Supporting Information to the manuscript entitled

Contribution of Li-ion batteries to the environmental impact of electric vehicles

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Number of pages: 42

Number of figures: 2

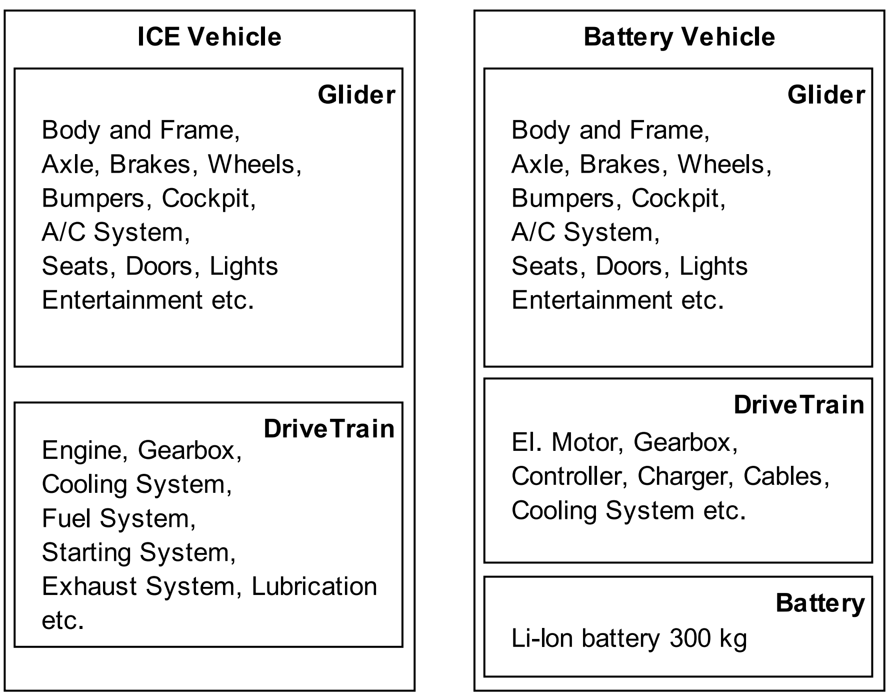
Number of tables: 21

Number of schemes: 2

Electric vehicle production and disposal

A typical middle-class passenger car from ecoinvent v2.0, represented by a Golf A4 (petrol, 55kW) is used as a base for the LCI [*1*]. This dataset originates on data from "Life Cycle Inventory for the Golf A4", a "Volkswagen" report from the year 2000 [*2*]. All sub-components constituting the ICE drive train were subtracted from the ecoinvent dataset, leaving the LCI of a motor less vehicle glider. Thus, two new LCI datasets for a Glider and an ICE drive train were generated which combined match the Golf A4 (Table S1 to S3). A new LCI dataset for an electric drive train was generated using data from. The components to build an LCI for an electric drive train are selected in such a way, that the same maximal permanent power of 55 kW followed from the ICE drive train. The LCI for the entire BEV finally consists of the LCI of the glider, the electric drive train and the Li-ion battery.

Scheme S1. The model of an internal combustion vehicle (ICE Vehicle) and a battery vehicle.



Using the same glider for both the ICEV and the BEV allows a fair comparison between the two cars in terms of space, comfort and top speed (171 km/h (106 mph)). Differences appear in acceleration

(BEV: 85 Nm nominal torque, max. 223 Nm; ICEV: 128 Nm) and in driving autonomy (ICEV approximately 940 km with 50 liter-tank and 5.2 liter per 100 km; BEV approximately 200 km with 34 kWh battery and 17 kWh/100 km).

The dataset for maintenance and disposal of the passenger car in ecoinvent has been used for this ICEV vehicle and the BEV with exception of the lead acid battery replacement in case of the BEV.

The energy consumption of the electric vehicle's operation is estimated based on existing vehicles and theoretical considerations. 14.1 kWh of electric energy is needed per 100 km to propel a golf-class vehicle with an overall efficiency of 80% (including charging losses and recuperation gains) in a standard driving cycle (New European Driving Cycle, NEDC). This energy consumption refers to a combination of the urban (12.8 kWh/100km) and extra-urban (16.8 kWh/100km) energy consumption in a NEDC and is calculated based on mechanical energy considerations and efficiency.

Auxiliary energy consumption for heating accounts for 2 kWh/100km. The energy consumption for heating is calculated assuming that there is a heating demand of four month within a year. In addition, 0.5 kWh/100 km electric energy is needed for air conditioning. The energy consumption for air conditioning is calculated assuming that there is an air conditioning demand of four month within a year. Other electricity consumer (light, windshield wiper, ventilation, radio, navigation) need 0.5 kWh/100km based on the assumption that each of these consumers is utilized during 50% of the time the BEV is in use. Heating, cooling and electronic devices consume altogether 2.9 kWh/100 km. The BEV thus requires in total 17 kWh/100 km.

Inventory for the Glider

Table S1. Detailed life cycle inventory for the glider

Phase	Component	Sub1	Sub2	Ecoinvent composition	Unit	Amount in vehicle [kg]	Waste factor	Amount in EI [kg]
production	Glider	Body&Frame	Chassis and body, sheet	reinforcing steel, at plant	kg	283	1.5	424.5
production	Glider	Body&Frame	Gaskets EPDM	Synthetic rubber, at plant/RER U	kg	10	1	10
production	Glider	Body&Frame	Front screen	Flat glass, uncoated, at plant/RER U	kg	10	1	10
production	Glider	Body&Frame	Zinc coating	Zinc, primary, at regional storage/RER U	kg	6	1	6
production	Glider	Body&Frame	Insulation	glass fibre reinforced plastic, polyester, hand-lamina	kg	6	1	6
production	Glider	Body&Frame	Paint	Alkyd paint, white, 60% in H2O, at plant/RER U	kg	4	1.1	4.4
production	Glider	Body&Frame	Wiper liquid (Glycol/Wate	Ethylene glycol, at plant/RER U	kg	5	1	5
production	Glider	Axle	Front axle steering	steel, low-alloyed, at plant	kg	40	1.25	50
production	Glider	Axle	Rear axle	steel, low-alloyed, at plant	kg	30	1.25	37.5
production	Glider	Breaks	Brake shoes, disks, supp	steel, low-alloyed, at plant	kg	25	1.25	31.25
production	Glider	Breaks	Brake pressure hoses	# Polyphenylene sulfide, at plant/GLO U	kg	2	1.1	2.2
production	Glider	Breaks	Brake oil	Lubricating oil, at plant/RER U	kg	2	1	2
production	Glider	Breaks	Brake shoes, supports	Aluminium, production mix, at plant/RER U	kg	2	1.25	2.5
production	Glider	Wheels	Rims	reinforcing steel, at plant	kg	18	1.5	27
production	Glider	Wheels	Tyres	Synthetic rubber, at plant/RER U	kg	30	1	30
production	Glider	Bumper (4 pcs)	Dampers and springs	steel, low-alloyed, at plant	kg	24	1.25	30
production	Glider	Air Conditioning	Compressor	reinforcing steel, at plant	kg	5	1.5	7.5
production	Glider	Air Conditioning	Compressor	Aluminium, production mix, at plant/RER U	kg	1	1.25	1.25
production	Glider	Air Conditioning	Air distribution	polyethylene, HDPE, granulate, at plant	kg	10	1.1	11
production	Glider	Air Conditioning	Adapters	Synthetic rubber, at plant/RER U	kg	1	1	1
production	Glider	Air Conditioning	Refrigerant R134a Tetraf	Refrigerant R134a, at plant/RER U	kg	1	1	1
production	Glider	Cockpit	Cockpit	glass fibre reinforced plastic, polyester, hand-lamina	kg	20	1.1	22
production	Glider	Safety (Belts, Airba	Belts airbags	reinforcing steel, at plant	kg	10	1.5	15
production	Glider	Safety (Belts, Airba	Belts airbags	Polyethylene terephthalate, granulate, amorphous,	kg	10	1.1	11
production	Glider	Interior / Linings	Linings	glass fibre reinforced plastic, polyester, hand-lamina	kg	57	1.1	62.7
production	Glider	Interior / Linings	Insulation	glass fibre reinforced plastic, polyester, hand-lamina	kg	10	1.1	11
production	Glider	Seats	Seat structure	reinforcing steel, at plant	kg	30	1.5	45
production	Glider	Seats	Seat covers	Polyethylene terephthalate, granulate, amorphous,	kg	30	1.1	33
production	Glider	Doors	Frames	reinforcing steel, at plant	kg	55	1.5	82.5
production	Glider	Doors	Windows side and rear	Flat glass, uncoated, at plant/RER U	kg	20	1	20
production	Glider	Electrics / Lights	Lights	Light emitting diode, LED, at plant/GLO U	kg	0.1	1	0.1
production	Glider	Electrics / Lights	Cables 3x1.5mm2 65g/m	Cable, connector for computer, without plugs, at pla	kg	3.25	1	3.25
production	Glider	Electrics / Lights	El. Motors St. 50%	steel, low-alloyed, at plant	kg	10	1.25	12.5
production	Glider	Electrics / Lights	El. Motors Al 30%	Aluminium, production mix, at plant/RER U	kg	6	1.25	7.5
production	Glider	Electrics / Lights	El. Motors Cu 20%	copper, at regional storage	kg	4	1	4
production	Glider	Electronics	Electronics	Printed wiring board, mixed mounted, unspec., sold	kg	2	1	2
production	Glider	Auxiliaries	processing copper	wire drawing, copper	kg			4
production	Glider	Auxiliaries	processing sheet steel	sheet rolling, steel	kg			425
production	Glider	Auxiliaries		Heat, natural gas, at industrial furnace >100kW/RE	MJ	*5'476*		1639
production	Glider	Auxiliaries		Electricity, medium voltage, production UCTE, at gr	kWh	*1'956*		1580
production	Glider	Auxiliaries		light fuel oil, burned in industrial furnace 1MW, non-	MJ			47
production	Glider	Auxiliaries		Tap water, at user/RER U	kg			2378
production	Glider	Auxiliaries		transport, lorry >16t	tkm			39
production	Glider	Auxiliaries		Transport, freight, rail/RER U	tkm			391
production	Glider	Auxiliaries		Road vehicle plant/RER/I U	p			2.15E-07
production	Glider	Emissions	emissions to water	COD, Chemical Oxygen Demand	kg			0.142517
production	Glider	Emissions	emissions to water	BOD5, Biological Oxygen Demand	kg			0.019199
production	Glider	Emissions	emissions to water	Phosphate	kg			0.000738
production	Glider	Emissions	emissions to air	NMVOC, non-methane volatile organic compounds,	kg			3.54
production	Glider	Emissions	emissions to air	Heat, waste	MJ			5686

Inventory for the ICE drive-train

Table S2. Detailed life cycle inventory for the ICE drive-train

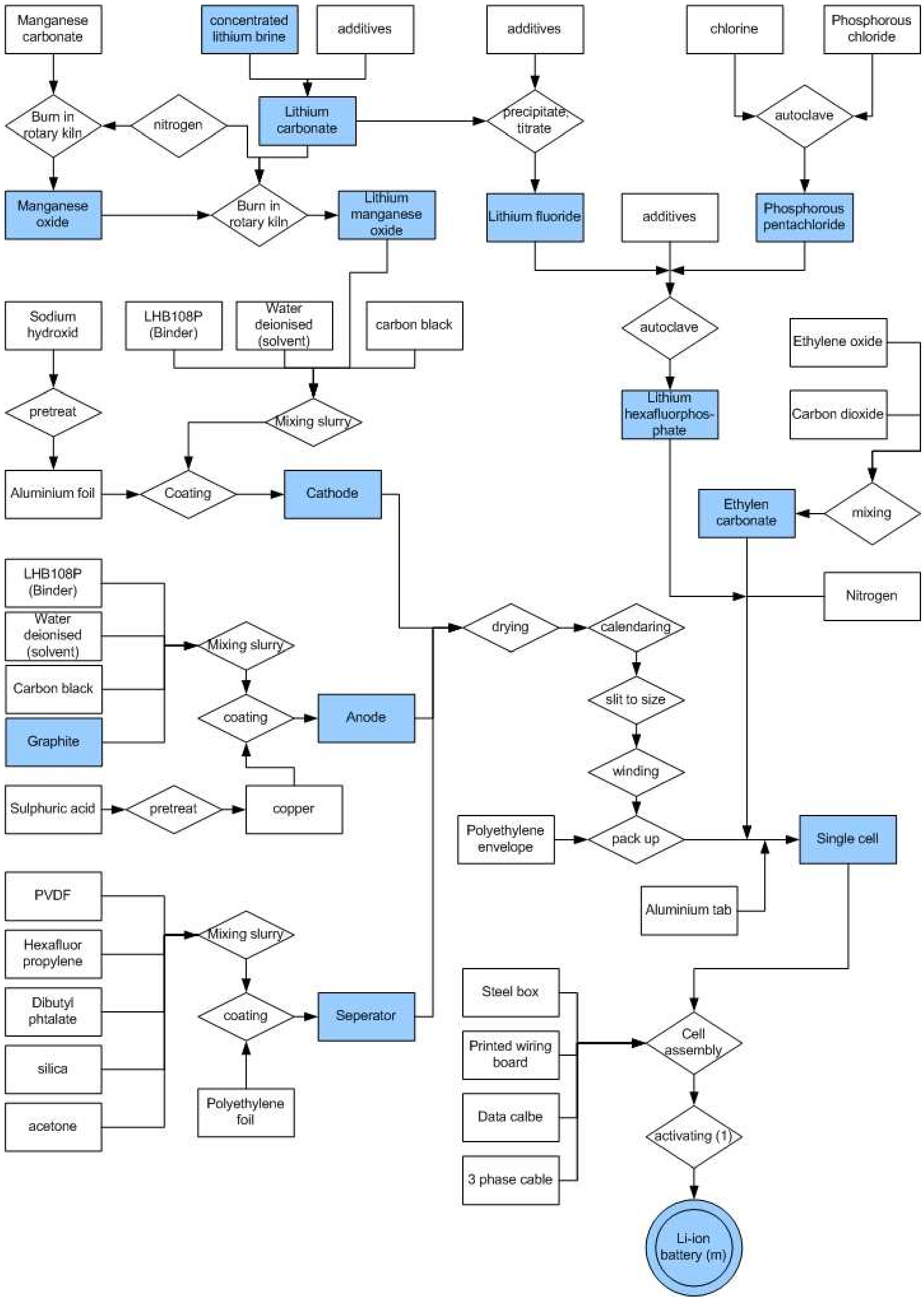
Phase	Component	Sub1	Sub2	Ecoinvent composition	Unit	Amount in vehicle [kg]	Waste factor	Amount in EI [kg]
production	ICE Drivetrain	Gearbox	Casing (100% sec. AlSi9	Aluminium, production mix, at plant/RER U	kg	17	1.25	21.25
production	ICE Drivetrain	Gearbox	Input shaft with gears	steel, low-alloyed, at plant	kg	7	1.25	8.75
production	ICE Drivetrain	Gearbox	Output shaft with gears	steel, low-alloyed, at plant	kg	8	1.25	10
production	ICE Drivetrain	Gearbox	Differential	steel, low-alloyed, at plant	kg	9	1.25	11.25
production	ICE Drivetrain	Gearbox	Shift parts	steel, low-alloyed, at plant	kg	1	1.25	1.25
production	ICE Drivetrain	Gearbox	Others	steel, low-alloyed, at plant	kg	8	1.25	10
production	ICE Drivetrain	Gearbox	Clutch	steel, low-alloyed, at plant	kg	5	1.25	6.25
production	ICE Drivetrain	Engine	Crankcase	steel, low-alloyed, at plant	kg	15	1.25	18.75
production	ICE Drivetrain	Engine	Crankcase	Aluminium, production mix, at plant/RER U	kg	15	1.25	18.75
production	ICE Drivetrain	Engine	Crankshaft	steel, low-alloyed, at plant	kg	8	1.25	10
production	ICE Drivetrain	Engine	Flywheel	steel, low-alloyed, at plant	kg	6	1.25	7.5
production	ICE Drivetrain	Engine	Ring gear	steel, low-alloyed, at plant	kg	0.5	1.25	0.625
production	ICE Drivetrain	Engine	Connecting rod (4 pc.)	steel, low-alloyed, at plant	kg	1.5	1.25	1.875
production	ICE Drivetrain	Engine	Cylinder head	Aluminium, production mix, at plant/RER U	kg	8	1.25	10
production	ICE Drivetrain	Engine	Camshaft	steel, low-alloyed, at plant	kg	2	1.25	2.5
production	ICE Drivetrain	Engine	Intake valve (4 pc.)	steel, low-alloyed, at plant	kg	0.2	1.25	0.25
production	ICE Drivetrain	Engine	Hydraulic valve lifter (8 p	steel, low-alloyed, at plant	kg	0.3	1.25	0.375
production	ICE Drivetrain	Engine	Exhaust valves	steel, low-alloyed, at plant	kg	0.2	1.25	0.25
production	ICE Drivetrain	Engine	Pistons (4 pcs)	Aluminium, production mix, at plant/RER U	kg	0.5	1.25	0.625
production	ICE Drivetrain	Engine	Intake Manifold	Aluminium, production mix, at plant/RER U	kg	4	1.25	5
production	ICE Drivetrain	Engine	injection system	steel, low-alloyed, at plant	kg	1	1.25	1.25
production	ICE Drivetrain	Engine	injection system	Aluminium, production mix, at plant/RER U	kg	1	1.25	1.25
production	ICE Drivetrain	Engine	injection system	# Polyphenylene sulfide, at plant/GLO U	kg	2	1.1	2.2
production	ICE Drivetrain	Engine	Air Filter	# Polyphenylene sulfide, at plant/GLO U	kg	5	1.1	5.5
production	ICE Drivetrain	Engine	Others	# Polyphenylene sulfide, at plant/GLO U	kg	10	1.1	11
production	ICE Drivetrain	Engine	Others	Lubricating oil, at plant/RER U	kg	6	1	6
production	ICE Drivetrain	Cooling System	Water cooler	reinforcing steel, at plant	kg	2	1.5	3
production	ICE Drivetrain	Cooling System	Water cooler	Aluminium, production mix, at plant/RER U	kg	2	1.25	2.5
production	ICE Drivetrain	Cooling System	Water cooler	polyethylene, HDPE, granulate, at plant	kg	1	1.1	1.1
production	ICE Drivetrain	Cooling System	Water cooler	Ethylene glycol, at plant/RER U	kg	7	1	7
production	ICE Drivetrain	Cooling System	Ventilator	reinforcing steel, at plant	kg	1	1.5	1.5
production	ICE Drivetrain	Cooling System	Ventilator	polyethylene, HDPE, granulate, at plant	kg	1	1.1	1.1
production	ICE Drivetrain	Cooling System	Piping	# Polyphenylene sulfide, at plant/GLO U	kg	4	1.1	4.4
production	ICE Drivetrain	Cooling System	Piping	Synthetic rubber, at plant/RER U	kg	2	1	2
production	ICE Drivetrain	Starting System	Starter motor	steel, low-alloyed, at plant	kg	4	1.25	5
production	ICE Drivetrain	Starting System	Starter motor	Aluminium, production mix, at plant/RER U	kg	1	1.25	1.25
production	ICE Drivetrain	Starting System	Starter motor	copper, at regional storage	kg	1	1	1
production	ICE Drivetrain	Starting System	Alternator	steel, low-alloyed, at plant	kg	4	1.25	5
production	ICE Drivetrain	Starting System	Alternator	Aluminium, production mix, at plant/RER U	kg	1	1.25	1.25
production	ICE Drivetrain	Starting System	Alternator	copper, at regional storage	kg	1	1	1
production	ICE Drivetrain	Starting System	Starter Battery	# Polyphenylene sulfide, at plant/GLO U	kg	4	1.1	4.4
production	ICE Drivetrain	Starting System	Starter Battery	lead, at regional storage	kg	13	1	13
production	ICE Drivetrain	Starting System	Starter Battery	Sulphuric acid, liquid, at plant/RER U	kg	1	1	1
production	ICE Drivetrain	Fuel System	Tubes, fuel pump, fittings	reinforcing steel, at plant	kg	1	1.5	1.5
production	ICE Drivetrain	Fuel System	Tank	polyethylene, HDPE, granulate, at plant	kg	12	1.1	13.2
production	ICE Drivetrain	Fuel System	Gasoline	Petrol, low-sulphur, at regional storage/RER U	kg	42	1	42
production	ICE Drivetrain	Exhaust System	Exhaust Manifold	reinforcing steel, at plant	kg	8	1.5	12
production	ICE Drivetrain	Exhaust System	Exhaust Pipes, Muffler	reinforcing steel, at plant	kg	16	1.5	24
production	ICE Drivetrain	Exhaust System	Exhaust Pipes, Muffler	Synthetic rubber, at plant/RER U	kg	1	1	1
production	ICE Drivetrain	Exhaust System	Catalyzer	steel, low-alloyed, at plant	kg	5	1.5	7.5
production	ICE Drivetrain	Exhaust System	Catalyzer	platinum, at regional storage	kg	0.0016	1	0.0016
production	ICE Drivetrain	Exhaust System	Catalyzer	palladium, at regional storage	kg	0.0003	1	0.0003
production	ICE Drivetrain	Auxiliaries	processing copper	wire drawing, copper	kg			2
production	ICE Drivetrain	Auxiliaries	processing HDPE	Injection moulding/RER U	kg			13
production	ICE Drivetrain	Auxiliaries		Heat, natural gas, at industrial furnace >100kW/RE	MJ	*1'933*		581
production	ICE Drivetrain	Auxiliaries		Electricity, medium voltage, production UCTE, at gr	kWh	*691*		560
production	ICE Drivetrain	Auxiliaries		light fuel oil, burned in industrial furnace 1MW, non-	MJ			16
production	ICE Drivetrain	Auxiliaries		Tap water, at user/RER U	kg			842
production	ICE Drivetrain	Auxiliaries		transport, lorry >16t	tkm			14
production	ICE Drivetrain	Auxiliaries		Transport, freight, rail/RER U	tkm			139
production	ICE Drivetrain	Auxiliaries		Road vehicle plant/RER/I U	p			7.61E-08
production	ICE Drivetrain	Emissions	emissions to water	COD, Chemical Oxygen Demand	kg			0.050483
production	ICE Drivetrain	Emissions	emissions to water	BOD5, Biological Oxygen Demand	kg			0.006801
production	ICE Drivetrain	Emissions	emissions to water	Phosphate	kg			0.000262
production	ICE Drivetrain	Emissions	emissions to air	NMVOC, non-methane volatile organic compounds,	kg			1.26
production	ICE Drivetrain	Emissions	emissions to air	Heat, waste	MJ			2014

Inventory for the electric drive-train

Table S3. Detailed life cycle inventory for the ICE drive-train

Phase	Component	Sub1	Sub2	Ecoinvent composition	Unit	Amount in vehicle [kg]	Waste factor	Amount in EI [kg]
production	El. drivetrain	el. motor	magnetic circuit sheet ste	steel, low-alloyed, at plant	kg	25.00	1.5	37.5
production	El. drivetrain	el. motor	shaft	steel, low-alloyed, at plant	kg	2.00	1.25	2.5
production	El. drivetrain	el. motor	permanent magnet	ferrite, at plant	kg	1.15	1.25	1.4375
production	El. drivetrain	el. motor	permanent magnet	neodymium oxide, at plant	kg	0.42	1.25	0.525
production	El. drivetrain	el. motor	permanent magnet	boron carbide, at plant	kg	0.02	1.25	0.025
production	El. drivetrain	el. motor	windings	copper, at regional storage	kg	10.00	1	10
production	El. drivetrain	el. motor	housing	Aluminium, production mix, at plant/RER U	kg	14.00	1.25	17.5
production	El. drivetrain	el. motor	housing	# Polyphenylene sulfide, at plant/GLO U	kg	1.10	1.1	1.21
production	El. drivetrain	gearbox	differential, transaxle, par	steel, low-alloyed, at plant	kg	10.00	1.25	12.5
production	El. drivetrain	gearbox	housing	Aluminium, production mix, at plant/RER U	kg	9.00	1.25	11.25
production	El. drivetrain	controller	electronics	Printed wiring board, mixed mounted, unspec., sold	kg	2.00	1	2
production	El. drivetrain	controller	housing	Aluminium, production mix, at plant/RER U	kg	7.00	1.25	8.75
production	El. drivetrain	controller	housing	# Polyphenylene sulfide, at plant/GLO U	kg	0.50	1.1	0.55
production	El. drivetrain	charger	electronics	Printed wiring board, mixed mounted, unspec., sold	kg	2.00	1	2
production	El. drivetrain	charger	housing	Aluminium, production mix, at plant/RER U	kg	3.70	1.25	4.625
production	El. drivetrain	charger	housing	# Polyphenylene sulfide, at plant/GLO U	kg	0.50	1.1	0.55
production	El. drivetrain	cables	high power 3x16mm2	cable, three-conductor cable, at plant	kg	3.12	1	3.12
production	El. drivetrain	Cooling System	Water cooler	reinforcing steel, at plant	kg	0.6	1.5	0.9
production	El. drivetrain	Cooling System	Water cooler	Aluminium, production mix, at plant/RER U	kg	0.6	1.25	0.75
production	El. drivetrain	Cooling System	Water cooler	polyethylene, HDPE, granulate, at plant	kg	0.3	1.1	0.33
production	El. drivetrain	Cooling System	Water cooler	Ethylene glycol, at plant/RER U	kg	2.1	1	2.1
production	El. drivetrain	Cooling System	Ventilator	reinforcing steel, at plant	kg	0.3	1.5	0.45
production	El. drivetrain	Cooling System	Ventilator	polyethylene, HDPE, granulate, at plant	kg	0.3	1.1	0.33
production	El. drivetrain	Cooling System	Piping	# Polyphenylene sulfide, at plant/GLO U	kg	1.2	1.1	1.32
production	El. drivetrain	Cooling System	Piping	Synthetic rubber, at plant/RER U	kg	0.6	1	0.6
production	El. drivetrain	Auxiliaries	processing steel	sheet rolling, steel	kg			37.5
production	El. drivetrain	Auxiliaries	processing copper	wire drawing, copper	kg			10
production	El. drivetrain	Auxiliaries		Heat, natural gas, at industrial furnace >100kW/RE	MJ	*683*		252
production	El. drivetrain	Auxiliaries		Electricity, medium voltage, production UCTE, at gr	kWh	*244*		243
production	El. drivetrain	Auxiliaries		light fuel oil, burned in industrial furnace 1MW, non-	MJ			7
production	El. drivetrain	Auxiliaries		Tap water, at user/RER U	kg			365
production	El. drivetrain	Auxiliaries		transport, lorry >16t	tkm			6
production	El. drivetrain	Auxiliaries		Transport, freight, rail/RER U	tkm			60
production	El. drivetrain	Auxiliaries		Road vehicle plant/RER/I U	p			3.30E-08
production	El. drivetrain	Emissions	emissions to water	COD, Chemical Oxygen Demand	kg			0.021882
production	El. drivetrain	Emissions	emissions to water	BOD5, Biological Oxygen Demand	kg			0.002948
production	El. drivetrain	Emissions	emissions to water	Phosphate	kg			0.000113
production	El. drivetrain	Emissions	emissions to air	NMVOC, non-methane volatile organic compounds,	kg			0.54
production	El. drivetrain	Emissions	emissions to air	Heat, waste	MJ			873

Scheme S2. Flow Diagram of the production steps from lithium containing brine to the lithium ion battery.



[1] Activating: Charge and discharge cycles of the battery

Table S4. Input-output table for the production of concentrated lithium brine.

General Flow information							Representation in ecoinvent								Uncertainty		
Input		Process Name		Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Li containing salt from salina lake	♏	concentrated lithium brine (6.7 % Li), at plant: Input				Brine Input: 43.8 kg; Li-content: 0.15 % loss: 2%	resource	in ground			Lithium, 0.15%in brine, in ground	6.70E-02	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
diesel fuel	♏						construction processes	machinery	No	GLO	diesel, burned in building machine	1.94E-01	MJ	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,11)
		concentrated lithium brine (6.7 % Li), at plant: Output	♏	Concentrated lithium brine (6.7 %Li), at plant			chemicals	inorganics	No	GLO	concentrated lithium brine (6.7 % Li), at plant	1.00E+00	kg				

The production of concentrated lithium brine includes inspissations of lithium containing brine by sun energy in the desert of Atacama. The diesel fuel is required for pumping the brine from ground and between different basins as well as for machinery used on the facility [*3*].

Table S5. Input-output table for the production of lithium carbonate (Li_2CO_3).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
concentrated lithium chloride brine	ε	lithium carbonate, at plant: Input					chemicals	inorganics	No	GLO	concentrated lithium brine (6.7 % Li), at plant	9.38E+00	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Quicklime	ε						construction materials	additives	No	CH	quicklime, milled, loose, at plant	1.76E-01	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Sulphuric acid	ε						chemicals	inorganics	No	RER	sulphuric acid, liquid, at plant	3.57E-02	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Hydrochloric acid	ε						chemicals	inorganics	No	RER	hydrochloric acid, 30% in H2O, at plant	5.71E-02	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Filtering earth	ε					Proxy for "filtering earth"	construction materials	additives	No	DE	bentonite, at processing	1.44E-02	kg	SEIA-CONAMA (2006)	1	1.53	(2,2,1,3,4,4,4)
Alcohol	ε					Proxy for 7-12 carbon alcohol	chemicals	organics	No	RER	2-methyl-2-butanol, at plant	1.19E-03	kg	SEIA-CONAMA (2006)	1	1.53	(2,2,1,3,4,4,4)
Soda ash	ε						chemicals	inorganics	No	RER	soda, powder, at plant	3.73E+00	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Organic solvent	ε					Proxy for a solvent containing "parafines and aromatic compunds"	chemicals	organics	No	GLO	solvents, organic, unspecified, at plant	4.75E-03	kg	SEIA-CONAMA (2006)	1	1.53	(2,2,1,3,4,4,4)
Sodium hydroxide	ε						chemicals	inorganics	No	RER	sodium hydroxide, 50% in H2O, production mix, at plant	1.88E-04	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,4)
Electricity	ε					Proxy for "electricity mix Chile"	electricity	supply mix	No	BR	electricity, medium voltage, at grid	5.60E-04	kWh	SEIA-CONAMA (2006)	1	1.53	(2,2,1,3,4,4,2)
Natural gas	ε					use heat: natural gas and heat from liquified gas	natural gas	heating systems	No	RER	natural gas, burned in industrial furnace >100kW	6.09E+00	MJ	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,1)
Natural gas	ε					credit: processing of natural gas subtracted, equal to the value of liquified gas	natural gas	fuels	No	RER	natural gas, high pressure, at consumer	-2.00E+00	MJ	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,1)
liquified natural gas	ε					The plant uses liq. gas. Liq. gas is not available as "heat…" or "burned…" . Thus we balanced more heat from natural gas and made a credit for preparation of natural gas, highg pressure.	natural gas	production	No	JP	natural gas, liquefied, at freight ship	9.53E-05	Nm3	SEIA-CONAMA (2006)	1	1.53	(2,2,1,3,4,4,11)

diesel oil	ε					construction processes	machinery	No	GLO	diesel, burned in building machine	2.84E-01	MJ	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,11)
Transport lorry 16-32t	ε				according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry 16-32t, EURO3	2.59E+00	tkm	SEIA-CONAMA (2006)	1	2.25	(5,2,1,3,1,4,5)
Transport lorry 7.5-16t	ε				according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry 7.5-16t, EURO3	2.40E-03	tkm	SEIA-CONAMA (2006)	1	2.25	(5,2,1,3,1,4,5)
Infrastructure, chemical plant	ε				ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.24	(5,2,1,3,1,4,9)
		lithium carbonate, at plant: Output	ε	hazardous waste, underground deposit		waste management	underground deposit	No	DE	disposal, hazardous waste, 0% water, to underground deposit	2.05E-04	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,6)
			ε	non - hazardous waste, residual material landfill		waste management	residual material landfill	No	CH	disposal, decarbonising waste, 30% water, to residual material landfill	6.41E+00	kg	SEIA-CONAMA (2006)	1	1.13	(2,2,1,3,1,4,6)
			ε	Waste heat to air		air	unspecified			Heat, waste	2.02E-03	MJ	calculated from eletricity input	1	1.24	(4,2,1,3,1,4,13)
			ε	Lithium carbonate, at plant		chemicals	inorganics	No	GLO	lithium carbonate, at plant	1.00E+00	kg				

The concentrated lithium brine is further treated with additives. After removal of boron and a purification step, soda is added for carbonation. As a result, Li_2CO_3 precipitates. The salt is then filtered, washed and dried. After this purification step, Li_2CO_3 reaches a purity of 99% or higher [*4*].

Table S6. Input-output table for the production of manganese oxide (Mn_2O_3).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Manganese carbonate	ε	manganese oxide (Mn2O3), at plant: Input				basic material, no specific quality demand (Kajiya (2005)	metals	extraction	No	GLO	manganese concentrate, at beneficiation	1.71E+00	kg	stoichiometrical calculation according to Kajiya (2005)	1	1.58	(2,4,1,3,4,5,12)
Nitrogen	ε					liquid, for inert atmosphere	chemicals	inorganics	No	RER	nitrogen, liquid, at plant	2.56E+00	kg	Kajiya (2005)	1	1.24	(1,4,1,3,1,5,4)
Oxygen	ε					liquid, for oxidizing atmosphere	chemicals	inorganics	No	RER	oxygen, liquid, at plant	5.37E-01	kg	Kajiya (2005)	1	1.24	(1,4,1,3,1,5,4)
Electricity	ε					mechanical drive of the rotary kiln	electricity	supply mix	No	CN	electricity, medium voltage, at grid	5.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					Heat	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	4.13E+00	MJ	calculated according to stoichiometry including enthalpy of reaction	1	1.40	(4,4,1,3,3,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	4.81E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	2.20E+00	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
		manganese oxide (Mn2O3), at plant: Output	ε	manganese carbonate		85 % manganese conversion from MnCO3 to Mn2O3, 15% loss	waste management	inert material landfill	No	CH	disposal, inert waste, 5% water, to inert material landfill	2.57E-01	kg	Kajiya (2005)	1	1.33	(2,4,1,1,3,5,6)
			ε	waste heat to air			air	unspecified			Heat, waste	1.80E-02	MJ	calculated from eletricity input	1	1.32	(4,4,1,3,1,5,13)
			ε	CO2		amount of CO2 that results from the stoichiometry	air	unspecified			Carbon dioxide, fossil	2.79E-01	kg	stoichiometrical calculation according to Kajiya (2005)	1	1.32	(4,4,1,3,1,5,14)

	ε	Equal amount of CO as CO2 (stoichiometry), conversion of CO to CO2,	Assumption: CO (stoichiometry) is redirected to the rotary kiln and oxidised to CO2	air	unspecified			Carbon dioxide, fossil	2.79E-01	kg	calculated, conversion of CO to CO2	1	1.32	(4,4,1,3,1,5,14)
	ε	CO	Assumption: CO to the atmosphere is equal to the CO after thermal post-combustion (<20mgC/Nm3)	air	unspecified			Carbon monoxide, fossil	4.67E-05	kg	stoichiometrical calculation according to Kajiya (2005)	1	5.38	(4,4,1,3,4,5,17)
	ε	Mn2O3		chemicals	inorganics	No	CN	manganese oxide (Mn2O3), at plant	1.00E+00	kg				

Mn_2O_3 is produced by a two stage roasting whereby manganese carbonate is roasted in an atmosphere low in oxygen content, followed by roasting in an atmosphere high in oxygen content [*5*]. According to Kajiya [5], the process does not require any specific quality to the basic raw material (manganese carbonate). Applying this process, Mn_2O_3 reaches battery grade quality. Thermal heat input is calculated from specific heat energy (heating up to 500°C) of manganese carbonate, nitrogen and oxygen and the reaction of enthalpy (stoichiometrical consideration) from the conversion of manganese carbonate to manganese oxide [*6*]. We assumed thermal post combustion for the carbon monoxide (CO- emission < 20 ppm). The conversion factor for manganese carbonate is 85%.

Table S7. Input-output table for the production of lithium manganese oxide ($LiMn_2O_4$).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Manganese oxide	ε	lithium manganese oxide, at plant: Input				manganese component	chemicals	inorganics	No	CN	manganese oxide (Mn2O3), at plant	9.18E-01	kg	stoichiometrical calculation according to Heil (2003)	1	1.25	(2,4,2,3,1,5,4)
Lithium carbonate	ε					lithium component	chemicals	inorganics	No	GLO	lithium carbonate, at plant	2.15E-01	kg	stoichiometrical calculation according to Heil (2003)	1	1.25	(2,4,2,3,1,5,12)
Oxygen	ε					liquid, for oxidising atmosphere	chemicals	inorganics	No	RER	oxygen, liquid, at plant	7.15E-01	kg	according to Heil (2003)	1	1.24	(1,4,2,3,1,5,4)
Nitrogen	ε					liquid, for inert atmosphere	chemicals	inorganics	No	RER	nitrogen, liquid, at plant	7.86E-01	kg	according to Heil (2003)	1	1.24	(1,4,2,3,1,5,4)
Water	ε					for suspension: 3 parts water, 1 part Mn2O3 and Li2CO3 powder	water supply	production	No	CH	water, deionised, at plant	3.40E+00	kg	according to Heil (2003)	1	1.25	(2,4,2,3,1,5,4)
Electricity	ε					mechanical drive of the rotary kiln	electricity	supply mix	No	CN	electricity, medium voltage, at grid	5.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					furnace for rotary kiln	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	1.53E+01	MJ	calculated according to stoichiometry including enthalpy of reaction	1	1.33	(4,4,2,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	5.64E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	3.23E+00	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)

lithium manganese oxide, at plant: Output	ε	Manganese oxide	95 % manganese conversion, 5% loss according to ecoinvent guidelines	waste management	inert material landfill	No	CH	disposal, inert waste, 5% water, to inert material landfill	4.59E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.25	(2,4,2,3,1,5,6)
	ε	Lithium carbonate	95 % manganese conversion, 5% loss according to ecoinvent guidelines	waste management	inert material landfill	No	CH	disposal, inert waste, 5% water, to inert material landfill	1.07E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.25	(2,4,2,3,1,5,6)
	ε	Waste heat to air		air	unspecified			Heat, waste	1.80E-02	MJ	calculated from eletricity input	1	1.33	(4,4,2,3,1,5,13)
	ε	Waste water to air	evaporated water	air	high population density			Water	3.40E+00	kg	Heil (2003)	1	1.33	(4,4,2,3,1,5,4)
	ε	CO2	amount of CO2 that results from the stoichiometry	air	unspecified			Carbon dioxide, fossil	1.28E-01	kg	stoichiometrical calculation according to Heil (2003)	1	1.33	(4,4,2,3,1,5,14)
	ε	Lithium manganese oxide		chemicals	inorganics	No	GLO	lithium manganese oxide, at plant	1.00E+00	kg				

The production of $LiMn_2O_4$ contains several roasting stages of Li_2CO_3 and Mn_2O_3 in a rotary kiln [*7*]. During the different stages, the atmosphere in the rotary kiln changes from inert (addition of N_2) to oxidizing (addition of O_2) condition. The powder is then suspended with water followed by spray drying (evaporation of the water). Thermal heat input is calculated from specific heat energy (heating up to 750°C) of Li_2CO_3, Mn_2O_3, N_2 and O_2 and the reaction of enthalpy (stoichiometrical consideration) from the conversion Li_2CO_3 and Mn_2O_3 [*6*] to $LiMn_2O_4$ [*8*]. CO_2 emissions are calculated considering stoichiometrical considerations.

Table S8. Input-output table for the production of phosphorous pentachloride (PCl_5).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Phosphorus trichloride	ε	phosphorous pentachloride, at plant: Input				calculated conversion: 93.9%	chemicals	inorganics	No	RER	phosphorous chloride, at plant	7.03E-01	kg	stoichiometrical calculation according to Münster (1981)	1	1.58	(2,4,5,3,1,5,4)
Chlorine	ε					calculated conversion: 93.9%	chemicals	inorganics	No	RER	chlorine, liquid, production mix, at plant	3.63E-01	kg	stoichiometrical calculation according to Münster (1981)	1	1.58	(2,4,5,3,1,5,4)
Electricity	ε					mechanical drive for stirring and pumping	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					furnace of the reactor	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	8.67E-02	MJ	calculated according to stoichiometry, specific heat and enthalpy of reaction according to Münster (1981)	1	1.64	(4,4,5,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.07E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	4.58E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
		phosphorous pentachloride, at plant: Output	ε	Phosphorus trichloride		Conversion: 93.8%	air	high population density			Phosphorus trichloride	4.32E-02	kg	Münster (1981)	1	2.29	(2,4,5,3,1,5,23)
			ε	Chlorine		Conversion: 93.8%	air	high population density			Chlorine	2.23E-02	kg	Münster (1981)	1	1.58	(2,4,5,3,1,5,24)
			ε	Waste heat to air			air	unspecified			Heat, waste	7.20E-03	MJ	calculated from eletricity input	1	1.64	(4,4,5,3,1,5,13)
			ε	Phosphorus pentachloride			chemicals	inorganics	No	CN	phosphorous pentachloride, at plant	1.00E+00	kg				

PCl_5 is manufactured from chlorine and phosphorus trichloride in the presence of molten PCl_5 [*9*]. The process can be carried out such that the reaction product flows out from the reactor continuously as a melt. Thermal heat input is calculated from specific heat energy (heating up to 180°C) for phosphorus chloride and chlorine [*6*]. The conversion factor is 93.8%.

Table S9. Input-output table for the production of lithium fluoride (LiF).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input		Process Name		Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
lithium carbonate	ε	lithium fluoride, at plant: Input				40% hydrogen fluoride in 60% water	chemicals	inorganics	No	GLO	lithium carbonate, at plant	1.49E+00	kg	stoichiometrical calculation according to Friedrich (1999)	1	1.25	(2,4,2,3,1,5,4)
hydrogen fluoride	ε					40% hydrogen fluoride in 60% water	chemicals	inorganics	No	GLO	hydrogen fluoride, at plant	8.06E-01	Kg	stoichiometrical calculation according to Friedrich (1999)	1	1.25	(2,4,2,3,1,5,4)
Ammoniac	ε					Assumption Gregor Wernet: 5% of protons have to be neutralised with NH3	chemicals	inorganics	No	RER	ammonia, liquid, at regional storehouse	3.28E-02	kg	Interview with G. Wernet, J. Sutter, ETH Zürich	1	1.33	(4,4,2,3,1,5,4)
water	ε					1.) 60% water in 40% hydrogen fluoride, 2.) 1 liter from washing LiF	water supply	production	No	CH	water, deionised, at plant	2.21E+00	kg	Friedrich (1999)	1	1.25	(2,4,2,3,1,5,4)
Process heat	ε					Assumption: water content of LiF according to Hansen (1985)	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	1.21E+00	MJ	Hansen (1985)	1	1.33	(4,4,2,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	2.33E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	1.40E+00	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)

lithium fluoride, at plant: Output	ε	wastewater	water from HF solution	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 1	2.21E-03	m3	Friedrich (1999)	1	1.33	(4,4,2,3,1,5,6)
	ε	wastewater	from chemical reaction	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 1	3.63E-04	m3	stoichiometrical calculation according to Friedrich (1999)	1	1.33	(4,4,2,3,1,5,6)
	ε	water	from washing the LiF, Assumption: 1 Liter water to wash 1 kg LIF	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 1	1.00E-03	m3	Friedrich (1999)	1	1.58	(5,4,2,3,1,5,6)
	ε	lithium carbonate	Li2CO3, 4.5% of input						6.70E-02	kg	Friedrich (1999)	1	1.25	(2,4,2,3,1,5,6)
	ε	hydrogen fluoride	HF, 4.5% of input	air	high population density			Hydrogen fluoride	3.63E-02	kg	Friedrich (1999)	1	1.25	(2,4,2,3,1,5,6)
	ε	Ammonium ion	mass calculated, based on 5% NH3 input	water	unspecified			Ammonium, ion	3.47E-02	kg	Friedrich (1999)	1	1.58	(2,4,2,3,1,5,33)
	ε	carbon dioxide	from chemical reaction	air	unspecified			Carbon dioxide, fossil	8.86E-01	kg	stoichiometrical calculation according to Friedrich (1999)	1	1.33	(4,4,2,3,1,5,24)
	ε	lithium fluoride		chemicals	inorganics	No	CN	lithium fluoride, at plant	1.00E+00	kg				

Li_2CO_3 reacts with hydrogen fluoride at room temperature to LiF. The filtrate is titrated (pH 7.5) with ammoniac, washed with water and dried. The conversion factor regarding Lithium is 95.5% [*10*].

Table S10. Input-output table for the production of Lithium hexafluorophosphate ($LiPF_6$).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
Lithium fluoride	ε	lithium hexafluorophosphate, at plant: Input				86.7% conversion of lithium	chemicals	inorganics	No	CN	lithium fluoride, at plant	1.97E-01	kg	stoichiometrical calculation according to Belt (1998)	1	1.27	(2,4,3,3,1,5,4)
Phosphorous pentachloride	ε					86.7% conversion of phosphorous chlorid, 25% overspill in relation to LiF	chemicals	inorganics	No	CN	phosphorous pentachloride, at plant	1.98E+00	kg	stoichiometrical calculation according to Belt (1998)	1	1.27	(2,4,3,3,1,5,4)
Hydrogen fluoride	ε					Overspill: 532%	chemicals	inorganics	No	GLO	hydrogen fluoride, at plant	4.04E+00	kg	stoichiometrical calculation according to Belt (1998)	1	1.27	(2,4,3,3,1,5,4)
Nitrogen	ε					Inert atmosphere	chemicals	inorganics	No	RER	nitrogen, liquid, at plant	1.25E-03	kg	Assumption from G. Wernet, J. Sutter	1	1.33	(4,4,2,3,1,5,4)
Ca(OH)2	ε					Neutralisation and disposal of HF	construction materials	binder	No	CH	lime, hydrated, packed, at plant	7.44E+00	kg	Assumption from G. Wernet, J. Sutter, ETH	1	2.39	(4,5,5,5,5,5,4)
Electricity	ε					Assumption:heat pump with coefficient of performance =1.5	electricity	supply mix	No	CN	electricity, medium voltage, at grid	5.39E-01	kWh	Calculation of cooling (including enthalpy of reaction) according to Belt (1985)	1	1.27	(2,4,3,3,1,5,2)
Electricity	ε					for pumps, stirring, milling of LiPF6, etc.	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.37E+00	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	8.19E+00	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)

lithium hexafluorophosphate, at plant: Output	ε	disposal of KF and KCL	disposal of salts from neutralisation process, proxy	waste management	inert material landfill	No	CH	disposal, limestone residue, 5% water, to inert material landfill	8.61E+00	kg	calculated	1	2.12	(4,4,3,3,5,5,6)
	ε	wastewater	water from reaction for neutralisation of HF and HCl	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 1	3.61E-03	m3	calculated	1	2.12	(4,4,3,3,5,5,6)
	ε	LiF	LiF to recycling						2.62E-02	kg	stoichiometrical calculation according to Belt (1998)	2	1.56	
	ε	Phosphorous trichliride	PCl3 13.3% of input, proxy for PCl5	air	high population density			Phosphorus trichloride	2.63E-01	kg	Belt (1998)	1	1.60	(2,4,3,3,1,5,31)
	ε	waste heat to air	heat pump and laboratory apparatus	air	unspecified			Heat, waste	1.95E+00	MJ	calculated from electricity input	1	1.34	(4,4,3,3,1,5,13)
	ε	Lithium hexafluororphosphate		chemicals	inorganics	No	CN	lithium hexafluorophosphate, at plant	1.00E+00	kg				

The production of $LiPF_6$ requires a reaction of PCl_5, LiF and hydrogen fluoride (HF), wherein PCl_5 and LiF are combined, cooled (to – 78°C) and the HF is added in excess for complete chlorine-fluorine exchange in the PCl_5. Electric energy input is calculated for a heat pump with an assumed coefficient of performance of 1.5 [*11*]. The reaction in the autoclave occurs in an inert nitrogen atmosphere. The conversion factor regarding LiF is 87% [*12*].

Table S11. Input-output table for the production of ethylene carbonate ($C_3H_4O_3$).

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Ethylene oxide	ε	ethylene carbonate, at plant: Input				99.95% conversion of ethylene oxide to ethylene carbonate	chemicals	organics	No	RER	ethylene oxide, at plant	5.01E-01	kg	stoichiometrical calculation according to Birnbach (2003)	1	1.25	(2,4,2,3,1,5,3)
Carbon dioxide	ε					1% CO2 excess	chemicals	inorganics	No	RER	carbon dioxide liquid, at plant	5.05E-01	kg	stoichiometrical calculation according to Birnbach (2003)	1	1.25	(2,4,2,3,1,5,4)
Infrastructure: chemical plant	ε					Ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
Electricity	ε					mechanical drive of labor mixer and pumps	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					furnace of the reactor	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	1.43E-01	MJ	calculated according to stoichiometry, specific heat and enthalpy of reaction according to Birnbach (2003)	1	1.33	(4,4,2,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.01E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	3.51E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
		ethylene carbonate, at plant: Output	ε	catalyst		according to ecoinvent ethylenoxide production (0.5 kg / 1000 kg product)	waste management	residual material landfill	No	CH	disposal, catalyst base Eth.oxide prod., 0% water, to residual material landfill	5.00E-03	kg	according to ecoinvent ethylenoxide production (0.5 kg / 1000 kg product)	1	1.33	(2,4,2,3,3,5,6)
			ε	ethylene oxide		loss: 0.05%	air	unspecified			Ethylene oxide	2.50E-04	kg	Birnbach (2003)	1	2.07	(2,4,2,3,1,5,23)
			ε	carbon dioxide		loss: 0.05% from conversion, 1% excess	air	unspecified			Carbon dioxide, fossil	5.30E-03	kg	Birnbach (2003)	1	1.25	(2,4,2,3,1,5,24)
			ε	Waste heat to air			air	unspecified			Heat, waste	7.20E-03	MJ	calculated from eletricity input	1	1.33	(4,4,2,3,1,5,13)

	ε	Ethylene carbonate		chemicals	organics	No	CN	ethylene carbonate, at plant	1.00E+00	kg					

Ethylene oxide and CO_2 react with the aid of a catalyst under adiabatic conditions to $C_3H_4O_3$. Thermal heat input is calculated from specific heat energy (heating up to 126°C) for ethylene oxide and CO_2 [*6*]. The conversion factor regarding ethylene oxide is 99.95% [*13*].

Table S12. Input-output table for the production of battery grade graphite

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
water	ε	graphite, battery grade, at plant: Input					resource	in water			Water, well, in ground	2.93E-05	m3	Ecoinvent dataset "graphite, at plant*	1	1.33	(2,4,1,3,3,5,4)
graphite containing rock	ε						resource	in ground			Metamorphous rock, graphite containing, in ground	1.05E+00	kg	Ecoinvent dataset "graphite, at plant*	1	1.33	(2,4,1,3,3,5,4)
Land use	ε						resource	land			Occupation, mineral extraction site	8.48E-05	m2a	Ecoinvent dataset "graphite, at plant*	1	1.33	(2,4,1,3,3,5,4)
Land transformation	ε						resource	land			Transformation, to mineral extraction site	6.52E-06	m2	Ecoinvent dataset "graphite, at plant*	1	1.33	(2,4,1,3,3,5,4)
Land transformation	ε						resource	land			Transformation, from forest	6.52E-06	m2	Ecoinvent dataset "graphite, at plant*	1	1.16	(1,4,1,3,1,4,4)
Recultivation, limestone mine	ε						construction materials	additives	No	CH	recultivation, limestone mine	6.52E-06	m2	Ecoinvent dataset "graphite, at plant*	1	1.16	(1,4,1,3,1,4,4)
Mine, limestone	ε						construction materials	additives	Yes	CH	mine, limestone	5.25E-11	unit	Ecoinvent dataset "graphite, at plant*	1	1.32	(4,4,1,3,1,5,4)
Blasting	ε						construction processes	civil engineering	No	RER	blasting	7.73E-05	kg	Ecoinvent dataset "graphite, at plant*	1	2.11	(4,4,1,3,1,5,5)
Heat	ε						oil	heating systems	No	RER	heat, light fuel oil, at industrial furnace 1MW	8.98E-02	MJ	Ecoinvent dataset "graphite, at plant*	1	3.36	(5,5,2,3,3,5,9)
Light fuel oil	ε						oil	heating systems	No	CH	light fuel oil, burned in boiler 100kW, non-modulating	3.59E-03	MJ	Ecoinvent dataset "graphite, at plant*	1	1.48	(4,5,3,5,3,5,2)
Diesel	ε						construction processes	machinery	No	GLO	diesel, burned in building machine	1.80E-02	MJ	Ecoinvent dataset "graphite, at plant*	1	1.32	(4,4,1,3,1,5,1)
Industrial machine	ε						construction processes	machinery	Yes	RER	industrial machine, heavy, unspecified, at plant	2.31E-04	kg	Ecoinvent dataset "graphite, at plant*	1	3.20	(5,5,5,2,5,5,5)
Conveyer belt	ε						construction processes	machinery	Yes	RER	conveyor belt, at plant	2.78E-08	m	Ecoinvent dataset "graphite, at plant*	1	3.20	(5,5,5,2,5,5,5)
Electricity							electricity	supply mix	No	CN	electricity, medium voltage, at grid	1.03E+00	kWh	calculated according to www.timcal.com and Ecoinvent dataset "graphite, at plant*	1	1.53	(2,2,1,3,4,4,2)

Hard coal coke					hard coal	fuels	No	GLO	hard coal coke, at plant	4.00E+01	MJ	calculated according to www.timcal.com	1	1.53	(2,2,1,3,4,4,1)
	graphite, battery grade, at plant: Output	ε	Particulates < 2.5um		air	unspecified			Particulates, < 2.5 um	8.87E-06	kg	Ecoinvent dataset "graphite, at plant*	1	1.58	(5,4,1,3,1,5,6)
		ε	Particulates > 2.5 um < 10 um		air	unspecified			Particulates, > 10 um	4.78E-05	kg	Ecoinvent dataset "graphite, at plant*	1	1.84	(5,4,1,3,1,5,33)
		ε	Particulates > 10 um		air	unspecified			Particulates, > 2.5 um, and < 10um	1.21E-04	kg	Ecoinvent dataset "graphite, at plant*	1	1.32	(4,4,1,3,1,5,13)
		ε	Waste heat to air		air	unspecified			Heat, waste	3.72E+00	MJ	calculated from eletricity input	1	1.63	(4,4,1,3,1,5,31)
		ε	Anode, lithium-ion battery		chemicals	inorganics	No	CN	graphite, battery grade, at plant	1.00E+00	kg				

This dataset is based on the ecoinvent dataset "graphite, at plant". Battery grade graphite is much more energy intense than industrial graphite. Hence, aditional inputs (coke and electricity) are added to the ecoinvent original graphite dataset. The purity of synthetic graphite is >99.9%.

Table S13. Input-output table for the production of a cathode.

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Latex	ε	Cathode, lithium-ion battery, lithium manganese oxide, at plant: Input				Binder, (Styrene-butadiene)	chemicals	organics	No	RER	latex, at plant	9.89E-03	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Water	ε					Solvent for the binder	water supply	production	No	CH	water, deionised, at plant	2.00E-01	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Lithium manganese oxide	ε					Active material, LiMn2O4	chemicals	inorganics	No	GLO	lithium manganese oxide, at plant	6.23E-01	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Carbon black	ε					Conductive carbon	chemicals	inorganics	No	GLO	carbon black, at plant	2.64E-02	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Aluminium foil	ε					Aluminium for the collector	metals	extraction	No	RER	aluminium, production mix, wrought alloy, at plant	3.93E-01	kg	Measurement M. Gauch, Kokam cell	1	1.16	(1,4,1,3,1,4,4)
Aluminium foil rolling	ε					Sheet in the range of 0.2 to 6 mm	metals	processing	No	RER	sheet rolling, aluminium	3.93E-01	kg	Measurement M. Gauch, Kokam cell	1	1.16	(1,4,1,3,1,4,4)
Sodium hydroxide	ε					NaOH, 50 % water, value per m2 from powder coating, aluminium sheet,	chemicals	inorganics	No	RER	sodium hydroxide, 50% in H2O, production mix, at plant	1.30E-01	kg	equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil	1	1.32	(4,4,1,3,1,5,4)
Sulfuric acid	ε					H2SO4 from the process "Anode,, lithium-ion battery" to neutralise NaOH						8.08E-02	kg	equivalent amount of OH- to neutralise H2SO4	1	1.32	(4,4,1,3,1,5,4)
Infrastructure, chemical plant	ε					Ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
Electricity	ε					Mechanical drive for pumping slurry, coating, coiling, cutting	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					Evaporating water, heating active amterial, alu-foil, binder, solvent, black carbon	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	6.46E-01	MJ	calculated from specific heat of the base materials	1	1.32	(4,4,1,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.26E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	7.58E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)

Cathode, lithium-ion battery, lithium manganese oxide, at plant: Output	ε	Disposal coated cathode	5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils, copper to recycling	waste management	municipal incineration	No	CH	disposal, residues, shredder fraction from manual dismantling, in MSWI	5.26E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.58	(5,4,1,3,1,5,6)
	ε	Waste water	Assumption: NaOH is neutralized with H2SO4, only 50% disposed, the other 50% is disposed in the dataset Cathode, lithoim-iom battery"	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 3	1.05E-04	m3	equal to the amount of NaOH input	1	1.84	(5,4,1,3,1,5,33)
	ε	Waste heat to air	Heat and electric power	air	unspecified			Heat, waste	7.20E-03	MJ	calculated from eletricity input	1	1.32	(4,4,1,3,1,5,13)
	ε	Waste water	Solvent water evaporated from the slurry	air	unspecified			Water	2.00E-01	kg	calculated from NaOH input	1	1.63	(4,4,1,3,1,5,31)
	ε	Cathode, lithium-ion battery		electronics	component	No	CN	Cathode, lithium-ion battery, lithium manganese oxide, at plant	1.00E+00	kg				

The production of the cathode requires the mixture of the components (binder and solvent, $LiMn_2O_4$, black carbon) in a ball mill to a slurry [*14, 15*], followed by coating the collector (with soda lye pre-treated aluminium foil) with the slurry. The binder (modified styrene butadiene copolymer [*16*]) is water soluble and has the advantage that no organic solvent is needed. Thermal heat energy is used to heat up the slurry to130°C and to evaporate water and to dry the coated cathode in a dry channel (H_2O content < 20ppm) [*17*].

Table S14. Input-output table for the production of an anode.

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
Latex	ε	Anode, lithium-ion battery, graphite, at plant: Input				Binder, (Styrene-butadiene)	chemicals	organics	No	RER	latex, at plant	1.85E-02	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Water	ε					Solvent for the binder	water supply	production	No	CH	water, deionised, at plant	4.24E-01	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Graphite	ε					Active material	chemicals	inorganics	No	CN	graphite, battery grade, at plant	4.94E-01	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
Carbon black	ε					Conductive carbon	chemicals	inorganics	No	GLO	carbon black, at plant	1.59E-02	kg	advanced battery materials	1	1.33	(2,4,1,3,3,5,4)
copper	ε					Copper for the collector	metals	extraction	No	RER	copper, at regional storage	5.24E-01	kg	Measurement M. Gauch, Kokam cell	1	1.16	(1,4,1,3,1,4,4)
Copper foil	ε					Sheet in the range of 0.2 to 6 mm	metals	processing	No	RER	sheet rolling, copper	5.24E-01	kg	Measurement M. Gauch, Kokam cell	1	1.16	(1,4,1,3,1,4,4)
Sulfuric acid	ε					Sulfuric acid, equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil	chemicals	inorganics	No	RER	sulphuric acid, liquid, at plant	8.08E-02	kg	equivalent amount of protons as in "cathode li-ion battery" OH- for treatment of alu foil	1	1.32	(4,4,1,3,1,5,4)
Sodium hydroxide	ε					NaOH from the process "Cathode, lithium-ion battery" to neutralise H2SO4						1.32E-01	kg	equivalent amount of OH- to neutralise H2SO4	1	2.11	(4,4,1,3,1,5,5)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
Electricity	ε					Mechanical drive for pumping slurry, coating, coiling, cutting	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					Evaporating water, heating active amterial, alu-foil, binder, solvent, black carbon	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	1.22E+00	MJ	calculated from specific heat of the base materials	1	1.32	(4,4,1,3,1,5,1)
Transport lorry	ε					According to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.13E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					According to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	4.70E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)

Anode, lithium-ion battery, graphite, at plant: Output	ε	coated copper to copper recycling	5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils, copper to recycling						5.26E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.58	(5,4,1,3,1,5,6)
	ε	Waste water	Assumption:NaOH is neutralized with H2SO4, only 50% disposed, the other 50% is disposed in the dataset Cathode, lithoim-iom battery"	waste management	wastewater treatment	No	CH	treatment, sewage, to wastewater treatment, class 3	1.06E-04	m3	equal to the amount of NaOH input	1	1.84	(5,4,1,3,1,5,33)
	ε	Waste heat to air	Heat and electric power	air	unspecified			Heat, waste	7.20E-03	MJ	calculated from eletricity input	1	1.32	(4,4,1,3,1,5,13)
	ε	Waste water	Solvent water evaporated from the slurry	air	unspecified			Water	4.24E-01	kg	calculated from NaOH input	1	1.63	(4,4,1,3,1,5,31)
	ε	Anode, lithium-ion battery		electronics	component	No	CN	Anode, lithium-ion battery, graphite, at plant	1.00E+00	kg				

Basically the same process is applied for the production of the anode. Instead of $LiMn_2O_4$, graphite is used for the anode. The collector is a copper foil, pre-treated with sulphuric acid.

Table S15. Input-output table for the production of a separator.

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Polyethylene fleese	ε	Separator, lithium-ion battery, at plant: Input				foil, carrier for slurry	plastics	polymers	No	RER	fleece, polyethylene, at plant	3.51E-01	kg	Assumption: Polytehylene foil is 33% of total weight (3 layers with equal weight)	1	1.64	(5,4,2,3,3,5,4)
PVDF	ε					PVF is a proxy für PVDF	chemicals	organics	No	US	polyvinylfluoride, at plant	1.92E-01	kg	Hyung-Gon (2002)	1	1.33	(2,4,2,3,3,5,4)
Hexafluorethane	ε					C2F6 is a proxy for C3F6 (recommended by G. Wernet)	chemicals	organics	No	GLO	hexafluorethane, at plant	2.62E-02	kg	Hyung-Gon (2002)	1	1.33	(2,4,2,3,3,5,4)
Phthalic anhydride	ε					Phthalic anhydride is a proxy für dibutyl phthalate (recommended by G. Wernet)	chemicals	organics	No	RER	phthalic anhydride, at plant	2.91E-01	kg	Hyung-Gon (2002)	1	1.33	(2,4,2,3,3,5,4)
Silica	ε						construction materials	additives	No	DE	silica sand, at plant	2.18E-01	kg	Hyung-Gon (2002)	1	1.25	(2,4,2,3,1,5,4)
Acetone	ε					Solvent, internally recycled (Brodd 2002), Recycling rate: 99% (Expert guess H-J. Althaus)	chemicals	organics	No	RER	acetone, liquid, at plant	1.44E-02	kg	Hyung-Gon (2002)	1	1.25	(2,4,2,3,1,5,4)
Infrastructure, chemical plant	ε					Ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)
Electricity	ε					Mechanical drive for pumping slurry, coating, coiling, cutting	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε					evaporating solvent, heating seperator base materials	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	1.93E-01	MJ	Assumption: Specific heat of the Seperator is equals to specific heat the anode in the dataset "Anode, lithium-ion battery"	1	1.33	(4,4,2,3,1,5,1)
Transport lorry	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	9.84E-02	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε					according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	5.25E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)

Separator, lithium-ion battery, at plant: Output	ε	Disposal coated cathode	5% loss, according to ecoinvent assumption for missing information, included waste from slitting the coils	waste management	municipal incineration	No	CH	disposal, residues, shredder fraction from manual dismantling, in MSWI	5.39E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.64	(5,4,2,3,3,5,6)
	ε	Acetone	evaporating solvent	air	unspecified			Acetone	1.44E-02	kg	equal the amount aceton input	1	1.63	(4,4,2,3,1,5,16)
	ε	Waste heat to air	Heat and electric power	air	unspecified			Heat, waste	7.20E-03	MJ	calculated from eletricity input	1	1.33	(4,4,2,3,1,5,13)
	ε	Seperator, lithium-ion battery		electronics	component	No	CN	separator, lithium-ion battery, at plant	1.00E+00	kg				

A porous polyethylene film is coated with a slurry consisting of a copolymer (polyvinylidedfluoride and hexafluorpropylene), dibutyl phthalate and silica dissolved in acetone [*18*]. Thermal heat energy is used to heat up the slurry to 130°C and to evaporate acetone and to dry the coated cathode in a dry channel (H_2O content < 20ppm) [*17*].

Table S16. Input-output table for the production of a single cell.

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Category	Sub category	Infrastructure	Location	Modul name in ecoinvent	Mean value	Unit	Source mean value	Type	StDv 95%	General Comment
Cathode	ε	single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant: Input				Based on LiMn2O4	electronics	component	No	CN	Cathode, lithium-ion battery, lithium manganese oxide, at plant	3.27E-01	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,3)
Anode	ε					Based on graphite	electronics	component	No	CN	Anode, lithium-ion battery, graphite, at plant	4.01E-01	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,3)
Separator	ε					coated polethylene film	electronics	component	No	CN	separator, lithium-ion battery, at plant	5.37E-02	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,3)
Electrolyt: Solvent	ε					Ethylencarbonate	chemicals	organics	No	CN	ethylene carbonate, at plant	1.60E-01	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,3)
Electrolyt: Salt	ε					1 molar solution of LiPF6 in EC	chemicals	inorganics	No	CN	lithium hexafluorophosphate, at plant	1.90E-02	kg	calculated	1	1.24	(2,4,1,3,1,5,3)
Aluminium electrode tab	ε					Electrode, current collector, aluminium	metals	extraction	No	RER	aluminium, production mix, wrought alloy, at plant	1.65E-02	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,12)
Aluminium sheet rolling	ε					thickness of the Alu-tab: 1 mm	metals	processing	No	RER	sheet rolling, aluminium	1.65E-02	kg	Measurement M. Gauch, Kokam cell	1	3.06	(2,4,1,3,1,5,9)
Inert atmosphere	ε					Nitrogen	chemicals	inorganics	No	RER	nitrogen, liquid, at plant	1.00E-02	kg	Assumption: R. Widmer, M. Gauch	1	1.32	(4,4,1,3,1,5,4)
Package	ε					Assumption: Polyethylen envelope	plastics	polymers	No	RER	polyethylene, LDPE, granulate, at plant	7.33E-02	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,4)
Package	ε					Polyethylen envelope production	plastics	processing	No	RER	extrusion, plastic film	7.33E-02	kg	Measurement M. Gauch, Kokam cell	1	1.24	(2,4,1,3,1,5,4)
Infrastructure, chemical plant	ε					ecoinvent standard dataset	chemicals	organics	Yes	RER	chemical plant, organics	4.00E-10	unit	ecoinvent standard dataset	1	3.36	(5,5,2,3,3,5,9)

Electricity	ε				Calendaring anode, seperator, cathode	electricity	supply mix	No	CN	electricity, medium voltage, at grid	2.00E-03	kWh	Estimation by M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Electricity	ε				charge of the single cell, 70% (of 0.148 kWh)	electricity	supply mix	No	CN	electricity, medium voltage, at grid	1.04E-01	kWh	Estimation by M. Gauch, R. Widmer	1	1.48	(4,5,3,5,3,5,2)
Process heat	ε				Heating anode, cathode and seperator,	natural gas	heating systems	No	RER	heat, natural gas, at industrial furnace >100kW	6.52E-02	MJ	calculated from specific heat of the base materials based on the specific heat of the components	1	1.32	(4,4,1,3,1,5,1)
Transport lorry	ε				according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	road	No	RER	transport, lorry >16t, fleet average	2.78E-02	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
Transport train	ε				according to ecoinvent standars transport distance for inorganic chemicals and metals (Europe)	transport systems	train	No	RER	transport, freight, rail	1.67E-01	tkm	ecoinvent standard distances	1	3.20	(5,5,5,2,5,5,5)
		battery, lithium manganese oxide/graphite, at	ε	single cell	5% loss, according to ecoinvent assumption for missing information,	waste management	recycling	No	GLO	disposal, Li-ions batteries, mixed technology	5.25E-02	kg	5% loss, according to ecoinvent assumption for missing information	1	1.58	(5,4,1,3,1,5,6)
			ε	Waste heat to air	Heat and electric power	air	unspecified			Heat, waste	3.80E-01	MJ	calculated from eletricity input	1	1.32	(4,4,1,3,1,5,13)
			ε	singel cell, lithium ion battery		electronics	component	No	CN	single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant	1.00E+00	kg				

Cathode, separator and anode are calendared, slit to size, winded and packed in a polyethylene envelope. In an inert atmosphere, the $LiPF_6$ dissolved in the electrolyte is added to the electrode [*14*].

Table S17. Input-output table for the production of a battery pack.

General Flow information							Representation in ecoinvent								Uncertainty information		
Input	□	Process Name	□	Output		Remarks	Cate gory	Sub category	Infra struc ture	Loca tion	Modul name in ecoinvent	Mean value	Uni t	Source mean value	Typ e	StDv 95%	General Comment
Single cell	ε	battery, Lilo, rechargeable, prismatic, at plant: Input				weight per kg battery	electronics	component	No	CN	single cell, lithium-ion battery, lithium manganese oxide/graphite, at plant	7.99E-01	kg	Estimation M. Gauch, R. Widmer	1	1.16	(1,4,1,3,1,4,3)
Steelbox, material	ε					unalloyed steel	metals	extraction	No	RER	reinforcing steel, at plant	1.45E-01	kg	Estimation M. Gauch, R. Widmer	1	1.27	(2,4,1,3,3,4,12)
steelbox, production	ε					steel, sheet rolling	metals	processing	No	RER	sheet rolling, steel	1.45E-01	kg	Estimation M. Gauch, R. Widmer	1	1.27	(2,4,1,3,3,4,3)
Battery management system, mounting	ε					mounting	electronics	module	No	GLO	printed wiring board, surface mounted, unspec., solder mix, at plant	3.38E-03	kg	Estimation M. Gauch, R. Widmer	1	1.16	(1,4,1,3,1,4,3)
Data cable	ε						electronics	component	No	GLO	cable, data cable in infrastructure, at plant	3.73E-01	m	Estimation M. Gauch, R. Widmer	1	1.19	(3,4,1,3,1,4,3)
3 phase cable	ε						electronics	component	No	GLO	cable, three-conductor cable, at plant	2.50E-02	m	Estimation M. Gauch, R. Widmer	1	1.19	(3,4,1,3,1,4,3)
Testing/activating	ε					Electricity	electricity	production mix	No	UCTE	electricity, low voltage, production UCTE, at grid	1.08E-01	kWh	Estimation M. Gauch, R. Widmer, 1 batter charge	1	1.48	(4,5,3,5,3,5,2)
metal working factory	ε					ecoinvent standard dataset	metals	general manufacturing	Yes	RER	metal working factory	4.58E-10	unit	reference unit of metal working factory according to Ecoinvent (Report 23)	1	3.36	(5,5,2,3,3,5,9)
Transport ship	ε					Assumption: single cell imported from China, battery pack produced in Europe	transport systems	ship	No	OCE	transport, transoceanic freight ship	7.81E+00	tkm	ecoinvent standard distances	1	2.12	(3,4,1,2,3,5,5)
Transport lorry	ε					Assumption: single cell imported from China, battery pack produced in Europe	transport systems	road	No	RER	transport, lorry >16t, fleet average	1.02E+00	tkm	ecoinvent standard distances	1	2.12	(3,4,1,2,3,5,5)
		battery, Lilo, rechargeable, prismatic, at plant: Output	ε	Waste heat to air		Electric power	air	unspecified			Heat, waste	3.87E-01	MJ	calculated from eletricity input	1	1.60	(4,4,1,2,4,4,13)
			ε	Lithium-ion battery 2009			electronics	module	No	GLO	battery, Lilo, rechargeable, prismatic, at plant	1.00E+00	kg				

Finally, single cells, the battery management system and cables are assembled in a steel box.

The production of concentrated lithium brine and Li_2CO_3 takes place in Chile. Therefore, we used an electricity mix from Brasil as a proxy for an electricity mix from Chile. For all other datasets, except assembly of the battery, we assumed the production in China. Thus, a Chinese electricity mix was utilized for these datasets. Cell assembly is expected to be accomplished in Europe, using therefore a European electricity mix [*19*].

Transport distances for the production of Li_2CO_3 are calculated with provided data from SEIA-CONAMA [*4*]. For all datasets produced in China, we hypothesise equal average transport distances for China as for Europe. Thus, European standard transport distances are balanced as recommended by ecoinvent [*1*]. All single components are transported by ship and road to Europe for the cell assembly.

Infrastructure is incorporated by accounting a chemical plant [*20*] or a metal working factory [*21*] for most datasets (for detailed information see supporting information).

Table S18. Material composition and weight of the components in kg of the internal combustion engine car (ICEV) and the battery powered electric car (BEV).

Material composition	Glider	ICEV drive train	Total ICE-V	Glider	BEV drive train	Battery	Total EV
Steel and iron	519.0	114.6	633.6	519.0	39.0	0.0	558.0
Synthetics	127.0	41.0	168.0	127.0	2.0	0.0	129.0
Fuel/oil/lubricants	6.0	58.0	64.0	6.0	0.0	0.0	6.0
Light metals	3.0	48.7	51.7	3.0	32.7	0.0	35.7
Tyres and rubber	41.0	3.0	44.0	41.0	0.0	0.0	41.0
Glass	30.0	0.0	30.0	30.0	0.0	0.0	30.0
Electric motors, cables	24.0	1.0	25.0	24.0	6.0	0.0	30.0
Base metals	2.0	17.0	19.0	2.0	19.0	0.0	21.0
Insulation	16.0	0.0	16.0	16.0	0.0	0.0	16.0
Paints	4.2	0.0	4.2	4.2	0.0	0.0	4.2
Others	2.0	0.0	2.0	2.0	0.0	300.0	302.0
Total	774.2	283.3	1057.5	774.2	98.7	300.0	1172.9

Table S19. Environmental burden assessed with 4 different impact assessment methods for E-mobility and mobility with an ICEV.

	EI 99 H/A points		CED 10^3 MJ eq.		GWP 10^3 kg CO_2 eq.		ADP kg Sb eq.	
	BEV	**ICEV**	**BEV**	**ICEV**	**BEV**	**ICEV**	**BEV**	**ICEV**
Total	1570	2530	480	593	24.3	37.7	190	261
Road	134	134	31.7	31.7	1.08	1.08	13.7	13.7
Glider	270	270	66.5	66.5	3.74	3.74	30.4	30.4
Drive-train	120	127	21.9	27.8	1.35	1.46	9.68	12.2
Maintenance, disposal car	81.5	84.4	23.7	24.0	1.14	1.17	9.80	10.1
Li-ion battery	240	0	31.2	0	1.80	0	14.6	0
Operation	720	1920	305	443	15.2	30.2	112	194

Table S19. Environmental burden assessed with Ecoindicator 99 H/A (EI 99 H/A, unit: points), non renewable cumulated energy demand (CED, unit: MJ equivalents (MJ-eq.)), global warming potential (GWP, unit: kg carbon dioxide equivalents (kg CO_2 eq.)) and abiotic depletion potential (ADP, unit: kg antimony equivalents (kg Sb eq.)).

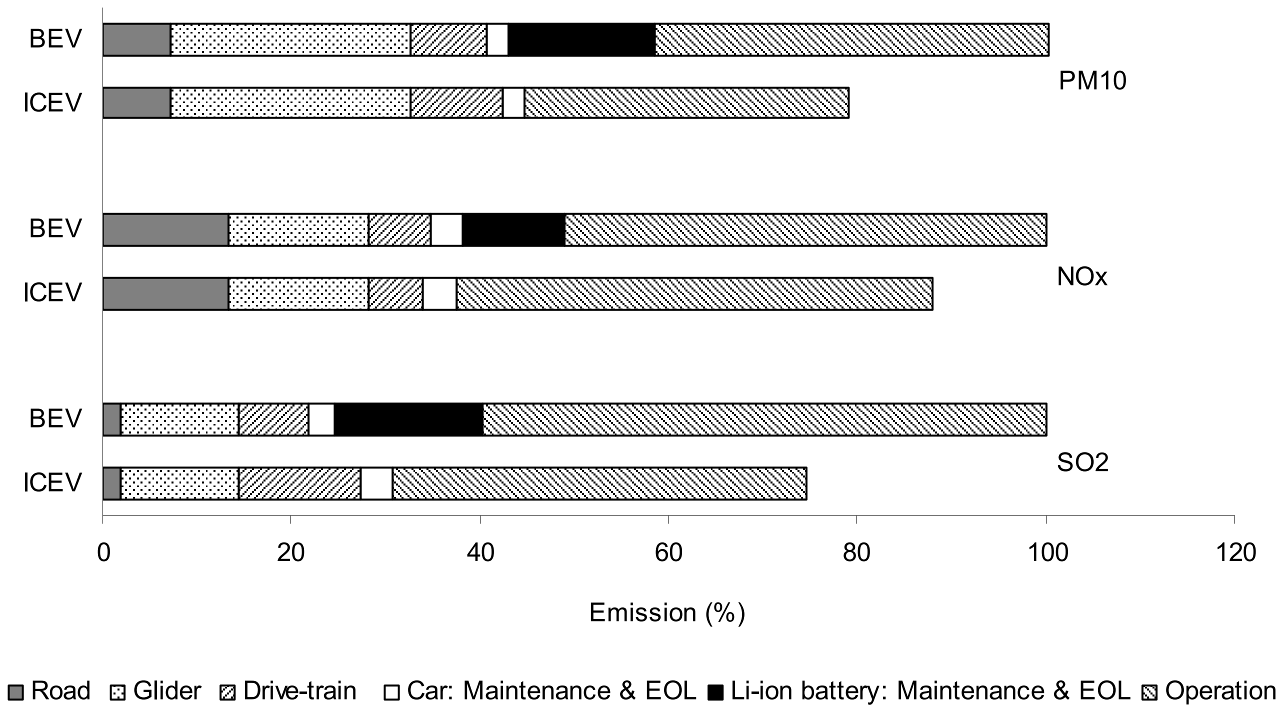


Figure S1. Shares of life cycle inventory results for sulfur dioxide (SO_2), nitrogen oxides (NO_x) and cumulative particulates (PM_{10}) caused by battery powered electric car (BEV; the BEV is set as 100%) and an internal combustion engine car (ICEV, value in % of the BEV). Road includes construction, maintenance and end of life treatment (EOL). All absolute values of the components are provided in the supporting information.

Table S20. Sulphur dioxide (SO_2), nitrogen oxides (NO_x) and cumulative particulates (PM_{10}) for E-mobility and mobility with an ICEV.

	Mobility with a BEV						**Mobility with an ICEV**					
	SO_2		NO_x		PM_{10}		SO_2		NO_x		PM_{10}	
	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%
Total E-mobility	83.7	100	49.5	100	16.2	100	62.5	74.7	43.5	87.9	12.8	79.0
Road	1.55	1.85	6.63	13.4	1.15	7.13	1.55	1.85	6.63	13.4	1.15	7.13
Glider	10.5	12.5	7.36	14.9	4.12	25.5	10.5	12.5	7.36	14.9	4.12	25.5
Drive-train	6.21	7.42	3.20	6.47	1.31	8.10	10.8	13.0	2.76	5.59	1.58	9.80
Maintenance, disposal car	2.41	2.88	1.69	3.41	0.364	2.25	2.92	3.48	1.80	3.64	0.384	2.38
Li-ion battery	13.1	15.7	5.33	10.8	2.51	15.5	0	0	0	0	0	0
Operation	49.9	59.7	25.3	51.1	6.75	41.8	36.7	43.9	25.0	50.4	5.53	34.2

Table S20. Inventory data of emission values for sulphur dioxide (SO2), nitrogen oxides (NOx) and cumulative particulates (PM10). The values for the life cycle battery powered electric vehicle (BEV) and mobility with an internal combustion engine vehicle (ICEV) refer to a covered distance of 150`000 km. The total emissions of the BEV are set as baseline (100%).

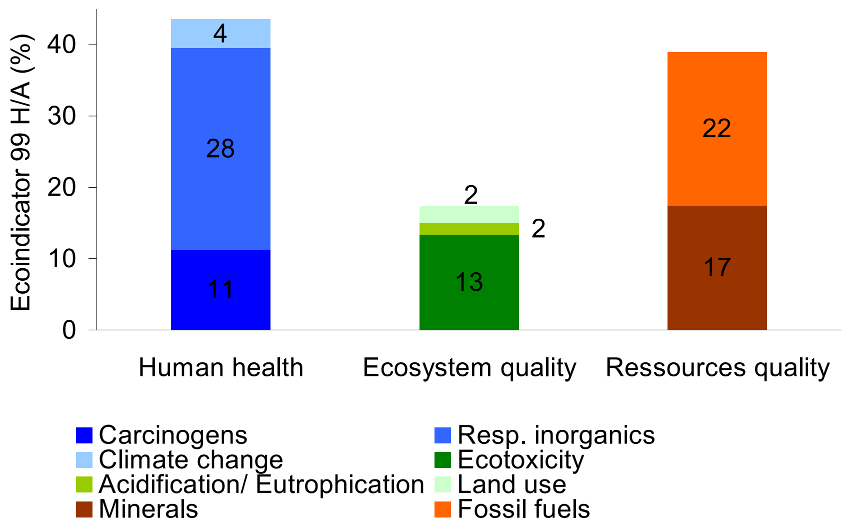


Figure S2. Life cycle impact assessment results for the Li-ion battery evaluated with the Ecoindicator 99 H/A. The score is split into the 3 damage categories Human Health, Ecosystem Quality and Ressource Quality and their subcategories.

Table S21. Absolute and relative values of environmental burden assessed with 4 different impact assessment methods for the production of 1 kg Li-ion battery.

	EI 99 H/A		CED		GWP		ADP	
	points	%	MJ eq.	%	kg CO_2 eq.	%	kg Sb eq.	%
Total Li-ion battery	0.801	100	104	100	6.00	100	0.0485	100
Battery pack	0.162	20.3	27.6	26.5	1.61	26.8	0.0126	25.9
Printed wiring board	0.0630	7.86	13.7	13.1	0.853	14.3	0.00617	12.7
Reinforcing steel	0.0150	1.88	3.31	3.18	0.212	3.53	0.00185	3.81
Three conductor cable	0.0312	3.89	2.06	1.97	0.083	1.39	0.000880	1.81
Single cell	0.638	79.7	76.5	73.5	4.39	73.2	0.0359	74.1
Anode	0.403	50.3	19.6	18.8	0.870	14.5	0.0113	23.4
Copper	0.346	43.2	5.24	5.03	0.339	5.65	0.00259	5.33
Graphite	0.0296	3.70	10.6	10.2	0.345	5.75	0.00709	14.6
Rest anode	0.0273	3.41	3.81	3.66	0.187	3.11	0.00165	3.41
Separator	0.0170	2.12	4.69	4.51	0.257	4.29	0.00208	4.28
Cathode	0.131	16.4	31.4	30.1	2.17	36.2	0.0135	27.8
Aluminium	0.082	10.3	16.8	16.1	1.28	21.3	0.00734	15.1
$LiMn_2O_4$	0.0448	5.59	13.0	12.5	0.831	13.8	0.00552	11.4
Rest cathode	0.00425	0.531	1.59	1.52	0.0635	1.06	0.000633	1.31
Ethylene carbonate	0.0176	2.20	5.03	4.83	0.185	3.09	0.00220	4.54
$LiPF_6$	0.0304	3.79	6.05	5.81	0.389	6.47	0.00248	5.11
LiF	0.00203	0.254	0.350	0.336	0.0257	0.428	0.000160	0.329
PCl_5	0.00499	0.624	1.78	1.71	0.0851	1.42	0.000725	1.49
Mn_2O_3	0.0162	2.03	5.41	5.20	0.364	6.06	0.00212	4.37
Li_2CO_3	0.0103	1.29	1.84	1.77	0.135	2.25	0.000904	1.86
Conc. Lithium brine	0.00072	0.0900	0.00653	0.109	0.06653	0.109	0.0000438	0.109

Table S21. Environmental burden assessed with Ecoindicator 99 H/A (EI 99 H/A, unit: points), non renewable cumulated energy demand (CED, unit: MJ equivalents (MJ-eq.)), global warming potential (GWP, unit: kg carbon dioxide equivalents (kg CO_2 eq.)) and abiotic depletion potential (ADP, unit: kg antimony equivalents (kg Sb eq.)).

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