	kg	4.58E-10	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Copper	-	-	kg	3.06E-7	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Chromium	-	-	kg	5.27E-9	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Nickel	-	-	kg	5.06E-9	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Zinc	-	-	kg	1.28E-7	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Lead	-	-	kg	1.54E-8	1	5.06	(2,3,2,1,3,1); calculated from passenger car emissions
	Selenium	-	-	kg	3.79E-10	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Mercury	-	-	kg	7.58E-13	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Chromium VI	-	-	kg	3.79E-12	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Carbon monoxide, fossil	-	-	kg	9.70E-3	1	5.06	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Nitrogen oxides	-	-	kg	2.26E-4	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Particulates, < 2.5 um	-	-	kg	1.60E-5	1	3.05	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Particulates, > 10 um	-	-	kg	7.49E-6	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Particulates, > 2.5 um, and < 10um	-	-	kg	8.45E-6	1	2.06	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	NMVOC, non-methane volatile organic compounds, unspecified origin	-	-	kg	2.37E-3	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average Emission, including tank evaporation
	Methane, fossil	-	-	kg	2.11E-4	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average Emission, including tank evaporation
	Benzene	-	-	kg	1.21E-4	1	3.05	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average Emission, including tank evaporation
	Toluene	-	-	kg	2.78E-4	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average Emission, including tank evaporation
	Xylene	-	-	kg	2.45E-4	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average Emission, including tank evaporation
	Formaldehyde	-	-	kg	3.67E-6	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
	Acetaldehyde	-	-	kg	1.70E-6	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
	Ammonia	-	-	kg	1.87E-6	1	1.31	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	Dinitrogen monoxide	-	-	kg	9.34E-7	1	1.57	(2,3,2,1,3,1); HBEFA v2.1, 50-150cc average emissions
	PAH, polycyclic aromatic hydrocarbons	-	-	kg	3.77E-10	1	3.24	(2,3,2,1,4,3); calculated from passenger car emissions
emission air, high population density	Heat, waste	-	-	MJ	5.72E-1	1	1.52	(2,3,2,1,4,3); calculated from passenger car emissions
emission water, unspecified	Zinc, ion	-	-	kg	1.69E-7	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Copper, ion	-	-	kg	4.01E-9	1	3.24	(2,3,2,1,4,3); calculated from passenger car emissions
	Cadmium, ion	-	-	kg	6.00E-11	1	3.24	(2,3,2,1,4,3); calculated from passenger car emissions
	Chromium, ion	-	-	kg	2.86E-10	1	3.24	(2,3,2,1,4,3); calculated from passenger car emissions
	Nickel, ion	-	-	kg	7.75E-10	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
	Lead	-	-	kg	2.47E-9	1	5.27	(2,3,2,1,4,3); calculated from passenger car emissions
emission soil, unspecified	Zinc	-	-	kg	1.69E-7	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
emission soil, agricultural	Copper	-	-	kg	4.01E-9	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
emission soil, unspecified	Cadmium	-	-	kg	6.00E-11	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
	Chromium	-	-	kg	2.86E-10	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
	Nickel	-	-	kg	7.75E-10	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions
	Lead	-	-	kg	2.47E-9	1	1.79	(2,3,2,1,4,3); calculated from passenger car emissions

1.7 Life cycle inventories of bicycle manufacture

The term electric bicycle stands for a wide range of electrically supported bicycles: from normal bicycles with an additional electric motor to small motorcycles. In this study electric bicycles are referred to as average bicycles (citybike) with an added auxiliary motor, usually at the wheel hub. Hence, the life cycle inventory of the manufacture of a bicycle and an electric bicycle only differ in the additional equipment for the auxiliary motor and the batteries.

1.7.1 Input material

The main components of a bicycle are the frame, the gears and the tyres. Consisting mainly of aluminium and steel they contribute the major part to the total mass. Smaller parts of a bicycle can be made of plastic or other composites, depending on their quality. In order to model bicycle components, the weight and type of material of the individual components are assessed (see Tab. 1.12).

An average bicycle for every day use weighs approximately 17 kg (simpel.ch 2009), mainly depending on the frame weight and the additional equipment installed. Taking into account, that the majority of today's bicycles have aluminium frames and posts, the major input is alloyed aluminium. Further components such as shifters, chains and crank sets were estimated using data from the leading manufacturer (Shimano 2009). The manufacturer displays weight information only for special lightweight products. In consequence, an inventory of a lightweight bicycle is established and the obtained data extrapolated to an average bicycle using 1.5 as extrapolation factor (see Tab. 1.13)[8].

The electric motor in electric bicycles usually is integrated in the hub of the wheel. Although the available technologies slightly differ, an average value of 4.4 kg for an electric motor and 2.6 kg for the LiIo battery can be set (Biketech 2009). This leads to a total weight of 24 kg, which corresponds with the weight of the majority of the electric bicycles in circulation.

[8] LCI data reviewed by Mr. Andreas Burkhardt, Komenda AG, St. Gallen, 2009-11-03 and Mr. Markus Baumann, Tour de Suisse Rad AG, Kreuzlingen, 2009-12-04

Tab. 1.12: Components of a lightweight and average weight bicycle

Componentes	Material	Weight minimal	Weight average	Unit	Source
Frame	Aluminium alloyed	1.5	2.50	kg	Estimation from manufacturer data
Handlebar	Aluminium alloyed	0.15	0.23	kg	Kalloy (2009)
Stem	Aluminium alloyed	0.15	0.23	kg	Kalloy (2009)
Seat Post	Aluminium alloyed	0.4	0.60	kg	Kalloy (2009)
Bearings	Stainless steel	0.4	0.60	kg	Dt Swiss (2009)
Wheels	Aluminium alloyed	0.2	0.30	kg	Dt Swiss (2009)
	Steel, alloyed	0.1	0.10	kg	Personal communication TdS
Tyres	Wire	0.125	0.19	kg	Schwalbe (2009)
	Rubber	0.375	0.56	kg	Schwalbe (2009)
Pedals	Aluminium alloyed	0.2	0.30	kg	Wellgo (2009)
Seat	Plastic	0.02	0.03	kg	Selle Italia (2009)
	Steel, alloyed	0.16	0.24	kg	Selle Italia (2009)
	PU, flexible foam	0.02	0.03	kg	Selle Italia (2009)
Chain	Stainless steel	0.1	0.15	kg	Shimano (2009)
		0.2	0.30	kg	Shimano (2009)
Crankset	Aluminium alloyed	0.56	0.84	kg	Shimano (2009)
	Stainless steel	0.16	0.24	kg	Shimano (2009)
		0.08	0.12	kg	Shimano (2009)
V-Brakes	Plastic	0	0.14	kg	Shimano (2009)
	Aluminium alloyed	0	0.28	kg	Shimano (2009)
	Steel, alloyed	0	0.28	kg	Shimano (2009)
Brakehandel	Aluminium alloyed	0.075	0.11	kg	Shimano (2009)
	Plastic	0.075	0.11	kg	Shimano (2009)
Cassett Sprokets	Steel, alloyed	0.35	0.53	kg	Shimano (2009)
Derailleurs	Aluminium alloyed	0.1	0.15	kg	Shimano (2009)
Derailleurs	Stainless steel	0.4	0.60	kg	Shimano (2009)
Shifters	Plastic	0.45	0.68	kg	Shimano (2009)
Cables	Wire	0.1	0.15	kg	Estimation from manufacturer data
Others	Plastic	0.2	1.00	kg	Estimation from manufacturer data
Others	Aluminium alloyed	0.1	2.00	kg	Estimation from manufacturer data
Others	Electronic equipment	0.1	0.50	kg	Estimation from manufacturer data
Others	Steel, alloyed	0	3.00	kg	Estimation from manufacturer data
Electric motor	Electric motor	4.4	4.40	kg	Bionx, Flyer (2009)
Battery	Battery	2.6	2.60	kg	Bionx, Flyer (2009)

1.7.2 Processing and energy demand

The production process for bicycle production includes the processing of metals such as wire drawing and turning. Consequently, for all materials the processing is included into the data set. All plastic components obtain their form from injection moulding.

The majority of frames and components are produced in Taiwan or other countries in Far East Asia. We therefore assume electricity consumption from the Chinese grid. As no environmental reports are available that show the energy demand of bicycle production, the value is extrapolated from the production of passenger car production according to the weight ratio of a bicycle (see Tab. 1.15). This energy input is further reduced to 25%, because bicycle manufacture contains less energy intensive processes than passenger car manufacture. The energy surplus of electric bicycle production is taken into account in the electric motor and battery production. The same values are used for both vehicles. Waste residues arising from the production process are accounted for according to Cherry et al. (2009).

1.7.3 Transports of bicycles

Being produced in Far East Asia, shipping of the components to the final assembly site in Europe is taken into account. Long distance transport is usually carried out by oceanic freight ships (13’000 km) whereas the distribution in Europe is effected by lorries with more than 16 tons cargo weight (1000 km).

1.7.4 Bicycle plant

The demand for bicycle plant infrastructure is extrapolated from the passenger car plant using the weight ratio bicycle to passenger car. Since bicycle production is considerably less complex, we assume that the extrapolated value needs to be reduced to further 25%.

Tab. 1.13: Unit process raw data of bicycle and electric bicycle manufacture

	Name	Location	InfrastructureProcess	Unit	bicycle, at regional storage	electric bicycle, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				1	1			
	Unit				unit	unit			
product	bicycle, at regional storage	RER	1	unit	1	0			
	electric bicycle, at regional storage	RER	1	unit	0	1			
	chromium steel 18/8, at plant	RER	0	kg	1.59E+0	1.59E+0	1	1.09	(2,1,1,1,1,3); Factsheets Bicycle parts manufacturere: Shimano, DT Swiss
	steel, low-alloyed, at plant	RER	0	kg	4.90E+0	4.90E+0	1	1.09	(2,1,1,1,1,3); Factsheets Bicycle parts manufacturere: Shimano, DT Swiss
	synthetic rubber, at plant	RER	0	kg	5.63E-1	5.63E-1	1	1.09	(2,1,1,1,1,3); Literature, Schwalbe
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.96E+0	1.96E+0	1	1.09	(2,1,1,1,1,3); Literature, Shimano/Selle Italia
	polyurethane, flexible foam, at plant	RER	0	kg	3.00E-2	3.00E-2	1	1.09	(2,1,1,1,1,3); Literature, Selle Italia
	aluminium, production mix, at plant	RER	0	kg	7.53E+0	7.53E+0	1	1.09	(2,1,1,1,1,3); Factsheets Bicycle parts manufacturere: Shimano, DT Swiss
	section bar extrusion, aluminium	RER	0	kg	3.77E+0	3.77E+0	1	1.57	(4,1,1,1,4,3); Assumption for pipe drawing
	wire drawing, steel	RER	0	kg	3.38E-1	3.38E-1	1	1.57	(4,1,1,1,4,3); Assumption
	turning, chromium steel, conventional, average	RER	0	kg	1.59E-1	1.59E-1	1	1.57	(4,1,1,1,4,3); Assumption
	injection moulding	RER	0	kg	1.96E+0	1.96E+0	1	1.57	(4,1,1,1,4,3); Assumption
	welding, arc, aluminium	RER	0	m	7.50E-1	7.50E-1	1	1.57	(4,1,1,1,4,3); Assumption: pipe diameter: 4cm --> 0.125 m per joint, 6 joints per bike
	powder coating, aluminium sheet	RER	0	m2	3.50E-1	3.50E-1	1	1.57	(4,1,1,1,4,3); Assumption: pipe diamter: 4cm, pipe length: 3m
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	1.43E+1	1.43E+1	1	1.60	(4,4,2,1,4,4); Extrapolation from passenger car manufacture; weight ratio
	electricity, medium voltage, at grid	CN	0	kWh	6.89E+0	6.89E+0	1	1.60	(4,4,2,1,4,4); Extrapolation from passenger car manufacture using weight ratio, thereof 25%
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	2.03E-1	2.03E-1	1	1.60	(4,4,2,1,4,4); Extrapolation from passenger car manufacture using weight ratio, thereof 25%
	tap water, at user	RER	0	kg	7.44E-1	7.44E-1	1	1.14	(2,3,1,1,1,4); Assumption based on: Cherry, C.R. 2009, 1488 liters waste water for all production phases (incl. Battery manufacturing --> 50%)
	transport, transoceanic freight ship	OCE	0	tkm	2.21E+2	3.12E+2	1	2.09	(4,5,na,na,na,na); Assumption for Asia--> Europe: 13000km
	transport, lorry >16t, fleet average	RER	0	tkm	1.70E+1	2.40E+1	1	2.09	(4,5,na,na,na,na); Assumption Rotterdam/Genoa --> assembly site: 1000km
	electric motor, electric vehicle, at plant	RER	0	kg		4.40E+0	1	1.09	(2,1,1,1,1,3); Literature, Biketec
	battery, LiIo, rechargeable, prismatic, at plant	GLO	0	kg		2.60E+0	1	1.09	(2,1,1,1,1,3); Literature, Biketec
	road vehicle plant	RER	1	unit	9.37E-10	1.32E-9	1	3.01	(2,1,1,1,1,3); Extrapolation for bicycle plant: 25% of weight ratio
emission air, high population density	Heat, waste	-	-	MJ	2.48E+1	2.48E+1	1	1.24	(2,4,1,1,1,5);
	treatment, sewage, to wastewater treatment, class 3	CH	0	m3	7.44E-4	7.44E-4	1	1.14	(2,3,1,1,1,4); Assumption based on: Cherry, C.R. 2009, 1488 liters waste water for all production phases (incl. Battery manufacturing --> 50%)
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	4.50E+0	4.50E+0	1	1.14	(2,3,1,1,1,4); Assumption based on: Cherry, C.R. 2009, 4.5 kg solid waste

1.8 Life cycle inventories of scooter manufacturing

The market for electric scooters in Switzerland was recently established and is especially promoted for sustainable commuter traffic in an urban environment. The majority of vehicles sold, reach a maximum speed of 60-70 km per hour (NewRide 2009). However, with a growing acceptance of e-scooters the demand for more powerful engines is arising[9].

This inventory is established for the current average fleet of electric scooters, which are comparable to 50cc class scooters. For the LCI of the manufacture of a scooter and an electric scooter the inventory of an average passenger car is used as a basis (Spielmann et al. 2007). The extrapolation factors are calculated using the weight ratio given in Tab. 1.3, which are calculated using the average vehicle

[9] Personal communication: Mr. Wirth, i.o. e-scooters Switzerland, Schöftland, 2009-07-06

weight shown in Tab. 1.14. For the conventional scooter the ecoinvent inventory of a passenger car and for the e-scooter the inventory of a battery electric vehicle was adapted.

Tab. 1.14: Total weights of scooter and e-scooter.

	Unit	Value	Source
Average weight e-scooter (70 km/h)	kg	144	NewRide 2009
Average weight scooter (50cc)	kg	90	Peugeot 2009

1.8.1 Input material

The internal parts of a scooter such as the chassis or engine parts are comparable to a passenger car. For these parts, the values from the passenger car proportionally are applied as material input using the weight ratio of passenger car to scooter. However, some parts differ strongly in both proportion and material. For instance, the housing of a scooter is made of plastic materials whereas passenger car housing is made of steel panels. Furthermore, the basic material of suspension forks and handle bars is aluminium[10]. This leads to proportionally higher amounts of plastics and aluminium. We therefore set 15% of the passenger car's plastic input for the scooter manufacture. As the ecoinvent inventory of the passenger car has a very low aluminium input, 15kg of aluminium input are assumed (see Tab. 1.16). On the other hand, the steel input needs to be reduced. In this case, only 5% of the passenger car's steel demand input value is used for the scooter inventory.

The latest models of electric scooters use a $LiMn_2O_4$ battery (Gauch et al. 2009) with an average weight of 32 kg (Vespino 2009). The electric motor is a wheel hub motor and is assumed to weight 11 kg, which is also extrapolated from the weight of an electric motor in a BEV.

1.8.2 Processing and energy demand

The manufacturing process is adapted from the ecoinvent data of passenger car manufacturing as well. In addition to the existing processing steps, injection moulding is added, as most of the plastic parts are formed using this method. Data on the energy demand are taken from the environmental report of Honda (Honda Motors Co Ltd. 2008). The environmental report gives a total of electricity and fuel consumption for all production sites, which include the production of different vehicle types. In order to attribute the energy demand of scooter production, an economic allocation is applied (see Tab. 1.15). This economic allocation includes the manufacture of heavier motorcycles. Therefore, only 50% of the energy is attributed to scooter manufacture.

[10] Personal communication: Mr. Wirth, i.o. e-scooters Switzerland, Schöftland, 2009-07-06

Tab. 1.15: Allocation of energy demand from figures of the environmental report Honda 2008

	Unit	Value
Total electricity demand	MWh	3875776
Total natural gas demand	GJ	11569566
Total oil based fuel demand	GJ	4280345
Motorcycles share of net sales	%	13
Motorcycles share of electricity demand	MWh	503851
Motorcycle production	Unit	13831000
Electricity demand per motorcycle	kWh	36
Natural gas demand per motorcycle	MJ	109
Light fuel oil demand per motorcycle	MJ	4
Electricity demand per scooter	kWh	18
Natural gas demand per scooter	MJ	54.5
Light fuel oil demand per motorcycle	MJ	2

1.8.3 Transport

The production plants of some providers of scooters and e-scooters are located in Europe (Piaggio, Aprilia, Gilera, Peugeot, Vespa). However, the market share of Asian motorcycles (Honda, Suzuki, Yahama, SYM) is growing and many manufacturers produce in Far East Asia. Hence, the data set is established for an Asian production site and includes shipping to Europe.

Tab. 1.16: Unit process raw data of e-scooter and scooter manufacturing

	Name	Location	InfrastructureProcess	Unit	electric scooter, at regional storage	scooter, ICE, at regional storage	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER	RER			
	InfrastructureProcess				1	1			
	Unit				unit	unit			
product	electric scooter, at regional storage	RER	1	unit	1	0			
	scooter, ICE, at regional storage	RER	1	unit	0	1			
technosphere	steel, low-alloyed, at plant	RER	0	kg	6.62E+0	6.62E+0	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	reinforcing steel, at plant	RER	0	kg	4.46E+1	4.46E+1	1	1.38	(4,3,1,1,3,5); 5% of passenger car
	sheet rolling, steel	RER	0	kg	2.71E+1	2.71E+1	1	1.38	(4,3,1,1,3,5); 5% of passenger car
	section bar rolling, steel	RER	0	kg	1.36E+1	1.36E+1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	wire drawing, copper	RER	0	kg	6.76E-1	6.76E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	copper, at regional storage	RER	0	kg	6.76E-1	6.76E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	chromium, at regional storage	RER	0	kg	1.61E-1	1.61E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	nickel, 99.5%, at plant	GLO	0	kg	9.37E-2	9.37E-2	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	aluminium, production mix, at plant	RER	0	kg	1.50E+1	1.50E+1	1	1.57	(4,3,2,3,4,3); 15 kg
	polyethylene, HDPE, granulate, at plant	RER	0	kg	1.53E+1	1.53E+1	1	1.38	(4,3,1,1,3,5); 15% of passenger car
	polypropylene, granulate, at plant	RER	0	kg	7.35E+0	7.35E+0	1	1.38	(4,3,1,1,3,5); 15% of passenger car
	polyvinylchloride, at regional storage	RER	0	kg	2.40E+0	2.40E+0	1	1.38	(4,3,1,1,3,5); 15% of passenger car
	injection moulding	RER	0	kg	1.53E+1	1.53E+1	1	1.57	(4,3,2,3,4,3); All HDPE
	synthetic rubber, at plant	RER	0	kg	2.95E+0	2.95E+0	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	alkyd paint, white, 60% in solvent, at plant	RER	0	kg	4.16E-1	4.16E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	platinum, at regional storage	RER	0	kg		1.07E-4	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	palladium, at regional storage	RER	0	kg		2.01E-5	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	zinc, primary, at regional storage	RER	0	kg	3.94E-1	3.94E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	natural gas, burned in industrial furnace >100kW	RER	0	MJ	1.09E+2	1.09E+2	1	1.31	(4,3,1,1,3,3); 50% of Environmental report Honda, 2008
	electricity, medium voltage, at grid	JP	0	kWh	1.80E+1	1.80E+1	1	1.31	(4,3,1,1,3,3); 50% of Environmental report Honda, 2008
	light fuel oil, burned in industrial furnace 1MW, non-modulating	RER	0	MJ	4.02E+0	4.02E+0	1	1.31	(4,3,1,1,3,3); 50% of Environmental report Honda, 2008
	tap water, at user	RER	0	kg	2.15E+2	2.15E+2	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	ethylene, average, at plant	RER	0	kg	1.24E+0	1.24E+0	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	battery, LiIo, rechargeable, prismatic, at plant	GLO	0	kg	3.20E+1		1	1.22	(1,2,1,1,3,3); Factsheet Vespino Sky Evolution 2009
	sulphuric acid, liquid, at plant	RER	0	kg		5.35E-2	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	lead, at regional storage	RER	0	kg		8.70E-1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	electric motor, electric vehicle, at plant	RER	0	kg	1.13E+1		1	1.22	(1,2,1,1,3,3); Factsheet Vespino Sky Evolution 2009
	transport, lorry >16t, fleet average	RER	0	tkm	5.78E+0	5.78E+0	1	2.09	(4,5,na,na,na,na); weight ratio scooter:passenger car
	transport, transoceanic freight ship	OCE	0	tkm	1.87E+3	1.87E+3	1	2.09	(4,5,na,na,na,na); Transport from Asia to Europe: 13000km
	transport, freight, rail	CH	0	tkm	5.78E+1	5.78E+1	1	2.09	(4,5,na,na,na,na); weight ratio scooter:passenger car
	road vehicle plant	RER	1	unit	1.95E-8	1.95E-8	1	3.28	(4,3,2,3,4,3); weight ratio scooter:passenger car
	NMVOC, non-methane volatile organic compounds, un	-		kg	3.21E-1	3.21E-1	1	1.58	(4,3,2,3,4,3); weight ratio scooter:passenger car
emission air, unspecified	Heat, waste	-		MJ	6.48E+1	6.48E+1	1	1.57	(4,3,2,3,4,3); weight ratio scooter:passenger car
	COD, Chemical Oxygen Demand	-		kg	1.29E-2	1.29E-2	1	1.58	(4,3,2,3,4,3); weight ratio scooter:passenger car
	BOD5, Biological Oxygen Demand	-		kg	1.74E-3	1.74E-3	1	1.58	(4,3,2,3,4,3); weight ratio scooter:passenger car
	Phosphate	-		kg	6.69E-5	6.69E-5	1	1.58	(4,3,2,3,4,3); weight ratio scooter:passenger car

1.9 Life cycle inventories of two-wheel vehicle maintenance

Some parts of a bicycle or scooter need to be replaced, because their life expectancy is shorter than the one of the entire vehicle. For bicycles, these are typically small parts such as shifters, chains or brakes. This leads to the assumption, that 50 % of plastic parts of a bicycle are replaced once in its life time. Furthermore, we assume that 5 % of the steel parts have to be exchanged. Aluminium is mostly used for frame and posts, which are rarely replaced (5 %). The bicycle tyres have a lifetime of four years[11], which corresponds to 4000 km.

Usually, similar parts have to be replaced in scooters. However, the percentages of materials are adapted with respect to the material composition of scooters. As scooters contain more steel in the chassis, we estimate that only 10% of the steel material needs replacement. The same assumption is taken for aluminium. Plastic is the most important component in scooter housing, hence not all plastic parts are replaced in a life time (see Tab. 1.18). Scooter tyres[12] have to be replaced every 5000 km.

Values used for the calculation of the replacement of batteries are given in Tab. 1.17. Although a Lithium-ion battery can be recharged more than 500 times, average life expectancy of an electric bicycle

[11] Personal communication: Mr. M. Kofmehl, Biketec AG, Huttwil, 2009-08-31

[12] Personal communication: Mr. Moser, 2-Rad-Center Hofer, Meilen, 2009-09-07

battery is 3-4 years (Biketech 2009). Over the lifetime of 15000km the battery has to be replaced 2.75 times.

Scooter batteries last for 500 charging cycles with an average operating distance of 50 km per cycle (i.o. E-Scooter 2009).

The service parts are mainly produced in Far East Asia. We assume that 100 % of the parts are shipped from Asia (13'000 km) and are delivered in lorries over 1000 km within Europe[13].

Tab. 1.17: Calculation of battery replacement in electric bicycles and scooters

battery life expectancy	number of charging cycles	life expectancy battery (km)	batteries replaced per vehicle life cycle	source
eBike (LiIo)	500	4000	2.75	Data sheet Flyer, Biketech
eScooter (LiIo)	500	25000	1	Personal communication i.o. e-scooter
Scooter	500	25000	1	estimation

Tab. 1.18: Unit process raw data of bicycle and scooter maintenance

	Name	Location	InfrastructureP	Unit	maintenance, bicycle	maintenance, electric bicycle	maintenance, electric scooter	maintenance, scooter	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH	CH			
	InfrastructureProcess				1	1	1	1			
	Unit				unit	unit	unit	unit			
product	maintenance, bicycle	CH	1	unit	1	0	0	0			
	maintenance, electric bicycle	CH	1	unit	0	1	0	0			
	maintenance, electric scooter	CH	1	unit	0	0	1	0			
	maintenance, scooter	CH	1	unit	0	0	0	1			
technosphere	aluminium alloy, AlMg3, at plant	RER	0	kg	3.77E-1	3.77E-1	1.50E+0	1.50E+0	1	1.24	(2,2,1,1,3,4); Estimation:5% of aluminium parts replaced
	steel, low-alloyed, at plant	RER	0	kg	2.28E-1	2.28E-1	1.06E+0	1.06E+0	1	1.24	(2,2,1,1,3,4); Estimation: 5% of steel parts replaced, Scooter: 10%
	synthetic rubber, at plant	RER	0	kg	1.69E+0	1.69E+0	4.72E+1	4.72E+1	1	1.24	(2,2,1,1,3,4); Estimation: 3.75 (bike)/3 (scooter) tyre-sets use in life-time
	polyethylene, HDPE, granulate, at plant	RER	0	kg	9.79E-1	9.79E-1	1.87E+0	1.87E+0	1	1.24	(2,2,1,1,3,4); Estimation: Bicycle: 50% of plastic parts once replaced, Scooter 15%
	polyurethane, flexible foam, at plant	RER	0	kg	3.00E-2	3.00E-2			1	1.24	(2,2,1,1,3,4); Estimation: saddle once replaced, Scooter: no replacement
	section bar extrusion, aluminium	RER	0	kg	3.77E-1	3.77E-1	1.50E+0	1.50E+0	1	1.58	(4,2,1,1,4,4); Assumption for pipe drawing
	turning, chromium steel, conventional, average	RER	0	kg	2.28E-1	2.28E-1	1.06E+0	1.06E+0	1	1.58	(4,2,1,1,4,4); Assumption
	injection moulding	RER	0	kg	9.79E-1	9.79E-1	1.87E+0	1.87E+0	1	1.58	(4,2,1,1,4,4); Assumption
	tap water, at user	RER	0	kg	7.44E-2	7.44E-2	3.44E+1	3.44E+1	1	1.14	(2,3,1,1,1,4); Assumption based on: Cherry, C.R. 2007, 1488 liters waste water for all
	transport, transoceanic freight ship	OCE	0	tkm	3.43E+1	3.43E+1	5.37E+2	5.37E+2	1	2.09	(4,5,na,na,na,na); 80% of parts: assumption for Asia--> Europe: 13000km
	transport, lorry >16t, fleet average	RER	0	tkm	3.30E+0	3.30E+0	5.16E+1	5.16E+1	1	2.09	(4,5,na,na,na,na); 100% of parts: assumption for distribution in Europe: 1000km
	battery, LiIo, rechargeable, prismatic, at plant	GLO	0	kg		7.15E+0	3.20E+1		1	1.24	(2,2,1,1,3,4); Personal communication: 2.75 batteries per 15000km bicycles, 2 batteries 50000 scooter
	sulphuric acid, liquid, at plant	RER	0	kg				8.00E-2	1	1.32	(4,2,1,1,3,4); Estimation: 2 batteries per 50000km
	lead, at regional storage	RER	0	kg				1.30E+0	1	1.32	(4,2,1,1,3,4); Estimation: 2 batteries per 50000km
	disposal, Li-ions batteries, mixed technology	GLO	0	kg	0	7.15E+0	3.20E+1	0	1	1.32	(4,2,1,1,3,4); all LiIo batteries into battery recycling
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	1.01E+0	1.01E+0	1.87E+0	1.87E+0	1	1.32	(4,2,1,1,3,4); plastics to municipal incineration
	disposal, rubber, unspecified, 0% water, to municipal incineration	CH	0	kg	8.44E-1	8.44E-1	2.36E+1	2.36E+1	1	1.32	(4,2,1,1,3,4); 50% of tyres to municipal incineration
	disposal, treatment of batteries	GLO	0	kg				1.38E+0	1	1.24	(2,2,1,1,3,4); Amount of S-Pb batteries replaced

1.10 Life cycle inventories of two-wheel vehicle disposal

The majority of raw materials in bicycles and scooters can easily be recycled. We therefore assume that all metal parts are fully recycled. Identically to the disposal process of passenger cars, we make a cut-off allocation for metal materials and allocate all environmental impacts to the secondary materials

[13] Personal communication: Mr. Roland Fuchs, Fachstelle für Zweiradfragen, Solothurn

produced by the recycling process. The tyres are either exported and/or used as a secondary fuel in cement works (50 % of the tyres) (ecoinvent Centre 2007) or burned in a municipal incineration plant (50 % of the tyres). The exported tyres are allocated to the cement production process (cut-off allocation). Plastic parts are incinerated. The environmental impact from the end of life treatment of the battery is attributed to the two-wheel vehicles' transport life cycle. Residues from the metal shredder are accounted for using the extrapolation of the values from car disposal.

For all recycled materials only the transport to the recycling plant is taken into account. We estimate an average distance of 100km.

Tab. 1.19: Unit process raw data of bicycle and scooter disposal

	Name	Location	InfrastructureProcess	Unit	disposal, bicycle	disposal, electric bicycle	disposal, electric scooter	disposal, scooter	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				CH	CH	CH	CH			
	InfrastructureProcess				1	1	1	1			
	Unit				unit	unit	unit	unit			
product	disposal, bicycle	CH	1	unit	1	0	0	0			
	disposal, electric bicycle	CH	1	unit	0	1	0	0			
	disposal, electric scooter	CH	1	unit	0	0	1	0			
	disposal, scooter	CH	1	unit	0	0	0	1			
technosphere	transport, lorry 20-28t, fleet average	CH	0	tkm	1.71E+0	2.41E+0	1.12E+2	1.45E+1	1	2.05	(4,1,1,1,1,3); Assumption: all materials to recycling plant
	disposal, plastics, mixture, 15.3% water, to municipal incineration	CH	0	kg	1.99E+0	1.99E+0	2.22E+1	2.22E+1	1	1.31	(4,1,1,1,3,3); Assumption for plastic recycling: all parts
	disposal, Li-ions batteries, mixed technology	GLO	0	kg		7.15E+0	3.20E+1		1	1.22	(2,1,1,1,3,3); Assumption for battery recycling
	disposal, treatment of batteries	GLO	0	kg				6.90E+0	1	1.22	(2,1,1,1,3,3); Assumption for battery treatment
	disposal, rubber, unspecified, 0% water, to municipal incineration	CH	0	kg	2.81E-1	2.81E-1	2.40E+0	2.40E+0	1	1.22	(2,1,1,1,3,3); 50% of tyres to municipal incineration
	disposal, zinc in car shredder residue, 0% water, to municipal incineration	CH	0	kg	9.10E-2	1.29E-1	6.77E-1	3.95E-1	1	1.22	(2,1,1,1,3,3); Extrapolated from car disposal

1.11 References

BfS 2007	BfS (2007) Mobilität in der Schweiz: Ergebnisse des Mikrozensus 2005 zum Verkehrsverhalten. Bundesamt für Statistik, Neuchâtel.
Biketech 2009	Biketech (2009) Spezifikationen Flyer C-Serie. Retrieved June 29 retrieved from: www.flyer.ch.
Bundesversammlung 1995	Bundesversammlung (1995) Verordnung über die technische Anforderung an Strassenfahrzeuge (VTS).
BUWAL & INFRAS 2004	BUWAL and INFRAS (2004) HBFEA Handbuch Emissionsfaktoren des Strassenverkehrs. BUWAL, Bern.
Cherry 2009	Cherry C. R. (2009) Comparative environmental impacts of electric bikes in China. *In: Transportation Research*, **Part D**(14), pp. 281-290.
ecoinvent Centre 2007	ecoinvent Centre (2007) ecoinvent data v2.01, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland, retrieved from: www.ecoinvent.org.
Frischknecht et al. 2007	Frischknecht R., Jungbluth N., Althaus H.-J., Bauer C., Doka G., Dones R., Hellweg S., Hischier R., Humbert S., Margni M. and Nemecek T. (2007) Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
Gauch et al. 2009	Gauch M., Widmer R., Notter D., Stamp A., Althaus H.-J. and Wäger P. (2009) Life Cycle Assessment LCA of Li-Ion batteries for electric vehicles. Project presentation. EMPA - Swiss Federal Laboratories for Materials Testing and Research, St. Gallen.
Honda Motors Co Ltd. 2008	Honda Motors Co Ltd. (2008) Honda Environmental Annual Report, Tokyo, Japan.
i.o. E-Scooter 2009	i.o. E-Scooter (2009) Der i.o. Scooter GT 1500 Elektroroller. Retrieved July 3 retrieved from: www.ioscooter.ch.
NewRide 2009	NewRide (2009) NewRide - das Förderprogramm für Elektro-Zweiräder. Retrieved August 25th retrieved from: www.newride.ch.
Peugeot 2009	Peugeot (2009) Données techniques Scooter. Retrieved 2009-10-25 retrieved from: http://www.peugeotmotos.ch/documents/showFile.asp?ID=2136.
Shimano 2009	Shimano (2009) Shimano Products. Retrieved September 4th retrieved from: www.cycle-shimano.eu.
simpel.ch 2009	simpel.ch (2009) Spezifikationen wegwärts II Damen. Retrieved 2009-10-25 retrieved from: http://www.simpel.ch/velos/citybikes.html.
Spielmann et al. 2007	Spielmann M., Dones R., Bauer C. and Tuchschmid M. (2007) Life Cycle Inventories of Transport Services. ecoinvent report No. 14, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.
velosuisse 2008	velosuisse (2008) Fahrradstatistik 2008 - Uebersicht Fahrradmarkt 2007/2008 (ohne Spiel- und Kindervelo 10"-18"). Retrieved September 7th retrieved from: http://www.velosuisse.ch/upload/pdf/fahrrad2008statistik.pdf.
Vespino 2009	Vespino (2009) Factsheet: Vespino Sky Evolution. Retrieved 2009-11-12 retrieved from: http://www.vespino.ch/de/sky-evolution.php.

Appendices: EcoSpold Meta Information

Tab. A. 1: Metainformation of datasets "transport"

Type	Field name, IndexNumber	277-08	277-09	277-10	277-11	277-12	277-20
ReferenceFunction	Name	transport, electric bicycle	transport, electric bicycle, certified electricity	transport, electric scooter	transport, electric scooter, certified electricity	transport, bicycle	transport, scooter
Geography	Location	CH	CH	CH	CH	CH	CH
ReferenceFunction	InfrastructureProcess	0	0	0	0	0	0
ReferenceFunction	Unit	pkm	pkm	pkm	pkm	pkm	pkm
	IncludedProcesses	This data includes the operation, maintenance and disposal of an electric bicycle and the use of the road infrastructure. For e-bike operation Swiss electricity mix is used.	This data includes the operation, maintenance and disposal of an electric bicycle and the use of the road infrastructure. For e-bike operation Swiss certified electricity is used.	This data includes the operation, maintenance and disposal of an electric scooter and the use of the road infrastructure. For e-scooter operation Swiss electricity mix is used.	This data includes the operation, maintenance and disposal of an electric scooter and the use of the road infrastructure. For e-scooter operation Swiss certified electricity is used.	This data includes the operation, maintenance and disposal of a bicycle and the use of the road infrastructure.	This data includes the operation, maintenance and disposal of scooter and the use of the road infrastructure. The data set refers to a mix of two and four-stroke engines.
	LocalName	Transport, Elektrofahrrad	Transport, Elektrofahrrad, zertifizierter Strom	Transport, Elektroscooter	Transport, Elektroscooter, zertifizierter Strom	Transport, Fahrrad	Transport, Scooter
	Synonyms	e-bike	e-bike	e-scooter	e-scooter	Citybike	
	GeneralComment	The data set reflects the transport of one person on one kilometer on an electric bicycle. Capacity utilisation: 1 person	The data set reflects the transport of one person on one kilometer on an electric bicycle. Capacity utilisation: 1 person	The data set reflects the transport of one person on one kilometer on an electric scooter. Capacity utilisation: 1.1 persons	The data set reflects the transport of one person on one kilometer on an electric scooter. Capacity utilisation: 1.1 persons	The data set reflects the transport of one person on one kilometer on an bicycle. Capacity utilisation: 1 person	The data set reflects the transport of one person on one kilometer on a scooter. Capacity utilisation: 1.1 persons
	InfrastructureIncluded	1	1	1	1	1	1
	Category	transport systems	transport systems	transport systems	transport systems	transport systems	transport systems
	SubCategory	road	road	road	road	road	road
	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse	Strasse	Strasse	Strasse	Strasse
	Formula						
	StatisticalClassification						
	CASNumber						
TimePeriod	StartDate	2005	2005	2005	2005	2005	2005
	EndDate	2009	2009	2009	2009	2009	2009
	DataValidForEntirePeriod	1	1	1	1	1	1
	OtherPeriodText						
Geography	Text	Data for transport in Switzerland	Data for transport in Switzerland	Data for transport in Switzerland	Data for transport in Switzerland	Data for transport in Switzerland	Data for transport in Switzerland
Technology	Text	Transport using Swiss electricity mix. Life expectancy: 15000km	Transport using Swiss certified electricity mix. Life expectancy: 15000km	Transport using Swiss electricity mix. Life expectancy: 50000km	Transport using Swiss certified electricity mix. Life expectancy: 50000km	Citybike with racks. Life expectancy: 15000km	Average transport by 50-150cc scooter: 45% 2-stroke and 55% 4-stroke engines. Life expectancy: 50000km
Representativeness	Percent						
	ProductionVolume	unknown	unknown	unknown	unknown	unknown	unknown
	SamplingProcedure	Literature	Literature	Literature	Literature	Literature	Literature and statistics
	Extrapolations	Some data extrapolated from motorcycle use	Some data extrapolated from motorcycle use	Some data extrapolated from motorcycle use	Some data extrapolated from motorcycle use	Some data extrapolated from motorcycle use	Some data extrapolated from motorcycle use
	UncertaintyAdjustments	none	none	none	none	none	none

Tab. A. 2: Metainformation of datasets "vehicle maintenance"

ReferenceFunction	Name	maintenance, bicycle	maintenance, electric bicycle	maintenance, electric scooter	maintenance, scooter
Geography	Location	CH	CH	CH	CH
ReferenceFunction	InfrastructureProcess	1	1	1	1
ReferenceFunction	Unit	unit	unit	unit	unit
	IncludedProcesses	This data sets includes the maintenance of a bicycle throughout its life cycle.	This data sets includes the maintenance of an electric bicycle throughout its life cycle.	This data sets includes the maintenance of an electric scooter throughout its life cycle.	This data sets includes the maintenance of a scooter throughout its life cycle.
	LocalName	Unterhalt, Fahrrad	Unterhalt, Elektrofahrrad	Unterhalt, Elektroscooter	Unterhalt, Scooter
	Synonyms				
	GeneralComment	The data set reflects the replacement of parts for the maintenance of a bike of 17 kg. Life expectancy battery: 4'000 km.	The data set reflects the replacement of parts for the maintenance of an e-bike of 24kg with a LiIo battery. Battery replacemnet: 2.75 times. Life expectancy battery: 4'000 km.	The data reflects the replacement of parts for the maintenance of an e-scooter of 144kg with a LiIo battery pack. Mainly the battery, plastic and steel parts are replaced. Battery replacement: once. Life expectancy battery: 25'000 km.	The data reflects the replacement of parts for the maintenance of a scooter of c 90kg (50cc). Mainly plastic and steel parts are replaced. Battery replacement: once. Life expectancy battery: 25'000 km.
	InfrastructureIncluded	1	1	1	1
	Category	transport systems	transport systems	transport systems	transport systems
	SubCategory	road	road	road	road
	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse	Strasse	Strasse
	Formula				
	StatisticalClassification				
	CASNumber				
TimePeriod	StartDate	2007	2007	2007	2007
	EndDate	2009	2009	2009	2009
	DataValidForEntirePeriod	1	1	1	1
	OtherPeriodText				
Geography	Text	Data cover maintenance in Switzerland	Data cover maintenance in Switzerland	Data cover maintenance in Switzerland	Data cover maintenance in Switzerland
Technology	Text	Maintenance of a citybike	Maintenance of an electric bicycle	Maintenance of an electric scooter (max. 60-70km/h)	Maintenance of a scooter (50cc)
Representativeness	Percent				
	ProductionVolume	unknown	unknown	unknown	unknown
	SamplingProcedure	Literture	Literature	Literature	Literature
	Extrapolations	none	none	none	none
	UncertaintyAdjustments	none	none	none	none

Tab. A. 3: Metainformation of datasets "vehicle disposal"

ReferenceFunction	Name	disposal, bicycle	disposal, electric bicycle	disposal, electric scooter	disposal, scooter
Geography	Location	CH	CH	CH	CH
ReferenceFunction	InfrastructureProcess	1	1	1	1
ReferenceFunction	Unit	unit	unit	unit	unit
	IncludedProcesses	This data set includes the disposal of all remaining parts, that are not recycled. All recycled parts are attributed to the reuse process (cut-off). Transport for recycled materials included.	This data set includes the disposal of all remaining parts, that are not recycled. All recycled parts are attributed to the reuse process (cut-off). Transport for recycled materials included.	This data set includes the disposal of all remaining parts, that are not recycled. All recycled parts are attributed to the reuse process (cut-off). Transport for recycled materials included.	This data set includes the disposal of all remaining parts, that are not recycled. All recycled parts are attributed to the reuse process (cut-off). Transport for recycled materials included.
	LocalName	Entsorgung, Fahrrad	Entsorgung, Elektrofahrrad	Entsorgung, Elektroscooter	Entsorgung, Scooter
	Synonyms				
	GeneralComment	The data set reflects the disposal of a bike of 17kg. Aluminium and steel parts are fully recycled. Plastics are incinerated.	The data set reflects the disposal of an electric bike of 24kg. Aluminium and steel parts are fully recycled. Plastics are incinerated, batteries are treated.	The data set reflects the disposal of an electric scooter of 144kg. Aluminium and steel parts are fully recycled. Plastics are incinerated, batteries are treated.	The data set reflects the disposal of a scooter of 90kg. Aluminium and steel parts are fully recycled. Plastics are incinerated, batteries are treated.
	InfrastructureIncluded	1	1	1	1
	Category	transport systems	transport systems	transport systems	transport systems
	SubCategory	road	road	road	road
	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse	Strasse	Strasse
	Formula				
	StatisticalClassification				
	CASNumber				
TimePeriod	StartDate	2007	2007	2007	2007
	EndDate	2009	2009	2009	2009
	DataValidForEntirePeriod	1	1	1	1
	OtherPeriodText				
Geography	Text	Data for disposal of vehicle parts in Europe.	Data for disposal of vehicle parts in Europe.	Data for disposal of vehicle parts in Europe.	Data for disposal of vehicle parts in Europe.
Technology	Text	unknown	unknown	unknown	unknown
Representativeness	Percent				
	ProductionVolume	unknown	unknown	unknown	unknown
	SamplingProcedure	Literture	Literature	Literature	Literature
	Extrapolations	Some data derived from car disposal	Some data derived from car disposal	Some data derived from car disposal	Some data derived from car disposal
	UncertaintyAdjustments	none	none	none	none

Tab. A. 4: Metainformation of the datasets "operation"

Type	Field name, IndexNumber	277-04	277-05	277-06	277-07
ReferenceFunction	Name	operation, electric bicycle	operation, electric bicycle, certified electricity	operation, electric scooter	operation, electric scooter, certified electricity
Geography	Location	CH	CH	CH	CH
ReferenceFunction	InfrastructureProcess	0	0	0	0
ReferenceFunction	Unit	km	km	km	km
	IncludedProcesses	This data set includes the electricity demand using Swiss electricity mix for bicycle operation.	This data set includes the electricity demand using certified electricity mix for bicycle operation.	This data set includes the electricity demand using Swiss electricity mix for scooter operation and emission from abrasion and tyre wear.	This data set includes the electricity demand using certified electricity mix for scooter operation and emission from abrasion and tyre wear.
	LocalName	Betrieb, Elektrofahrrad	Betrieb, Elektrofahrrad, zertifizierter Strom	Betrieb, Elektroscooter	Betrieb, Elektroscooter, zertifizierter Strom
	Synonyms				
	GeneralComment	The data set reflects the average operation (1 kWh/100km) of a e-bike of 24kg total weight.	The data set reflects the average operation (1 kWh/100km) of a e-bike of 24kg total weight.	The data set reflects the average operation (3 kWh/100km) of a e-scooter of 144kg total weight.	The data set reflects the average operation (3 kWh/100km) of a e-scooter of 144kg total weight.
	InfrastructureIncluded	1	1	1	1
	Category	transport systems	transport systems	transport systems	transport systems
	SubCategory	road	road	road	road
	LocalCategory	Transportsysteme	Transportsysteme	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse	Strasse	Strasse
	Formula				
	StatisticalClassification				
	CASNumber				
TimePeriod	StartDate	2009	2009	2007	2007
	EndDate	2009	2009	2009	2009
	DataValidForEntirePeriod	1	1	1	1
	OtherPeriodText				
Geography	Text	Data cover operation in Switerland	Data cover operation in Switerland	Data cover operation in Switerland	Data cover operation in Switerland
Technology	Text	eBike with four level support function of electric motor. Maximal speed 25km/h. Battery charged with Swiss electricity mix.	eBike with four level support function of electric motor. Maximal speed 25km/h. Battery charged with certified electricity mix.	Electric scooter with max. speed 60-70km/h. Battery charged with Swiss electricity mix.	Electric scooter with max. speed 60-70km/h. Battery charged with certified electricity mix.
Representativeness	Percent				
	ProductionVolume	unknown	unknown	unknown	unknown
	SamplingProcedure	unknown	unknown	unknown	unknown
	Extrapolations			Some emissions extrapolated from BEV operation (10%)	Some emissions extrapolated from BEV operation (10%)
	UncertaintyAdjustments	none	none	none	none

Tab. A. 5: Metainformation of the dataset "scooter operation"

ReferenceFunction	Name	operation, scooter
Geography	Location	CH
ReferenceFunction	InfrastructureProcess	0
ReferenceFunction	Unit	km
	IncludedProcesses	Dataset for operation of a scooter with a 50cc motor. Fuel consumption for two-stroke petrol included. Direct airborne emissions of gaseous substances and particulates matter according to HBEFA (2004) for motorcycles (with catalyst). Heavy metal emissions caused by tyre wear extrapolated from average passenger car emissions.
	LocalName	Betrieb, Scooter
	Synonyms	
	GeneralComment	Data derived from average data for motorcycle operation in Europe in the year 2010. HBEFA data extrapolated to 3.5 lt/100km fuel consumption.
	InfrastructureIncluded	1
	Category	transport systems
	SubCategory	road
	LocalCategory	Transportsysteme
	LocalSubCategory	Strasse
	Formula	
	StatisticalClassification	
	CASNumber	
TimePeriod	StartDate	2004
	EndDate	2010
	DataValidForEntirePeriod	1
	OtherPeriodText	
Geography	Text	Data refers to Swiss Conditions
Technology	Text	average values for Swiss 50cc-150cc fleet: two-stroke: 45%, four-stroke: 55%
Representativeness	Percent	
	ProductionVolume	unknown
	SamplingProcedure	unknown
	Extrapolations	some data extrapolated from passenger car emissions
	UncertaintyAdjustments	none

Tab. A. 6: Metainformation of datasets "bicycle manufacture"

ReferenceFunction	Name	bicycle, at regional storage	electric bicycle, at regional storage
Geography	Location	RER	RER
ReferenceFunction	InfrastructureProcess	1	1
ReferenceFunction	Unit	unit	unit
	IncludedProcesses	This data set includes the material use for the manufacturing of an average bicycle. Manufacturing of the bike parts is assumed to take place in China. Transport to Europe included.	This data set includes the material use for the manufacturing of an average bicycle with an additional electric motor. Manufacturing of the bike parts is assumed to take place in China. Transport to Europe included.
	LocalName	Fahrrad, ab Regionallager	Elektrofahrrad, ab Regionallager
	Synonyms	Citybike	e-Bike
	GeneralComment	The data set reflects a bike of 17kg including additionals (e.g. carriers, lights). The frame material is Aluminium.	The data set reflects a e-bike of 24kg including additionals (e.g. carriers, lights). The frame material is Aluminium and the battery contains LiMn2O4-cells.
	InfrastructureIncluded	1	1
	Category	transport systems	transport systems
	SubCategory	road	road
	LocalCategory	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse
	Formula		
	StatisticalClassification		
	CASNumber		
TimePeriod	StartDate	2000	2000
	EndDate	2009	2009
	DataValidForEntirePeriod	1	1
	OtherPeriodText		
Geography	Text	Data cover manufacturing in China and retail in Europe	Data cover manufacturing in China and retail in Europe
Technology	Text	Citybike	Electric bicycle with electric motor at wheel-hub and LiMn2O4 battery pack, 100Wh/kg-
Representativeness	Percent		
	ProductionVolume	unknown	unknown
	SamplingProcedure	Literature	Literature
	Extrapolations	Manufacturing plant is extrapolated from passenger car plant, electricity consumption extrapolated according to weight ratio from passenger car (50%)	Electric motor and battery extrapolated from BEV, Manufacturing plant is extrapolated from passenger car plant, electricity consumption extrapolated according to weight ratio from passenger car
	UncertaintyAdjustments	none	none

Tab. A. 7: Metainformation of the datasets "scooter manufacturing"

ReferenceFunction	Name	electric scooter, at regional storage	scooter, ICE, at regional storage
Geography	Location	RER	RER
ReferenceFunction	InfrastructureProcess	1	1
ReferenceFunction	Unit	unit	unit
	IncludedProcesses	This data set includes all processes and materials for eScooter manufacturing, containing a LiIo battery. Transport to regional storage included.	This data set includes all processes and materials for eScooter manufacturing, containing an ICE motor. Transport to regional storage included.
	LocalName	Elektroscooter, ab Regionallager	Scooter, ICE, ab Regionallager
	Synonyms	eScooter, eRoller	Roller
	GeneralComment	The data set reflects a scooter running 60-70 km/h at max. speed. Corresponding 50cc .Manufacturing in Asia.	The data set reflects a scooter running 60-70km/h at max. speed, 50cc. Manufacturing in Asia.
	InfrastructureIncluded	1	1
	Category	transport systems	transport systems
	SubCategory	road	road
	LocalCategory	Transportsysteme	Transportsysteme
	LocalSubCategory	Strasse	Strasse
	Formula		
	StatisticalClassification		
	CASNumber		
TimePeriod	StartDate	2000	2000
	EndDate	2009	2009
	DataValidForEntirePeriod	1	1
	OtherPeriodText		
Geography	Text	Data for manufacturing in Asia and retail in Europe	Data for manufacturing in Asia and retail in Europe
Technology	Text	Automised production of small e-scooters. LiMn2O4 battery pack, 100Wh/kg.	Automised production of 50cc scooters
Representativeness	Percent		
	ProductionVolume	unknown	unknown
	SamplingProcedure	Literature, manufacturer data	Literature, manufacturer data
	Extrapolations	All values extrapolated from BEV production. Some adaptations made for change of material.	All values extrapolated from passenger car production. Some adaptations made for change of material.
	UncertaintyAdjustments	none	none