ÜBERBLICK ÜBER NEU ERSTELLTE LCA-DATENSÄTZE

ARBEITSDOKUMENT

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1 DATENSÄTZE

1.1 STROMSPEICHER

1.1.1 electricity production, adiabatic compressed air energy storage - DE

according to Bouman, Evert A.; Øberg, Martha M.; Hertwich, Edgar G. (2016): Environmental impacts of balancing offshore wind power with compressed air energy storage (CAES). In: Energy 95, S. 91–98. DOI: 10.1016/j.energy.2015.11.041.

capacity: 150 MW

storage capacity: 19.2 MWh

annual production: 1150 GWh

lifetime ACAES: 100 a

1.1.2 electricity production, compressed air energy storage system - DE

according to Bouman, Evert A.; Øberg, Martha M.; Hertwich, Edgar G. (2016): Environmental impacts of balancing offshore wind power with compressed air energy storage (CAES). In: Energy 95, S. 91–98. DOI: 10.1016/j.energy.2015.11.041.

Bouman et al. do not provide detailed data on emissions of gas turbine. Therefore emissions are modelled according to the ecoinvent process "electricity production, natural gas, combined cycle power plant [DE]" scaled upon the input of natural gas.

capacity: 200 MW

storage capacity: 19.2 MWh

annual production: 1473 GWh

lifetime CAES: 100 a

1.1.3 electricity production, hydro, pumped storage, 1400MW - DE

This dataset represents the production of 1 kWh of electricity in a pumped storage power plant unit in Germany in 2016. The calculation of this dataset is based on data of a specific pumped storage hydro power plant unit in Germany with an annual gross production output of 2.6 TWh and an installed capacity of 1400 MW. Lifetime is assumed to be 80 years. The data refers to planning data.

From water pumped up from a lower to an upper reservoir. The activity ends with 1 kWh of high voltage electricity produced at the power plant and arrived at the busbar.

Source: Primary data from a German electricity supplier.

Modified published in:

Immendoerfer, A., Tietze, I., Hottenroth, H., Viere, T. (2017): Life-cycle impacts of pumped hydropower storage and battery storage. International Journal of Energy and Environmental Engineering. doi:10.1007/s40095-017-0237-5.

Tietze, I., Immendoerfer, A., Viere, T., Hottenroth, H. (2016): Comparing pumped hydropower storage and battery storage - Applicability and impacts. Euro-Asian Journal of sustainable energy development policy 5: 15–29.

1.1.4 hydropower plant construction, pumped storage, non-alpine regions, 1400MW - DE

This dataset represents a specific pumped storage hydro power plant unit for non-alpine regions in Germany with a capacity of 13.4 GWh and a power rating of 1400 MW. This dataset is mainly based on data for a specific plant in Germany (concrete, steel, copper). Missing data (diesel, electricity, emissions) are scaled according to the concrete demand of the dataset of hydropower plant construction, reservoir, non-alpine regions, RER.

Lifetime is assumed to be 80 years.

Source: Primary data from a German electricity supplier.

Modified published in:

Immendoerfer, A., Tietze, I., Hottenroth, H., Viere, T. (2017): Life-cycle impacts of pumped hydropower storage and battery storage. International Journal of Energy and Environmental Engineering. doi:10.1007/s40095-017-0237-5.

Tietze, I., Immendoerfer, A., Viere, T., Hottenroth, H. (2016): Comparing pumped hydropower storage and battery storage - Applicability and impacts. Euro-Asian Journal of sustainable energy development policy 5: 15–29.

This activity ends with a pumped storage hydro power plant. The dataset includes particle emissions during the construction activities. Transformers, further infrastructure like outdoor substations, high-voltage lines, etc. are excluded. Due to the lack of information or insignificant amounts, the need for landfill capacity for the excavated materials of adits and the recycling potential of materials after expiration of the life time are not taken into account.

1.1.5 battery production, PbA, rechargeable – DE

according to: Spanos, Constantine, Turney, Damon E., Fthenakis, Vasilis (2015): Life-cycle analysis of flow-assisted nickel zinc-, manganese dioxide-, and valve-regulated lead-acid batteries designed for demand-charge reduction. Renewable and Sustainable Energy Reviews 43: 478–494. doi:10.1016/j.rser.2014.10.072.

This process includes the production and transport of 1 kg of a valve regulated lead acid battery (absorbed glass matt) with 27 Wh/kg (in 8 h discharge).

DC/DC round trip efficiency: 0.8

cycles to failure: 1200 (at a 8 h discharge rate and DoD of 100 %); 800 (at a 2 h discharge rate and DoD of 71.9 %)

1.2 ÜBERTRAGUNGSNETZKOMPONENTEN

1.2.1 transmission network, high voltage direct current aerial line - RER

This dataset describes a transmission network high voltage direct current subsea cable. It contains the production and the maintenance for 1 km of the subsea cable (450 kV, 2x790-mm² copper conductors, mass-impregnated paper insulation, and steel and lead sheeting) over 40 years. Different from the literature source recycling was modelled according to the cut-off approach.

Sources: Arvesen, A., Nes, R.N.; Huertas-Hernando, D, Hertwich, E.G. (2014): Life cycle assessment of an offshore grid interconnecting wind farms and customers across the North Sea. Int J Life Cycle Assess 19: 826-837

Jorge, R., Hawkins, T.R., Hertwich, E..G (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15

1.2.2 aerial line production, high voltage direct current aerial line – RER

This dataset describes the production of 1 km of an high voltage direct current arieal line (FeAl conductor at 250/350 kV) over the lifetime of 40 years.

Source: Jorge, R., Hawkins, T.R., Hertwich, E.G. (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. supplementary matierial p.11, table S9.

1.2.3 aerial line maintenance, high voltage direct current aerial line – RER

This dataset describes the maintenance of 1 km of an high voltage direct current arieal line (FeAl conductor at 250/350 kV) over the lifetime of 40 years.

Source: Jorge, R., Hawkins, T.R., Hertwich, E..G (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. supplementary matierial p.12, table S10.

1.2.4 treatment of used aerial line, high voltage direct current aerial line – RER

This dataset describes the end-of-life phase of 1 km of an high voltage direct current arieal line (FeAl conductor at 250/350 kV) over the lifetime of 40 years.

Different from the literature source recycling was modelled according to the cut-off approach.

Source: Jorge, R., Hawkins, T.R., Hertwich, E..G (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. supplementary matierial p.11, table S9.

1.2.5 transmission network, high voltage direct current land cable - RER

This dataset describes a transmission network high voltage direct current land cable. It contains the production, disposal and the maintenance for 1 km of the land cable (Cu conductor 400 kV) over 40 years.

Source: Jorge, R., Hawkins, T.R., Hertwich, E.G. (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15

Different from the literature source recycling was modelled according to the cut-off approach.

1.2.6 land cable production, high voltage direct current land cable – RER

This dataset describes the production of 1 km of an high voltage direct current land cable (Cu conductor 400 kV) over the lifetime of 40 years.

Source: Jorge, R., Hawkins, T.R., Hertwich, E.G. (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. supplementary matierial p.15, table S13.

1.2.7 land cable maintenance, high voltage direct current land cable – RER

This dataset describes the maintenance of 1 km of an high voltage direct current land cable (Cu conductor 400 kV) over the lifetime of 40 years.

Source: Jorge, R., Hawkins, T.R., Hertwich, E..G (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. supplementary matierial p.15, table S14.

1.2.8 treatment of used land cable, high voltage direct current land cable – RER

This dataset describes the end-of-life phase of 1 km of an high voltage direct current land cable (Cu conductor 400 kV) over the lifetime of 40 years.

Different from the literature source recycling was modelled according to the cut-off approach.

Source: Jorge, R., Hawkins, T.R., Hertwich, E.G. (2012): Life cycle assessment of electricity transmission and distribution - part 1: power lines and cables. Int J Life Cycle Assess 17: 9-15. p.15, table S13.

1.2.9 transmission network, high voltage direct current subsea cable - RER

This dataset describes 1 km of an high voltage direct current subsea cable transmission network (450 kV, 2x790-mm² copper conductors, mass-impregnated paper insulation, and steel and lead sheeting) over the lifetime of 40 years.

Source: A. Arvesen et al. (2014) LCA of an offshore grid interconnecting wind farms and customers across the north sea. Int J Life Cylce Assess 19:826-837. p.831, table 2.

1.2.10 subsea cable production, high voltage direct current – RER

This dataset describes the production of 1 km of an high voltage direct current land cable (450 kV, 2x790-mm² copper conductors, mass-impregnated paper insulation, and steel and lead sheeting) over the lifetime of 40 years.

Source: A. Arvesen et al. (2014) LCA of an offshore grid interconnecting wind farms and customers across the north sea. Int J Life Cylce Assess 19:826-837. p.831, table 2.

1.2.11 subsea cable maintenance, high voltage direct current – RER

This dataset describes the maintenance of 1 km of an high voltage direct current land cable (450 kV, 2x790-mm² copper conductors, mass-impregnated paper insulation, and steel and lead sheeting) over the lifetime of 40 years.

Source: Arvesen, A., Nes, R.N.; Huertas-Hernando, D, Hertwich, E.G. (2014): Life cycle assessment of an offshore grid interconnecting wind farms and customers across the North Sea. Int J Life Cycle Assess 19: 826-837. p.831, table 2 (export cables)

1.3 Transport – Fuel cell electric

1.3.1 transport, passenger, fuel cell electric passenger car (w/o H2 provider) - DE

Notice: project specific dataset; without provider process for hydrogen.

This dataset describes a journey of 1 person kilometer (pkm) with a fuel cell electric passenger car, mainly according to the current scenario of Cox (2018).

Occupancy rate according to infas (2018)

Dataset starts with transport per vehicle km and ends with transport per person km.

Soruces:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developmemts until 2050. Zurich.

infas Institut für angewandte Sozialwissenschaft GmbH (2018) Mobilität in Deutschland. Tabellarische Grundauswertung. p. 43

1.3.2 transport, passenger car, fuel cell electric (w/o H2 provider) – DE

Notice: project specific dataset; without provider process for hydrogen

This dataset describes a journey of one vehicle kilometer (vkm) with a fuel cell electric passenger car, mainly according to the current scenario of Cox (2018).

The dataset is parametrized with respect to mass of the vehicle, hydrogen consumption and lifetime of vehicle, battery and fuel cell stack.

Currently, default values for a compact sized car (1570 kg curb mass). A cargo mass of 100 kg is assumed.

The construction of the datasets allows to change key parameters (like mass of the vehicle, consumption, life times, etc.) in order to cover a wide spectrum of situations. However, it is important to consider that changing one parameter of a vehicle, e.g. its mass, may lead to changes in other parameters, e.g. the consumption. When modifying the default parameters given, attention should be payed to the possible influence which one parameter may have over the other.

The dataset takes as input the car, maintenance, non-exhaust emissions, road infrastructure and the amount of energy (based on the LHV of hydrogen) that is consumed for the journey. Over the lifetime of 180,000 vkm one replacement of fuel cell stack and battery is assumed according to Cox (2018).

Disposal of the whole vehicle is also included in the dataset.

Soruces:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. Doctoral Thesis: ETH Zurich (Diss. ETH No: 25081).

1.3.3 passenger car production, fuel cell electric - GLO

This dataset describes the production of a fuel cell electric passenger car, according to the current scenario of Cox (2018).

The dataset is parametrized with respect to mass of the vehicle. The construction of the dataset allows to change key parameters (like mass of the vehicle, mass of the battery, etc.) in order to cover a wide spectrum of situations. However, it is important to consider that changing one parameter of a vehicle, e.g. its mass, may lead to changes in other parameters, e.g. the consumption. When modifying the default parameters given, attention should be payed to the possible influence which one parameter may have over the other.

The vehicle is described in terms of a vehicle (94.2 kW) with a fuel cell system containing the hydrogen tank, fuel cell stack and the balance of plant. The lifetime of the fuel cell stack is 150,000 vkm. Replacement is modelled in the transport dataset. Currently, default values for a compact sized car with a weight of 1570 kg consisting of glider (1200 kg), Li-ion power battery (20.8 kg), and powertrain

(33 kg) is given. Additionally, a fuel cell system consisting of fuel cell stack, tank and balance of plant is used.

The disposal is accounted for in the single datasets unless the fuel cell system.

Sources:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developmemts until 2050. Zurich.

Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, Table S8 and S11

1.3.4 powertrain production, for fuel cell electric passenger car – 2017 - GLO

This dataset describes the electric drivetrain for an fuel cell electric passenger car according to Cox (2018, p. 168f.). The optimal system comprises an electric motor (20 kg), an inverter (9 kg), a power distribution unit (4 kg) and cables (3 m).

The data describing all the modules in this dataset (except cables) is based on direct information from the Swiss manufacturer Brusa. This dataset takes as input the manufactured modules in the electric drivetrain (motor, inverter, power distribution unit and cables) and assembles them together. The production efforts and materialzation for each module is provided in the respective dataset. The dataset brings the various components modularly together. The production efforts are described in each module.

Source: Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. Doctoral Thesis: ETH Zurich (Diss. ETH No: 25081).

1.3.5 disposal, fuel cell system - GLO

This dataset describes the disposal of a fuel cell system.

Source: Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material Table S11 and S10.

1.3.6 balance of plant production, for fuel cell passenger car - GLO

This dataset discribes the balance of plant production for a fuel cell system for the current scenario according to Simons et al. (2015). The input data is scaled to 1 kW and based on 2012 data.

The inputs are materials, material processing processes and transport. The output is on mass basis per kW.

Source: Simons, A.; Bauer, C. (2015): A life-cycle perspective on automotive fuel cells. In: Applied Energy 157, S. 884–896. Supplementary material, Table S7

1.3.7 fuel cell stack production, for fuel cell system - GLO

This dataset discribes the production of the fuel cell stack for a fuel cell system (P=80 kW) for the current scenario according to Miotti et al. (2017).

All masses are gross including a defined waste factor.

Source: Miotti et al. (2017) Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.8 bipolar plates production, for fuel cell stack

This dataset describes the production of the bipolar plates (A=13.1 m²active, m=60.020 kg (net)) of an 80 kW (nominal net power) fuel cell system for the current scenario according to Miotti et al. (2017). The inputs are materials, material processing processes and electricity. The output is one item of bipolar plates. All inputs are gross masses including the losses during production.

Source: Miotti et al. (2017) Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.9 gas diffusion layer production, for fuel cell stack - GLO

This dataset describes the production of the gas diffusion layer (A=8.5 m²active, m=3.229 kg (net)) of an 80 kW (nominal net power) fuel cell system for the current scenario according to Miotti et al. (2017).

The inputs are materials, material processing processes and electricity. The output is one item of gas diffusion layer.

All masses are gross including a defined waste factor.

Source: Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.10 membrane electrode assembly, for fuel cell stack - GLO

This dataset describes the assembly of the membrane electrode (A=13.1 m² active, m=3.427 kg) of an 80 kW (nominal net power) fuel cell system for the current scenario according to Miotti et al. 2017,

The inputs are materials, material processing processes and electricity. The output is one item of membrane electrode assembly.

All masses are gross including a defined waste factor.

Source: Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.11 membrane production, for fuel cell stack - GLO

This dataset describes the membrane production (A=13.1 m² active, m=0.756 kg (net)) of an 80 kW (nominal net power) fuel cell system for the current scenario according to Miotti et al. 2017.

The inputs are materials, material processing processes and electricity. The output is one item of membrane.

All masses are gross including a defined waste factor.

Source: Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.12 other and assembly, for fuel cell stack - GLO

This dataset describes other material use and the assembly (A=13.1 m²active, m=7.881 kg) of an 80 kW (nominal net power) fuel cell stack for the current scenario according to Miotti et al. 2017.

The inputs are materials, and material processing processes. The output is one item of other and assembly.

All masses are gross including a defined waste factor.

Source: Miotti et al. 2017, Integrated environmental and economic assessment of current and future fuel cell vehicles, Int J Life Cycle Assess 22 (1), p94–110, Supplementary material, table S11.

1.3.13 transport, passenger, bus, fuel cell electric (w/o H2 provider) – DE

Notice: project specific dataset; without provider process for hydrogen

Inventory refers to the entire transport life cycle of a fuel cell electric bus: production, operation and maintenance as well as disposal of vehicles; construction of road.

For the attribution of vehicle share to the transport performance a vehicle life time performance of 5.19E06 pkm/vehicle has been assumed. The value corresponds to 14.5 persons * 35759 km/a * 10a as mentioned in Mottschall & Bergmann (2013). Battery replacement (8 kWh) is assumed for every 150,000 km, fuel cell stack replacement twice according to Cox (2018).

Hydrogen demand (10.6 MJ/km) according to Cox (2018, p. 60). Non-exhaust emissions of particular matter for German conditions according to HBEFA v.4.1 for 2020.

Expenditures due to operation of the road infrastructure, as well as land use and maintenance have been adapted from regular bus (allocated based on the yearly vehicle kilometre performance).

Sources:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich

Mottschall, M., Bergmann, T. (2013): Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland; Arbeitspaket 4 des Projektes "Weiterentwicklung des Analyseinstrumentes Renewbility". Texte 96/2013.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

1.3.14 bus production, fuel cell electric – RER

The dataset represents the production of one fuel cell driven bus (material composition, energy consumption and emissions of the manufacturing). The disposal of bus is included too. Data set adapted from the ecoinvent production process "bus production, cut-off - RER".

The dataset starts with the material used for the production of the bus. The dataset ends with the production of one bus. The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and including the emissions to water. Vehicle disposal is as well included.

With the bus being produced as a single entity with no separate flows for a glider and the flows contributing to the engine manufacturing have been available. All input flows strictly related to the diesel bus and not relevant to the fuel cell electric model have been removed (diesel for engine testing, lead and sulfuric acid for battery, lubricating oil for diesel engine, propylene glycol). With limited access to detailed breakdown between truck assembly, engine manufacturing and manufacturing of metal parts, a parameter has been included to account for the engine manufacturing, a 50 % decrease is applied to input of cast iron, heat and electricity as well as all output components representing the share of engine testing and engine manufacturing.

Data related to fuel cell system, powertrain and Li-ion batteries set were added. Fuel cell, battery requirement and electric drive values according to Cox (2018) for bus.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.3.15 fuel cell system production, for bus/lorry - GLO

This dataset describes the production and disposal of the fuel cell system for a fuel cell bus/lorry (150 kW fuel cell) based on the fuel system for a passenger car.

Its inputs are balance of plant, carbon fiber tank (1480 kWh) and the fuel cell stack for one fuel cell system. For the balance of plant no scaling is assumed since it is not dependent on the power, tank is scaled by storage capacity and fuel cell stack is scaled by fuel cell power according to Cox (2018).

Source:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.3.16 transport, freight, lorry, average, fuel cell electric (w/o H2 provider) - DE

Notice: project specific dataset; without provider process for hydrogen

This dataset represents the service of 1 tkm freight transport in an average fuel cell electric driven lorry in Germany. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures.

Vehicle lifetime: 540,000 km; Battery replacement (53 kg) is assumed for every 150.000 km; hydrogen demand according to Cox (2018).

Load and infrastructure data taken from regular diesel driven lorry transport process in ecoinvent as follows:

The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report, share of lorry size class in Europe from ecoinvent v3.3 (transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified, cut-off, U - RER). These are as follows:

Lorry size class	Average load factor	GVW	share size class
3.5-7.5t	0.98t	4.98t	0.030
7.5-16t	3.29t	9.29t	0.061
16-32t	5.79t	15.79t	0.303
>32t	15.96t	29.96t	0.606
average	11.7t		

The lorry size and load factor determines the GVW and therefore also the non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear referring to the 16-32 t size class.

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometer performance referring to the 16-32 t size class lorry.

Sources:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

Spielmann, M., et al. (2007) Transport Services. ecoinvent report No. 14., Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

1.3.17 lorry production, 16 metric ton, fuel cell electric - RER

This dataset represents the production and disposal of one fuel cell electric driven lorry, 16 t.

Data set adapted from the ecoinvent production process "Lorry production, 16 metric ton, cut-off - RER".

The dataset starts with the material used for the production of the lorry. The dataset ends with the production of one lorry 16 t. The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and including the emissions to water. Vehicle disposal is as well included.

With the diesel lorry being produced as a single entity with no separate flows for a lorry glider and the flows contributing to the engine manufacturing have been available. All input flows strictly related to the diesel lorry and not relevant to the fuel cell electric model have been removed (diesel for engine testing, lead and sulfuric acid for battery, lubricating oil for diesel engine, propylene glycol). With limited access to detailed breakdown between truck assembly, engine manufacturing and manufacturing of metal parts, a parameter has been included to account for the engine manufacturing, a 50 % decrease is applied to input of cast iron, heat and electricity as well as all output components representing the share of engine testing and engine manufacturing.

Data related to fuel cell system, powertrain and Li-ion batteries set were added. Fuel cell, battery requirement and electric drive values according to Cox (2018) for bus.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.4 Transport – Battery electric

1.4.1 transport, passenger, electric passenger car - DE

This dataset describes a journey of 1 pkm with an electric passenger car assuming 1.5 passengers per vehicle.

1.4.2 transport, passenger car, electric – DE

This dataset describes a journey of 1 km with an electric passenger car. The dataset is parametrized with respect to mass of the vehicle, consumption and lifetimes of vehicle and battery. The amount of battery includes battery exchange due to maintenance. Currently, default values for a compact size car with a weight without battery of 1245 kg and a battery of 70 kWh are given. Assuming a life expectancy for the car of 180000 km and an average lifetime for the battery of 150000 km the remaining share is taken into account for the maintenance. The current nominal value of battery mass has been derived assuming an energy density of 200 Wh/kg. The energy demand corresponds to German conditions in 2020 according to HBEFA v.4.1. The construction of the datasets allows to change key parameters (like mass of the vehicle, mass of the battery, consumption, life times, etc.) in order to cover a wide spectrum of situations. However, it is important to consider that changing one parameter of a vehicle, e.g. its mass, may lead to changes in other parameters, e.g. the consumption. When modifying the default parameters given, attention should be payed to the possible influence which one parameter may have over the other. The dataset takes into account the car, the battery, the maintenance and the electric energy consumed for the journey. Both, the car and battery are considered as infrastructure even though they are expressed in kg. The datsets returns as by-products the non-exhaust emissions caused by brake, tyre and road wear.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. ETH Zurich.

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Stutzer B. et al. (2019): Handbook Emission Factors of Road Transport, HBEFA v4.1/1.11.2019

1.4.3 passenger car production, electric – 2017 - GLO

This dataset describes the production of an electric passenger car with battery. The entries are based on a per kg basis. The model is optimized for a vehicle of about 1593.5 kg including the battery. The power to mass ratio is defined by 60 W/kg (95.6 kW/vehicle). The vehicle is subdivided in modules, the glider (1200 kg), the battery (20 kWh) and the drivetrain (43.5 kg). Each module contains the specific materialization and production efforts and emissions. The specific end of life treatment of each module is covered in the respective dataset. The dataset includes the manual dismantling of the car at the end of its life and the waste fractions deriving from this process. The dataset takes as input the three modules (glider, battery and drivetrain) which build the vehicle. The production efforts, emissions and manufacturing infrastructure are in the respective modules. The dataset also includes the manual dismantling of the vehicle at the end of its lifetime. The activity ends with the assembly of the car and returns the waste fractions from the dismantling. Lifetime is assumed to be 180,000 km. Battery replacement is accounted for in the use phase.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.4.4 powertrain production, for electric passenger car – 2017 - DE

This dataset describes the production and disposal of an electric drivetrain for an electric passenger car according to Cox (2018, p. 168f.). The optimal system comprises an electric motor (20 kg), a converter (4.5 kg), an inverter (9 kg), a charger (6 kg), a power distribution unit (4 kg) and cables (3 m).

The data describing all the modules in this dataset (except cables) is based on direct information from the Swiss manufacturer Brusa. This dataset takes as input the manufactured modules in the electric drivetrain (motor, converter, inverter, charger, power distribution unit and cables) and assembles them together. The production efforts and materialization for each module is provided in the respective dataset. The dataset brings the various components modularly together. The production efforts are described in each module.

Source:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.4.5 transport, passenger, bus, battery electric – DE

Inventory refers to the entire transport life cycle of a battery electric bus: production, operation and maintenance as well as disposal of vehicles; construction of road.

For the attribution of vehicle share to the transport performance a vehicle life time performance of 5.19E06 pkm/vehicle has been assumed. The value corresponds to 14.5 persons * 35759 km/a * 10a as mentioned in Mottschall & Bergmann (2013). Battery replacement (233 kWh) is assumed for every 150,000 km according to Cox (2018).

Electricity consumption and non-exhaust emissions according to HBEFA v4.1 for LBus 2020.

Expenditures due to operation of the road infrastructure, as well as land use have been adapted from regular bus (allocated based on the yearly vehicle kilometre performance).

Sources:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Doctoral thesis. ETH Zuerich

Mottschall, M., Bergmann, T. (2013): Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland; Arbeitspaket 4 des Projektes "Weiterentwicklung des Analyseinstrumentes Renewbility". Texte 96/2013.

Notter, B. et al. (2019) Handbuch Emissionsfaktoren des Strassenverkehrs (Handbook Emission Factors for Road Traffic, HBEFA) v4.1/1.11.2019

1.4.6 Bus production, battery electric – RER

The dataset represents the production of one battery driven bus (material composition, energy consumption and emissions of the manufacturing). The disposal of bus is included too.

Data set adapted from the ecoinvent bus production process "Bus production, cut-off - RER".

The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and until and including the emissions to water, as well as the vehicle disposal.

With the bus being produced as a single entity with no separate flows for a glider and the flows contributing to the engine manufacturing have been available. All input flows strictly related to the diesel bus and not relevant to the electric model have been removed (diesel for engine testing, lead and sulfuric acid for battery, and lubricating oil for diesel engine).

A 50 % decrease is applied to input of cast iron, heat and electricity as well as all output components representing the share of engine testing.

Data related to power train and Li-ion batteries set were added. Battery requirement and electric drive values according to Cox (2018) for bus.

Source:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

1.4.7 transport, freight, lorry, average, battery electric - DE

This dataset represents the service of 1 tkm freight transport in an average electric battery driven lorry. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures. Electricity consumption are for average German journeys according to HBEFA v4.1.

Vehicle lifetime: 540,000 km. Battery replacement is assumed for every 150.000 km according to Cox (2018).

Load and infrastructure data taken from regular diesel driven lorry transport process in ecoinvent as follows:

The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report, share of lorry size class in Europe from ecoinvent v3.3 (transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified, cut-off, U - RER). These are as follows:

Lorry size class	Average load factor	GVW	share size class
3.5-7.5t	0.98t	4.98t	0.030
7.5-16t	3.29t	9.29t	0.061
16-32t	5.79t	15.79t	0.303
>32t	15.96t	29.96t	0.606
average	11.7t		

The lorry size and load factor determines the GVW and therefore also the non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear referring to the 16-32 t size class.

Non-exhaust emissions are accounted for as weight dependent by-products and exist as separate datasets.

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance referring to the 16-32 t size class lorry.

Sources:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

Notter, B. et al. (2019) Handbuch Emissionsfaktoren des Strassenverkehrs (Handbook Emission Factors for Road Traffic, HBEFA) v4.1/1.11.2019

Spielmann, M., et al. (2007) Transport Services. ecoinvent report No. 14., Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

1.4.8 lorry production, 16 metric ton, battery electric - RER

This dataset represents the production of one battery electric driven lorry, 16 t.

Data set adapted from the ecoinvent production process "Lorry production, 16 metric ton, cutt-off - RER".

The dataset starts with the material used for the production of the lorry. The dataset ends with the production of one lorry 16 t. The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and including the emissions to water. Vehicle disposal is as well included.

With the diesel lorry being produced as a single entity with no separate flows for a lorry glider and the flows contributing to the engine manufacturing have been available. All input flows strictly related to the diesel bus and not relevant to the fuel cell electric model have been removed (diesel for engine testing, lead and sulfuric acid for battery, lubricating oil for diesel engine, propylene glycol). With limited access to detailed breakdown between truck assembly, engine manufacturing and manufacturing of metal parts, a parameter has been included to account for the engine manufacturing, a 50 % decrease is applied to input of cast iron, heat and electricity as well as all output components representing the share of engine testing and engine manufacturing.

Data related to powertrain and Li-ion batteries set were added. Battery requirement and electric drive values according to Cox (2018) for bus.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developmemts until 2050. Zurich

1.4.9 powertrain production, for electric lorry - GLO

This dataset describes production and disposal of the electric drivetrain for an electric lorry adapted from an electric passenger car according to Cox (2018, p. 168f.). The optimal system comprises a converter (4.5 kg), an inverter (9 kg), a charger (6 kg), a power distribution unit (4 kg). The electric motor was scaled according to the power (0.5 kg/kW), and cables were scaled (3 m times 3).

The data describing all the modules in this dataset (except cables) is based on direct information from the Swiss manufacturer Brusa. This dataset takes as input the manufactured modules in the electric drivetrain (motor, converter, inverter, charger, power distribution unit and cables) and assembles them together. The production efforts and materialization for each module is provided in the respective dataset. The dataset brings the various components modularly together. The production efforts are described in each module.

Source:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

1.5 Transport – Plug-in hybrid

1.5.1 Transport, passenger, plug-in hybrid (petrol) passenger car - DE

Occupancy rate (1.5 persons per vehicle) according to infas (2018)

Soruce: infas Institut für angewandte Sozialwissenschaft GmbH (2018) Mobilität in Deutschland. Tabellarische Grundauswertung. p. 43

1.5.2 transport, passenger car, plug-in hybrid (petrol) - DE

This dataset was adopted from transport, passenger car, medium size, petrol, EURO 5 - RER.

This dataset represents the service of transport in a plug-in hybrid (petrol/electric) passenger car for a journey length of 1vkm and is valid for Germany. Fuel consumption and emissions are for average vehicle use and not representative of a specific driving cycle. The dataset is parametrized with respect to vehicle size, fuel consumption and vehicle lifetime.

This dataset considers an average plug-in hybrid petrol passenger car of Euro 6d class.

Non-exhaust emissions are those resulting from tyre, brake and road wear. These emissions are considered as by-products.

From combustion of fuel in the engine.

The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport over 1vkm and the emissions of exhaust and non-exhaust emissions into air, water and soil.

The dataset includes the construction, operation, maintenance and disposal of the vehicle and road infrastructure. Operation of the vehicle includes all the direct emissions produced by fuel combustion and evaporation as well as from tyre, brake and road wear.

The dataset doesn't specifically model cold start emissions. These are assumed to be included in the data for average driving which was used. Fuel and electricity consumption, exhaust and evaporation emissions according to HBEFA v4.1.

Vehicle lifetime was assumed to be 180000 km. Battery replacement (20 kWh) is assumed for every 150,000 km according to Cox (2018).

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Doctoral thesis. ETH Zuerich

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Stutzer B. et al. (2019): Handbook Emission Factors of Road Transport, HBEFA v4.1/1.11.2019

1.5.3 passenger car production, plug-in hybrid – RER

This dataset describes the production of a plug-in hybrid (petrol) passenger car of compact size. The entries are based on a per kg basis. The model is optimized for a vehicle of about 1470 kg. It is subdivided in several modules, glider (1200 kg), electric drivetrain (45 kg), engine (60 kg) and the battery (20 kWh). Weights according to Cox (2018).

Each module contains the specific materialization and production efforts and emissions. The specific end of life treatment of each module is covered in the respective dataset. The treatment of the used passenger car only includes the manual dismantling of the car in the various modules. The production efforts, emissions and manufacturing infrastructure are in the respective modules. The activity ends with the assembly of the car and the dismantling of the vehicle at the end of its life. Lifetime is assumed to be 180,000 km. Battery replacement is accounted for in the use phase.

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. ETH Zurich.

1.5.4 transport, passenger, bus, plug-in hybrid - DE

Inventory refers to the entire transport life cycle of a plug-in hybrid (electric/diesel) bus: production, operation and maintenance as well as disposal of vehicles; construction of road.

For the attribution of vehicle share to the transport performance a vehicle life time performance of 5.19E06 pkm/vehicle has been assumed. The value corresponds to 14.5 persons * 35759 km/a * 10a as mentioned in Mottschall & Bergmann (2013). Battery replacement (15 kWh) is assumed for every 150,000 km according to Cox (2018).

Expenditures due to operation of the road infrastructure, as well as land use have been adapted from regular bus (allocated based on the yearly vehicle kilometre performance).

Tank to wheel energy demand is given with 2.28 kWh/km in all electric drive and 0.392 kg/km in all combustion drive according to HBEFA v.4.1 for battery electric and internal combustion engine bus, respectively. The utility factor is 0.67 (Cox 2018, adapted from PHEV). Exhaust emissions and carbon dioxide emissions are for average German journeys for full battery electric and diesel bus, respectively according to HBEFA v4.1. The utility factor has been applied. Other emissions taken from regular bus dataset and scaled with diesel demand.

Exhaust emissions are taken from v4.1 of the HBEFA model, using the data for Germany and without applying model weighting. Expenditures due to operation of the road infrastructure, as well as land use have been adapted from regular bus (allocated based on the yearly vehicle kilometre performance).

Sources:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

Mottschall, M., Bergmann, T. (2013): Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland; Arbeitspaket 4 des Projektes "Weiterentwicklung des Analyseinstrumentes Renewbility". Texte 96/2013.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

1.5.5 Bus production, plug-in hybrid – RER

The dataset represents the production of one plug-in hybrid (electric/diesel) bus (material composition, energy consumption and emissions of the manufacturing). The disposal of bus is included too.

Data set adapted from the ecoinvent bus production process "Bus production, cut-off - RER".

The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and the emissions to water, as well as the vehicle disposal.

Input flows for lead-acid battery have been removed (lead and sulfuric acid), cast iron and lubricating oil for diesel engine have been reduced by 25 % due to downsizing of diesel engine (Öko-Institut e.V., DLR-Instiut für Verkehrsforschung, 2009).

Data related to power train (150 kW) and Li-ion batteries set (15 kWh) were added. Battery requirement and mass of electric drivetrain components according to Cox (2018).

Source:

Cox, B. (2018): Mobility and the energy transition: A life cycle assessment of swiss passenger transport technologies including developments until 2050. Zurich.

Öko-Institut e.V., DLR-Instiut für Verkehrsforschung (2009): RENEWBILITY "Stoffstromanalyse nachhaltige Mobilität im Kontext erneuerbarer Energien bis 2030"; Endbericht an das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Berlin, p. 161.

1.5.6 transport, freight, lorry, plug-in hybrid - DE

This dataset represents the service of 1 tkm freight transport in an average plug-in hybrid (diesel/battery electric) lorry. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures. Electricity and diesel consumption are for average German journeys for full battery electric and diesel lorry, respectively according to HBEFA v4.1.

Vehicle lifetime: 540,000 km. Battery replacement is assumed for every 150.000 km; utility factor: 0.67. Parameters according to Cox (2018).

Load and infrastructure data taken from regular diesel driven lorry transport process in ecoinvent as follows:

The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report, share of lorry size class in Europe from ecoinvent v3.3 (transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified, cut-off, U - RER). These are as follows:

Lorry size class	Average load factor	GVW	share size class
3.5-7.5t	0.98t	4.98t	0.030
7.5-16t	3.29t	9.29t	0.061
16-32t	5.79t	15.79t	0.303
>32t	15.96t	29.96t	0.606
average	11.7t		

The lorry size and load factor determines the GVW and therefore also the non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear referring to the 16-32 t size class.

Non-exhaust emissions are accounted for as weight dependent by-products and exist as separate datasets.

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance referring to the 16-32 t size class lorry.

Exhaust emissions are taken from v4.1 of the HBEFA model scaled with utility factor, using the data for Germany and without applying model weighting. The exhaust emissions caused by the burning of fuel are either fuel dependent (fuel type and quantity) or Euro class dependent. The latter reflect the emission regulations to which the vehicle complies. Regulated emissions are CO, NOx, particulate matter (PM) and total hydrocarbons (HC).

Sources:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

1.5.7 lorry production, 16 metric ton, plug-in hybrid - DE

This dataset represents the production of one plug-in hybrid driven lorry, 16 t. The disposal of lorry is included too. Data set adapted from the ecoinvent dataset "lorry production, 16 metric ton, RER, cut-off". The dataset starts with the material used for the production of the lorry. The dataset ends with the production of one lorry 16 t. The dataset includes the material used for the production, the energy consumption of the building machines, the water consumption, the airborne emissions and until and including the emissions to water. Vehicle disposal is as well included.

Input flows for lead-acid battery have been removed (lead and sulfuric acid), cast iron and lubricating oil for diesel engine have been reduced by 25 % due to downsizing of diesel engine (Öko-Institut e.V., DLR-Instiut für Verkehrsforschung, 2009).

Data related to power train and Li-ion batteries set were added. Battery requirement (15 kWh) and mass of electric drivetrain components (98.5 kg) according to Cox (2018).

Source:

Cox, B. (2018): Mobility and the Energy Transition: A Life Cycle Assessment of Swiss Passenger Transport Technologies including Developments until 2050. ETH Zurich.

Öko-Institut e.V., DLR-Instiut für Verkehrsforschung (2009): RENEWBILITY "Stoffstromanalyse nachhaltige Mobilität im Kontext erneuerbarer Energien bis 2030"; Endbericht an das Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Berlin, p. 161.

1.6 TRANSPORT – INTERNAL COMBUSTION ENGINE

1.6.1 transport, passenger, passenger car, diesel, average, EURO 6d -DE

Occupancy rate (1.5 persons per vehicle) according to infas (2018)

Soruce: infas Institut für angewandte Sozialwissenschaft GmbH (2018) Mobilität in Deutschland. Tabellarische Grundauswertung. p. 43

1.6.2 transport, passenger car, average, diesel, EURO 6d - DE

This dataset represents the service of transport in a passenger car for a journey length of 1vkm and is valid for Germany. Fuel consumption and emissions are for average vehicle use and not representative of a specific driving cycle. The dataset is parametrized with respect to vehicle size, fuel consumption and vehicle lifetime. Vehicle lifetime was assumed to be 180000 km, vehicle weight 1600 kg.

This dataset considers an average diesel passenger car of Euro 6d class. Non-exhaust emissions are those resulting from tyre, brake and road wear. These emissions are considered as by-products. The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport over 1vkm and the emissions of exhaust and non-exhaust emissions into air, water and soil.

The dataset includes the construction, operation, maintenance and disposal of the vehicle and road infrastructure. Operation of the vehicle includes all the direct emissions produced by fuel combustion and evaporation as well as from tyre, brake and road wear.

The dataset doesn't specifically model cold start emissions. Fuel consumption, exhaust and evaporation emissions according to HBEFA v4.1 (D, 2020, mit Flottenmix gewichtete, warme E-Faktoren, agg. Verkehrssituationen (inkl. Längsneigungen, PKW Diesel EURO-6d)

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Stutzer B. et al. (2019): Handbook Emission Factors of Road Transport, HBEFA v4.1/1.11.2019

1.6.3 transport, passenger, passenger car, petrol, average, EURO 6d - DE

Occupancy rate (1.5 persons per vehicle) according to infas (2018)

Soruce: infas Institut für angewandte Sozialwissenschaft GmbH (2018) Mobilität in Deutschland. Tabellarische Grundauswertung. p. 43

1.6.4 transport, passenger car, average, petrol, EURO 6d - DE

This dataset represents the service of transport in a passenger car for a journey length of 1vkm and is valid for Germany. Fuel consumption and emissions are for average vehicle use and not representative of a specific driving cycle. The dataset is parametrized with respect to vehicle size, fuel consumption and vehicle lifetime. Vehicle lifetime was assumed to be 180000 km, vehicle weight 1600 kg.

This dataset considers an average petrol passenger car of Euro 6d class. Also included within the direct exchanges to the environment are the fuel evaporation emissions from the fuel tank, relevant to petrol vehicles only.

Non-exhaust emissions are those resulting from tyre, brake and road wear. These emissions are considered as by-products. The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport over 1vkm and the emissions of exhaust and non-exhaust emissions into air, water and soil.

The dataset includes the construction, operation, maintenance and disposal of the vehicle and road infrastructure. Operation of the vehicle includes all the direct emissions produced by fuel combustion and evaporation as well as from tyre, brake and road wear.

The dataset doesn't specifically model cold start emissions. Fuel consumption, exhaust and evaporation emissions according to HBEFA v4.1 (D, 2020, mit Flottenmix gewichtete, warme E-Faktoren, agg. Verkehrssituationen (inkl. Längsneigungen, PKW Petrol EURO-6d)

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Stutzer B. et al. (2019): Handbook Emission Factors of Road Transport, HBEFA v4.1/1.11.2019

1.6.5 transport, passenger, passenger car, CNG, average, EURO 6 - DE

Occupancy rate (1.5 persons per vehicle) according to infas (2018)

Soruce: infas Institut für angewandte Sozialwissenschaft GmbH (2018) Mobilität in Deutschland. Tabellarische Grundauswertung. p. 43

1.6.6 transport, passenger car, average, CNG, EURO 6 - DE

This dataset represents the service of transport in a passenger car for a journey length of 1 vkm and is valid for Germany. Fuel consumption and emissions are for average vehicle use and not representative of a specific driving cycle. The dataset is parametrized with respect to vehicle size, fuel consumption and vehicle lifetime. Vehicle lifetime was assumed to be 180000 km, vehicle weight 1600 kg.

This dataset considers an average CNG passenger car. Also included within the direct exchanges to the environment are the fuel evaporation emissions from the fuel tank.

Non-exhaust emissions are those resulting from tyre, brake and road wear. These emissions are considered as by-products. The dataset takes as input the infrastructure of the car and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport over 1 vkm and the emissions of exhaust and non-exhaust emissions into air.

The dataset includes the construction, operation, maintenance and disposal of the vehicle and road infrastructure. Operation of the vehicle includes all the direct emissions produced by fuel combustion and evaporation as well as from tyre, brake and road wear.

The dataset doesn't specifically model cold start emissions. Fuel consumption, exhaust and evaporation emissions according to HBEFA v4.1 (D, 2020, mit Flottenmix gewichtete, warme E-Faktoren, agg. Verkehrssituationen (inkl. Längsneigungen, PKW CNG/Benzin EURO-6_(CNG))

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Stutzer B. et al. (2019): Handbook Emission Factors of Road Transport, HBEFA v4.1/1.11.2019

1.6.7 transport, regular bus, diesel, EURO 6 - DE

Dataset adapted from “transport, regular bus – CH” ecoinvent v3.3, cut-off to German conditions in 2020.

Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 5.19E06 pkm/vehicle has been assumed. The value corresponds to 14.5 persons * 35759 km/a * 10a as mentioned in Mottschall & Bergmann (2013).

Regulated exhaust emissions and carbon dioxide emissions according to HBEFA v.4.1. Other emissions scaled with diesel demand from original dataset which represents average data for the operation of an average Swiss regular bus (fleet average) in the year 2005, comprising various emission technologies.

For the energy use and combustion emissions dataset, the fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions. Heavy metal emissions to soil and water caused by tyre abrasion are included.

Mottschall, M., Bergmann, T. (2013): Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland; Arbeitspaket 4 des Projektes "Weiterentwicklung des Analyseinstrumentes Renewbility". Texte 96/2013.

Notter, B., Keller, M., Althaus, H.-J., Cox, B., Knörr, W., Heidt, C., Biemann, K., Räder, D., Jamet, M. (August 2019): HBEFA 4.1. Development Report, Bern, Heidelberg.

1.6.8 transport, regular bus, CNG, EURO 6 - DE

Dataset adapted from “transport, regular bus – CH” ecoinvent v3.3, cut-off to German conditions in 2020.

Inventory refers to the entire transport life cycle. For road infrastructure, expenditures and environmental interventions due to construction of roads have been allocated based on the Gross tonne kilometre performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometre performance. For the attribution of vehicle share to the transport performance a vehicle life time performance of 5.19E06 pkm/vehicle has been assumed. The value corresponds to 14.5 persons * 35759 km/a * 10a as mentioned in Mottschall & Bergmann (2013).

Fuel demand, regulated and further exhaust emissions and non-exhaust emissions according to HBEFA v.4.1 for LBUS, CNG, Euro-VI, 2020, hot emission factor.

For the energy use and combustion emissions dataset, the fuel consumption is included. Direct airborne emissions of gaseous substances, particulate matters and heavy metals are accounted for. Particulate emissions comprise exhaust- and abrasions emissions.

Mottschall, M., Bergmann, T. (2013): Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland; Arbeitspaket 4 des Projektes "Weiterentwicklung des Analyseinstrumentes Renewbility". Texte 96/2013.

Notter, B. et al. (2019) Handbuch Emissionsfaktoren des Strassenverkehrs (Handbook Emission Factors for Road Traffic, HBEFA) v4.1./1.11.2019. Infras. Berne, CH.

1.6.9 transport, freight, lorry, average, diesel, EURO6 - DE

This dataset represents the service of 1 tkm freight transport in an average diesel lorry and Euro VI emissions class. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures. Fuel consumption and emissions are for average German journeys and European load factors and not representative of a specific transport scenario. The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report, share of lorry size class in Europe from ecoinvent v3.3 (transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified, cut-off, U - RER). These are as follows:

Lorry size class	Average load factor	GVW	share size class
3.5-7.5t	0.98t	4.98t	0.030
7.5-16t	3.29t	9.29t	0.061
16-32t	5.79t	15.79t	0.303
>32t	15.96t	29.96t	0.606
average	11.7t		

The lorry size and load factor determines the GVW and therefore also the fuel consumption and amount of both exhaust and non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear referring to the 16-32 t size class.

Fuel consumption and exhaust emissions are taken from v4.1 of the HBEFA model, using the data for Germany and without applying model weighting. The exhaust emissions caused by the burning of fuel are either fuel dependent (fuel type and quantity) or Euro class dependent. The latter reflect the emission regulations to which the vehicle complies. Regulated emissions are CO, NOx, particulate matter (PM) and total hydrocarbons (HC).

Non-exhaust emissions are accounted for as weight dependent by-products and exist as separate datasets.

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance. Expenditures due to operation of the road infrastructure, as well as land use have been allocated based on the yearly vehicle kilometer performance. The production, maintenance and disposal of the vehicle are as reported in the ecoinvent (2007) report on transport services and reflect a lorry of the size class 16-32 metric tons gross vehicle weight (GVW).

Main data sources:

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

Notter, B. et al. (2019) Handbuch Emissionsfaktoren des Strassenverkehrs (Handbook Emission Factors for Road Traffic, HBEFA) v4.1/1.11.2019

Spielmann, M., et al. (2007) Transport Services. ecoinvent report No. 14., Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

From combustion of fuel in the engine. The dataset takes as input the infrastructure of the lorry and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport service of 1tkm and the emissions of exhaust and non-exhaust emissions into air.

1.6.10 transport, freight, lorry, average, CNG - DE

This dataset represents the service of 1 tkm freight transport in an average CNG lorry. The transport datasets refer to the entire transport life cycle i.e. to the construction, operation, maintenance and end of life of vehicle and road infrastructures. Fuel consumption and emissions are for average German journeys and European load factors and not representative of a specific transport scenario. Load and infrastructure data taken from regular diesel driven lorry transport process in ecoinvent as follows:

The average load factors are taken from the Tremove model v2.7b (2009) and EcoTransIT (2011) report, share of lorry size class in Europe from ecoinvent v3.3 (transport, freight, lorry, all sizes, EURO6 to generic market for transport, freight, lorry, unspecified, cut-off, U - RER). These are as follows:

Lorry size class	Average load factor	GVW	share size class
3.5-7.5t	0.98t	4.98t	0.030
7.5-16t	3.29t	9.29t	0.061
16-32t	5.79t	15.79t	0.303
>32t	15.96t	29.96t	0.606
average	11.7t		

The lorry size and load factor determines the GVW and therefore also the non-exhaust emissions. Non-exhaust emissions are those resulting from tyre, brake and road wear referring to the 16-32 t size class. Non-exhaust emissions are accounted for as weight dependent by-products and exist as separate datasets.

For road infrastructure the expenditures and environmental interventions due to construction of roads have been allocated based on the gross tonne kilometer performance referring to the 16-32 t size class lorry.

Fuel consumption and exhaust emissions are taken from v4.1 of the HBEFA model, using the data for Germany and without applying model weighting. The exhaust emissions caused by the burning of fuel are either fuel dependent (fuel type and quantity) or Euro class dependent. The latter reflect the emission regulations to which the vehicle complies. Regulated emissions are CO, NOx, particulate matter (PM) and total hydrocarbons (HC).

Main data sources:

De Ceuster, G., et al. (2009) TREMOVE: Final Report. Model code v2.7b, 2009. European Commission, Brussels.

Keller, M. et al. (2019) Handbook emission factors for road transport v4.1/1.11.2019, HBEFA. INFRAS, Berne, CH.

Knörr, W. et al. (2011) Ecological Transport Information Tool for Worldwide Transports (EcoTransIT): Methodology and data update. Berlin, Hannover, Heidelberg, DE.

Spielmann, M., et al. (2007) Transport Services. ecoinvent report No. 14., Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

From combustion of fuel in the engine. The dataset takes as input the infrastructure of the lorry and road network, the materials and efforts needed for maintenance of these and the fuel consumed in the vehicle for the journey. The activity ends with the transport service of 1 tkm and the emissions of exhaust and non-exhaust emissions into air.

1.7 PV - Open ground installations

1.7.1 1.3 MWp open ground installation, multi-Si, panel, on open ground/p/DE/I

Photovoltaic installation with a capacity of 1.3 kWp and a life time of 30 years

Included processes: All components (modules, mounting system, electric installation, inverter) for the installation of a 1.3 MWp photovoltaic plant, energy use for the mounting. Disposal of components after end of life.

Demand of electric installation and inverter according to 1.3 MWp slanted-roof installation, multi-Si, panel, mounted, on roof/p/CH/I

Electricity and diesel demand scaled according to 570 kWp open ground installation

Specific cell capacity: 0.147 kWp/m²

1.7.2 1.3 MWp open ground installation, CdTe, panel, on open ground/p/DE/I

Photovoltaic installation with a capacity of 1.3 kWp and a life time of 30 years

Included processes: All components (modules, mounting system, electric installation, inverter) for the installation of a 1.3 MWp photovoltaic plant, energy use for the mounting. Disposal of components after end of life.

Demand of electric installation and inverter according to 1.3 MWp slanted-roof installation, multi-Si, panel, mounted, on roof/p/CH/I

Electricity and diesel demand scaled according to 570 kWp open ground installation

Specific cell capacity: 0.1399972 kWp/m²

1.7.3 1.3 MWp open ground installation, single-Si, panel, on open ground/p/DE/I

Photovoltaic installation with a capacity of 1.3 kWp and a life time of 30 years

Included processes: All components (modules, mounting system, electric installation, inverter) for the installation of a 1.3 MWp photovoltaic plant, energy use for the mounting. Disposal of components after end of life.

Demand of electric installation and inverter according to 1.3 MWp slanted-roof installation, multi-Si, panel, mounted, on roof/p/CH/I

Electricity and diesel demand scaled according to 570 kWp open ground installation

Specific cell capacity: 0.151 kWp/m²

1.7.4 570 kWp open ground installation, multi-Si, on open ground/p/DE/I

Übersetzung

1.7.5 570 kWp open ground installation, CdTe, on open ground/p/DE/I

Photovoltaic installation with a capacity of 570 kWp and a life time of 30 years. Adaption from multi-Si installation installed in 2008 in ES

Included processes: All components (modules, mounting system, electric installation, inverter, fence) for the installation of a 570 kWp photovoltaic plant, energy use for the mounting, transport of materials and persons to the construction place. Disposal of components after end of life.

Specific cell capacity: 0.1399972 kWp/m²

1.7.6 570 kWp open ground installation, single-Si, on open ground/p/DE/I

Photovoltaic installation with a capacity of 570 kWp and a life time of 30 years. Adaption from multi-Si installation installed in 2008 in ES.

Included processes: All components (modules, mounting system, electric installation, inverter, fence) for the installation of a 570 kWp photovoltaic plant, energy use for the mounting, transport of materials and persons to the construction place. Disposal of components after end of life.

Specific cell capacity: 0.151 kWp/m²

2 FÜR ECOINVENT AUFBEREITETE PROZESSE

battery production, lead acid, rechargeable, stationary, US, 2009 – 2010

compressed air energy storage plant construction, adiabatic, RER, 2015 – 2015

compressed air energy storage plant construction, RER, 2015 – 2015

electricity production, compressed air energy storage, adiabatic, RER, 1998 – 2015

electricity production, compressed air energy storage, RER, 1998 – 2015

gas turbine production, 80MW electrical, for compressed air energy storage, GLO, 2015 – 2015

maintenance, transmission network, electricity, high voltage direct current aerial line, RER, 1998 – 2012

maintenance, transmission network, electricity, high voltage direct current land cable, RER, 1998 – 2012

maintenance, transmission network, electricity, high voltage direct current subsea cable, RER, 1998 – 2012

thermal energy storage production, for adiabatic compressed air energy storage, GLO, 2015 – 2015

transmission network production, electricity, high voltage direct current aerial line, RER, 1998 – 2012

transmission network production, electricity, high voltage direct current land cable, RER, 1998 – 2012

transmission network production, electricity, high voltage direct current subsea cable, RER, 1998 – 2012