LCA CASE STUDY
Freight Transport

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Goal & Functional Unit

1. The goal for layer 1 is to quantify the life cycle impacts of a Longer and Heavier Vehicle (LHV) compared to a normal truck. This layer compares of the environmental performance between these two vehicle types, focusing on the vehicle itself, its fuel consumption, and direct emissions.
2. The goal for layer 2 is to understand how road infrastructure influences the impacts of an LHV compared to a normal truck. This comparison incorporates the impacts due to road construction, maintenance, and end-of-life phase into the comparison model, providing a more comprehensive assessment that includes infrastructure considerations.
3. For Layers 1 and 2 the functional unit is 1 tonne-kilometer (t*km) of goods transported by freight road transport mode in Germany.

Scenarios

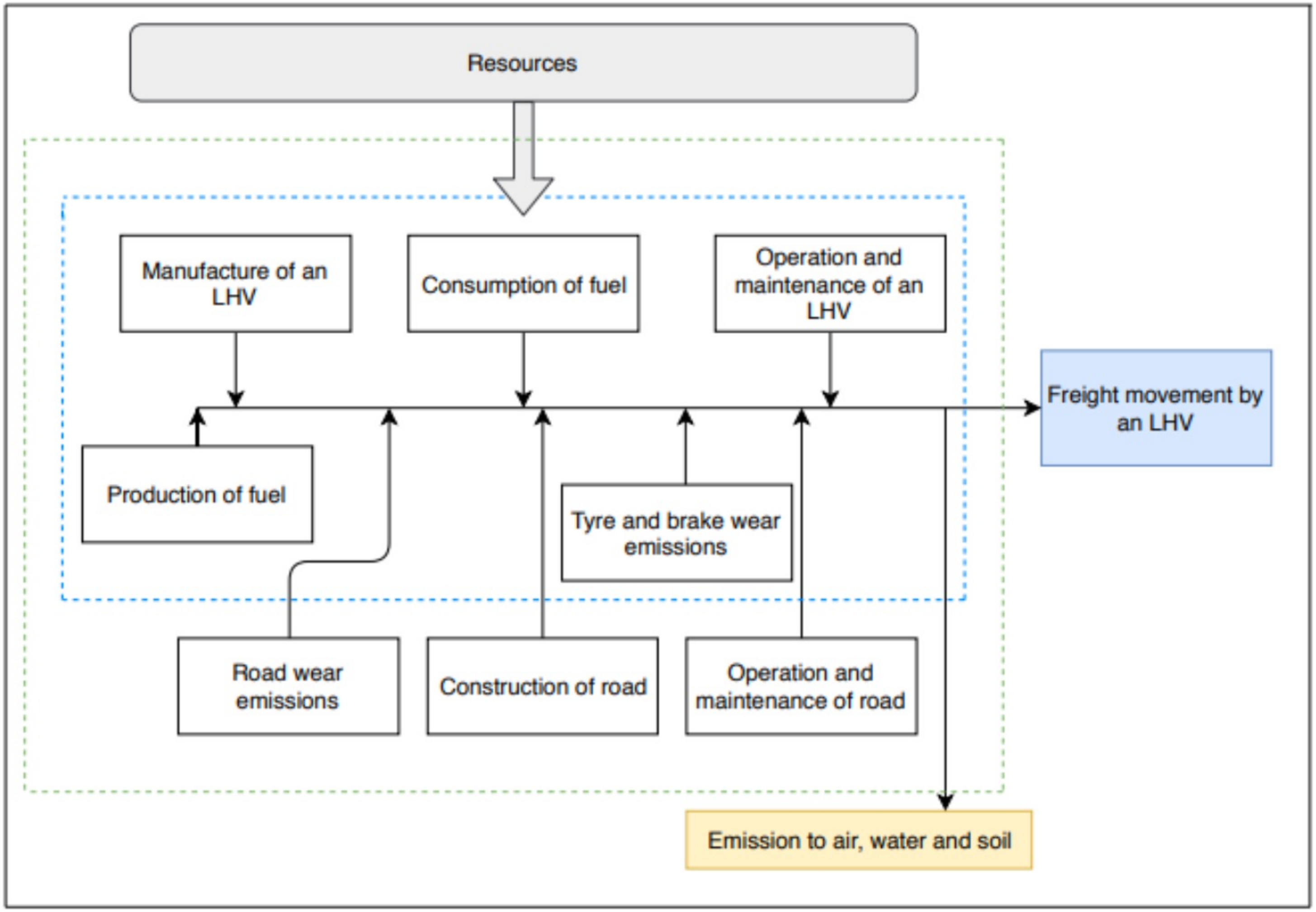
Layer 1: Simple Model - Direct Vehicle Comparison

- LHV Scenario: Longer and Heavier Vehicle (up to 25.25m long, 60 tons weight)
- Normal Truck Scenario: Conventional truck (16-32 metric ton, EURO6)

Layer 2: Full Model - Including Road Infrastructure

- LHV + Road Scenario: LHV impacts + road construction, maintenance, and end-of-life impacts
- Normal Truck + Road Scenario: Normal truck impacts + road construction, maintenance, and end-of-life impacts

System Boundary

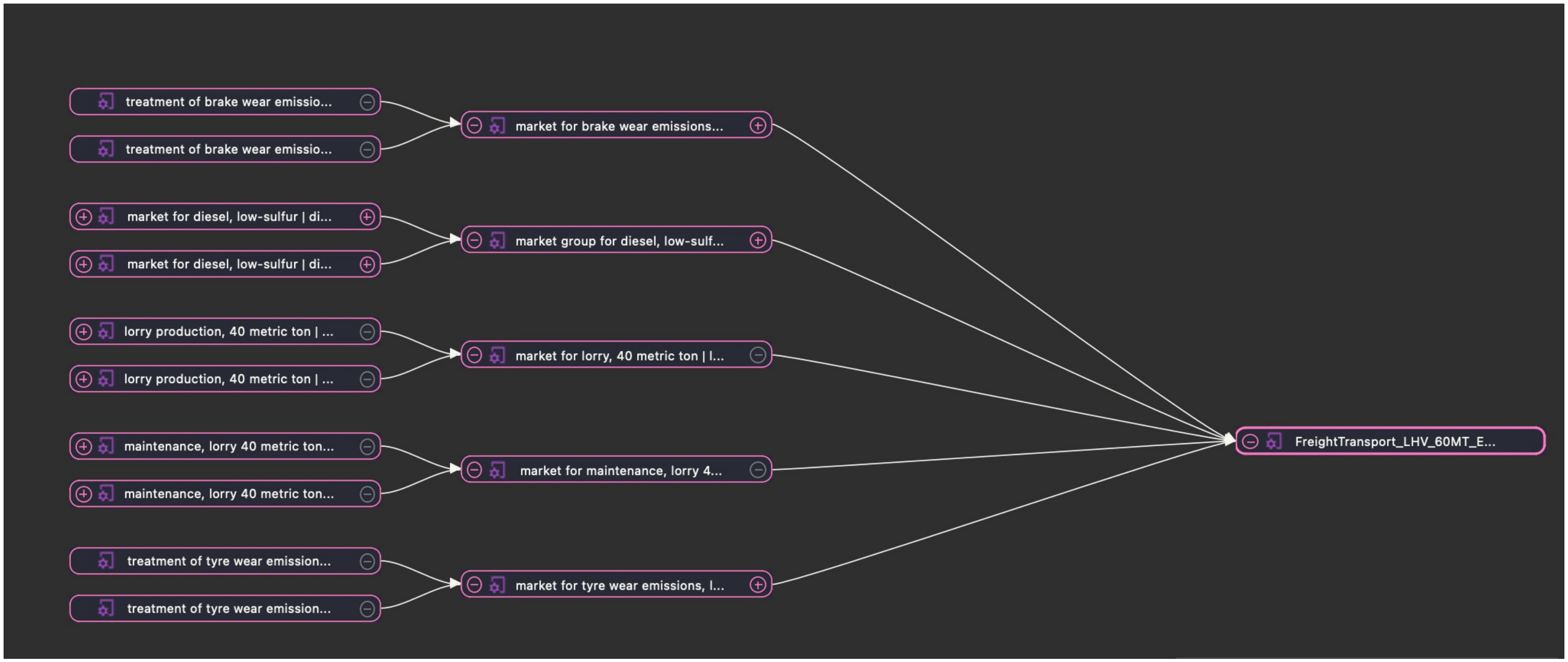


The system boundaries for layer one are outlined in blue dashes. The system boundaries for layer 2 are in the green dashes, which include the processes from layer 1. These boundaries apply to both the LHV and the normal truck.

It can be assumed that once you consider the road wear emissions, construction of the road, and operations + maintenance, the impact from both options will increase.

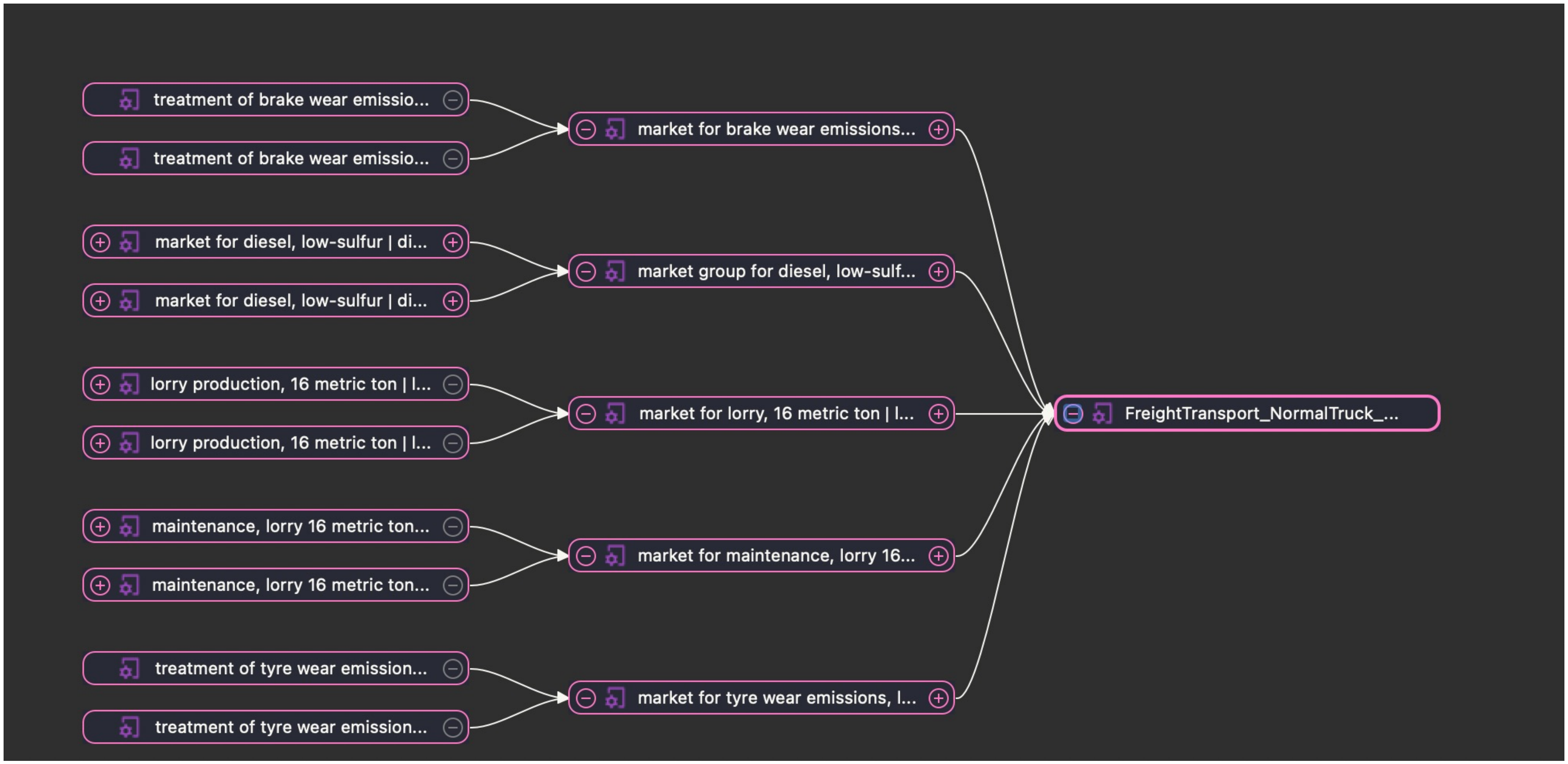
Life-cycle Diagram

(Layer 1) LHV without road



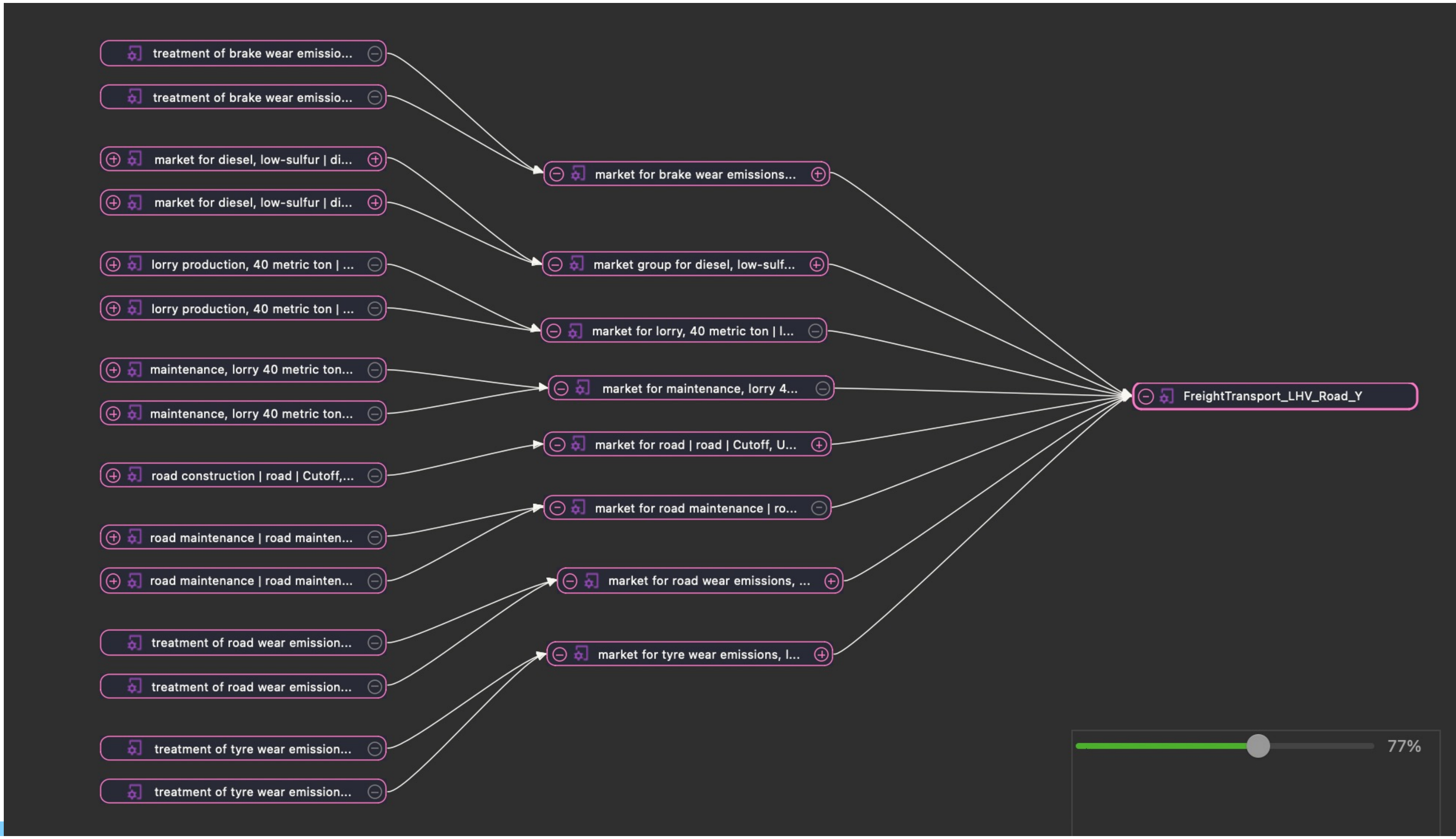
Life-cycle Diagram

(Layer 1) Normal truck without road



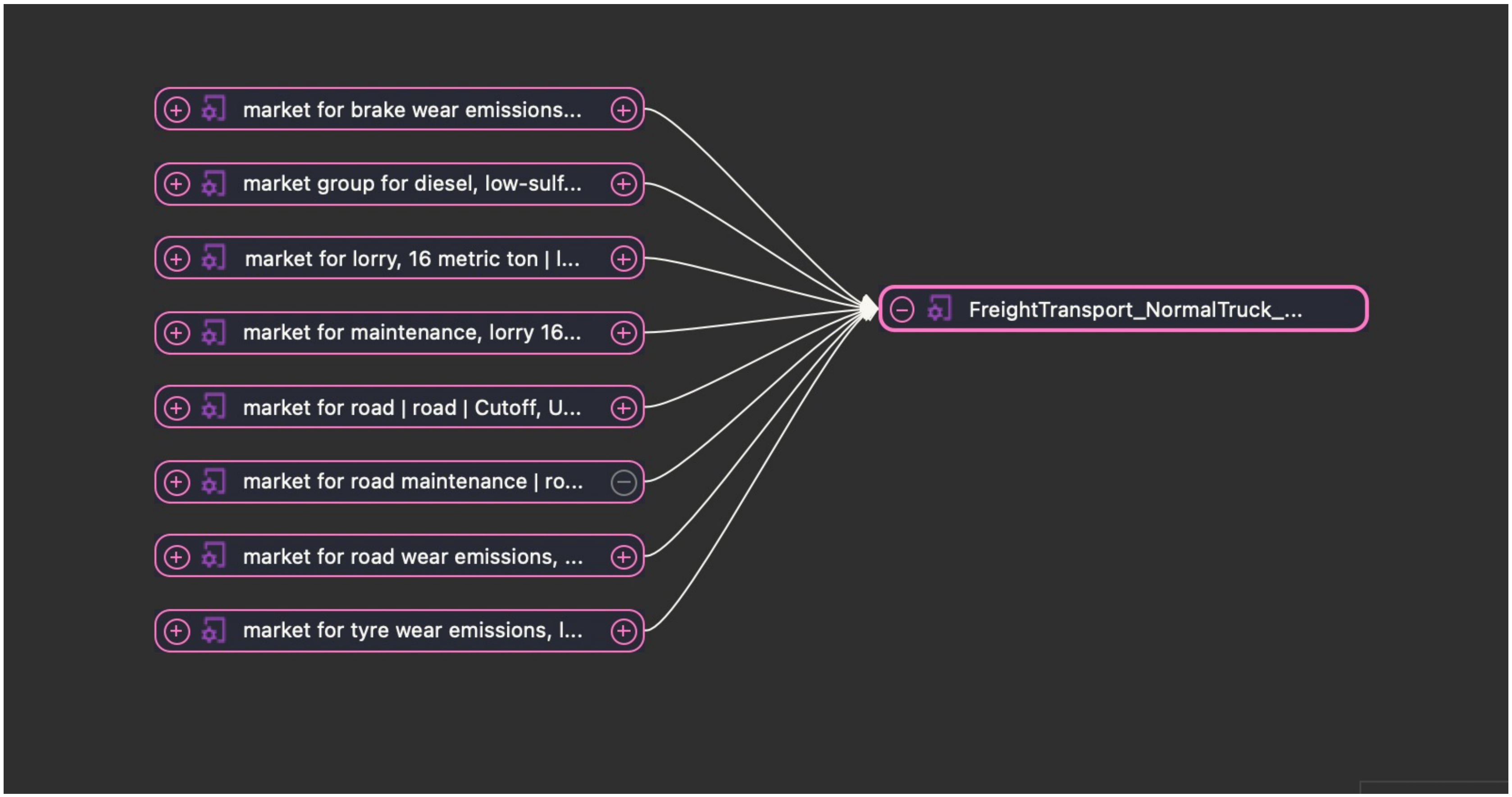
Life-cycle Diagram

(Layer 2) LHV with road



Life-cycle Diagram

(Layer 2) Normal truck with road



Impact Assessment Method

The LCIA method that will be used for assessment is the ReCiPe 2016 Midpoint (H).

Impact categories include:
Ecosystem impacts:
- Fine particulate matter formation (kg PM2.5 eq)
- Freshwater ecotoxicity (kg 1,4-DCB)
- Freshwater eutrophication (kg P eq)
- Global warming (kg CO_2 eq)
- Ionizing radiation (kBq Co-60 eq)
- Marine ecotoxicity (kg 1,4-DCB)
- Marine eutrophication (kg N eq)
- Ozone formation, Terrestrial ecosystems (kg NO_x eq)
- Stratospheric ozone depletion (kg CFC11 eq)
- Terrestrial acidification (kg SO_2 eq)
- Terrestrial ecotoxicity (kg 1,4-DCB)

Human health impacts:
- Ozone formation, Human health (kg NO_x eq)
- Human carcinogenic toxicity (kg 1,4-DCB)
- Human non-carcinogenic toxicity (kg 1,4-DCB)

Resource impacts:
- Fossil resource scarcity (kg oil eq)
- Land use (m2a crop eq)
- Mineral resource scarcity (kg Cu eq)
- Water consumption (m3)

Life Cycle Inventory – LHV without road

Inputs:

- Brake wear emissions, lorry, -1.691203E-5 * brake kg
- Diesel, low sulfur, 0.0192*diesel kg
- Lorry, 40 metric ton, 9.65E-8 items
- Maintenance, lorry 40 metric ton 9.65E-8 items
- Tire wear emissions, lorry, -1.6756E-4*tire kg

Outputs:

- Acetaldehyde 7.50144E-8 kg
- Acrolein 2.90537E-8 kg
- Ammonia 1.87970E-7 kg
- Arsenic 1.91934E-12 kg
- Benzaldehyde 2.24879E-8 kg
- Benzene 1.14902E-9 kg
- Butane 2.46218E-8 kg
- Cadmium 1.66982E-10 kg
- Carbon dioxide, fossil 0.05753 kg
- Carbon monoxide, fossil 5.24249E-5 kg
- Chromium 5.75801E-10 kg
- Chromium VI 1.15160E-12 kg
- Copper 4.06899E-10 kg
- Dinitrogen monoxide 3.13367E-6 kg
- Ethane 4.92436E-10 kg
- Formaldehyde 1.37882E-7 kg
- Heptane 4.92436E-9 kg
- Lead 9.99974E-10 kg
- M-Xylene 1.60862E-8 kg
- Mercury 1.01725E-10 kg
- Methane, fossil 4.03636E-8 kg
- Nickel 1.68902E-10 kg
- Nitrogen oxides 2.62908E-5 kg
- NMVOC, non-methane volatile organic compounds 1.33335E-6 kg

Outputs:

- O-Xylene 6.56581E-9 kg
- PAH, polycyclic aromatic hydrocarbons 1.50092E-9 kg
- Particulates, <2.5um 2.37249E-7 kg
- Pentane 9.84872E-10 kg
- Propane 1.64145E-9 kg
- Selenium 1.9193E-12 kg
- Styrene 9.19214E-9 kg
- Sulfur dioxide 3.12742E-7 kg
- Toluene 1.64145E-10 kg
- Zinc 3.33581E-8 kg

Life Cycle Inventory – Normal truck without road

Inputs:

- Brake wear emissions, lorry -2.21658E-5 kg
- Diesel, low sulfur 0.03665 kg
- Lorry, 16 metric ton 3.2E-7 items
- Maintenance, lorry 16 metric ton 3.2E-7 items
- Tyre wear emissions, lorry -0.00022 kg

Outputs:

- Acetaldehyde 1.50635E-7 kg
- Acrolein 5.83423E-8 kg
- Ammonia 5.18457E-7 kg
- Arsenic 3.66461E-12 kg
- Benzaldehyde 4.51576E-8 kg
- Benzene 2.30732E-9 kg
- Butane 4.94426E-9 kg
- Cadmium 3.18821E-10 kg
- Carbon dioxide, fossil 0.11480 kg
- Carbon monoxide, fossil 0.00011 kg
- Chromium 1.09938E-9 kg
- Chromium VI 2.19876E-12 kg
- Copper 7.76896E-10 kg
- Dinitrogen monoxide 6.13869E-6 kg
- Ethane 9.88852E-10 kg
- Formaldehyde 2.76879E-7 kg
- Heptane 9.88852E-9 kg
- Lead 1.90926E-9 kg
- M-Xylene 3.23025E-8 kg
- Mercury 1.94224E-10 kg
- Methane, fossil 8.10535E-8 kg

Outputs:

- Nickel 3.22485E-10 kg
- Nitrogen oxides 5.22432E-5 kg
- NMVOC, non-methane volatile organic compounds 2.67748E-6 kg
- O-Xylene 1.31847E-9 kg
- PAH, polycyclic aromatic hydrocarbons 2.86572E-9 kg
- Particulates, <2.5um, 4.94100E-7 kg

Life Cycle Inventory – LHV with road

Inputs:

- Brake wear emissions, lorry, -1.691203E-5 * brake kg
- Diesel, low sulfur, 0.0192*diesel kg
- Lorry, 40 metric ton, 9.65E-8 items
- Maintenance, lorry 40 metric ton 9.65E-8 items
- Tire wear emissions, lorry, -1.6756E-4*tire kg
- Road, 0.00109*road m*a
- Road maintenance, 0.00109*road m*a
- Road wear emissions, lorry, -1.456E-5*roadwear kg

Outputs:

- Acetaldehyde 7.50144E-8 kg
- Acrolein 2.90537E-8 kg
- Ammonia 1.87970E-7 kg
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- Lorry, 16 metric ton 3.2E-7 items
- Maintenance, lorry 16 metric ton 3.2E-7 items
- Tyre wear emissions, lorry -0.00022 kg
- Road, 0.00105 m*a
- Road maintenance, 0.00105 m*a
- Road wear emissions, lorry, -1.9085E-5 kg

Outputs:

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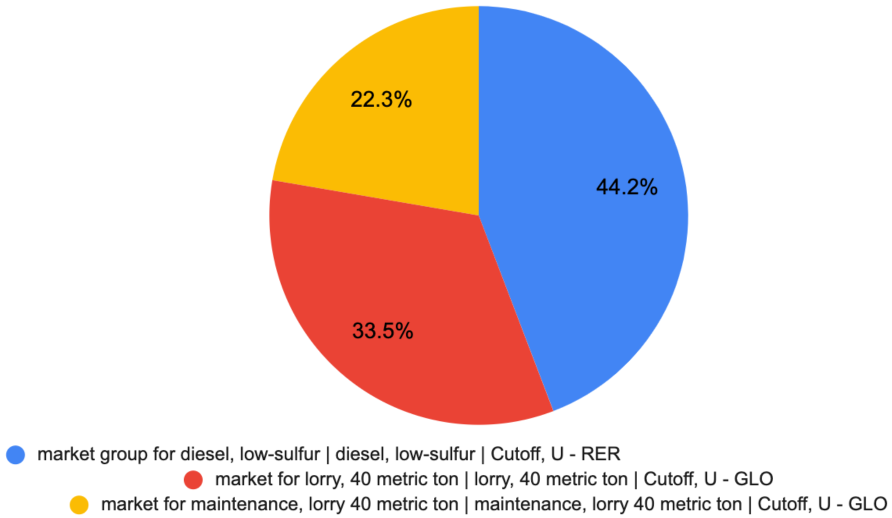
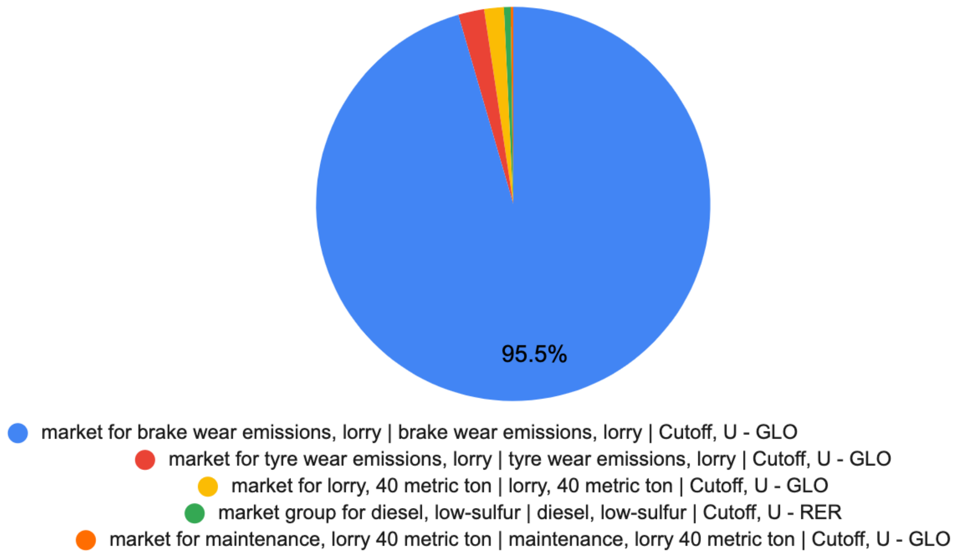
Impact Assessment – LHV without road

The Life Cycle Impact Assessment method used was the ReCiPe Endpoint (H) method, and the ecoinvent3.4 database was used for the Life Cycle Inventory.

LHV without Road, Land Use



LHV without road, Terrestrial Ecotoxicity



Impact Assessment – LHV with road

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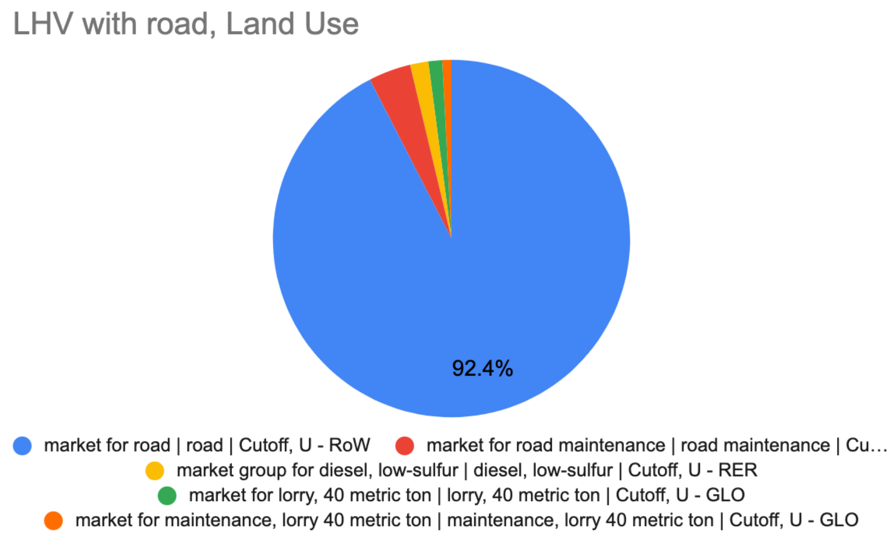
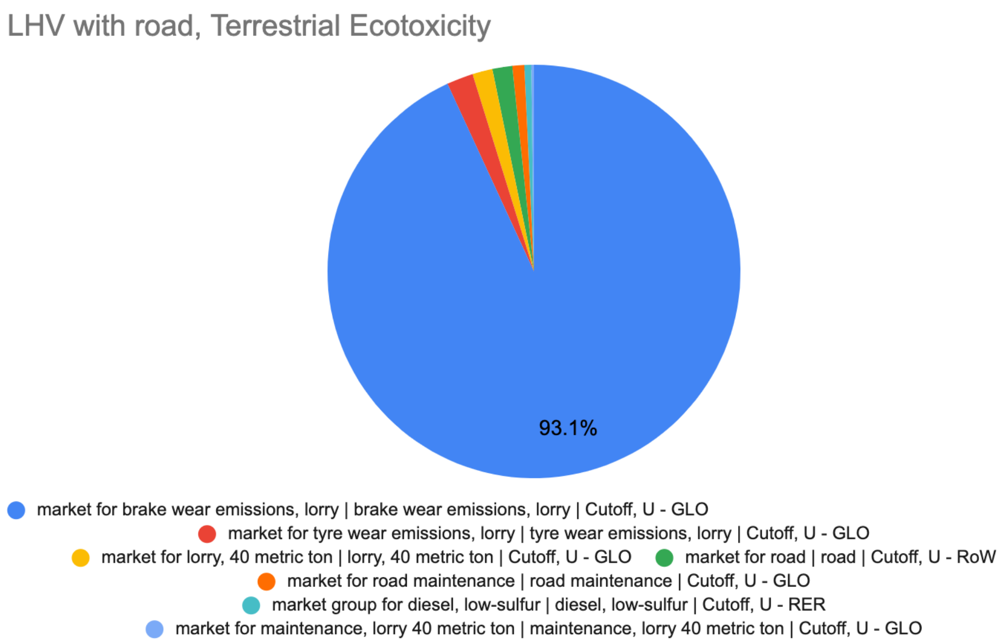
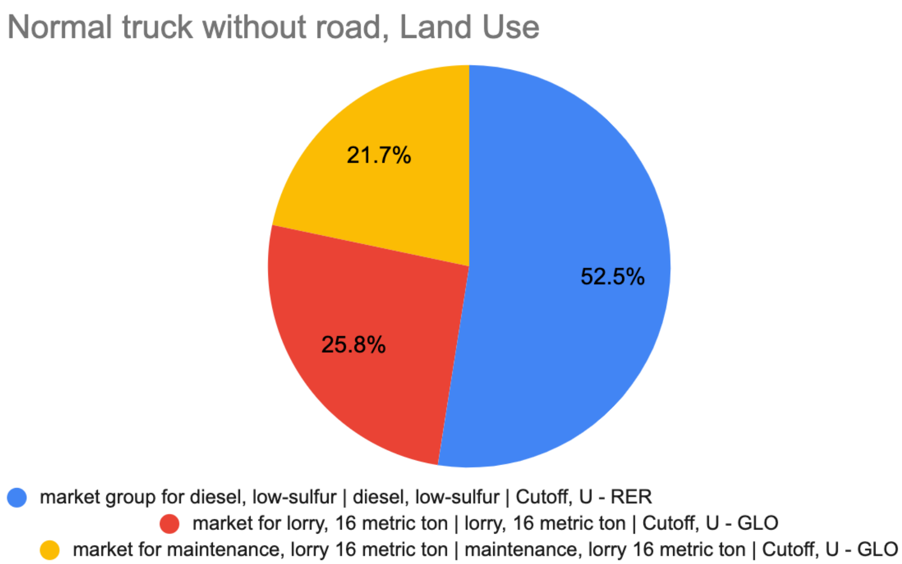
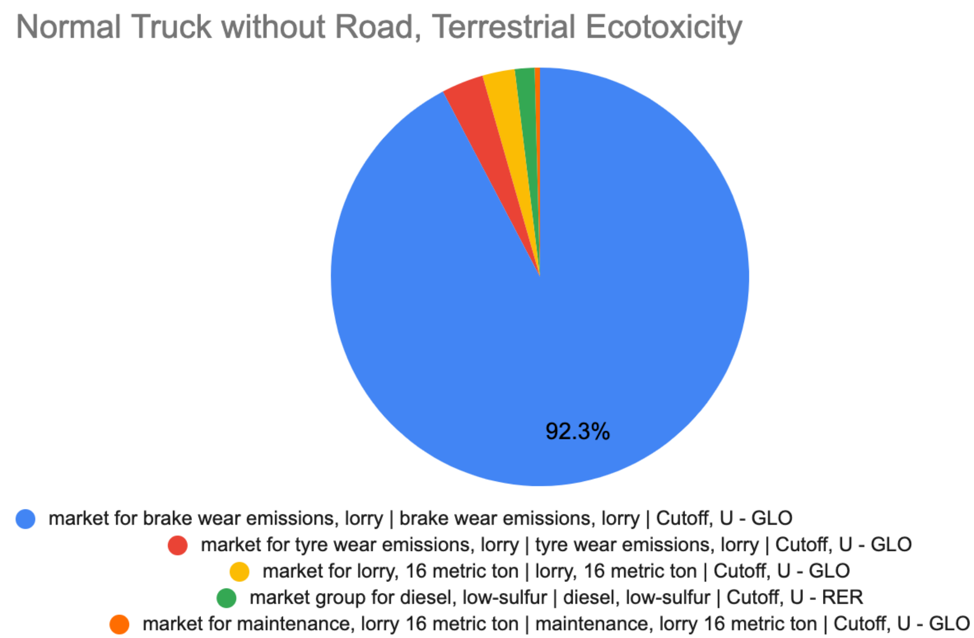




Impact Assessment- Normal Truck without Road

The Life Cycle Impact Assessment method used was the ReCiPe Endpoint (H) method, and the ecoinvent3.4 database was used for the Life Cycle Inventory.





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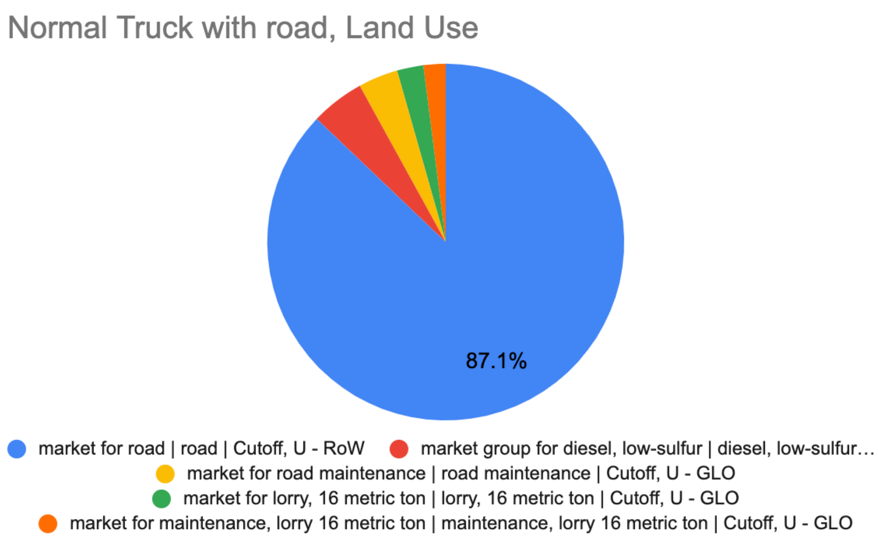

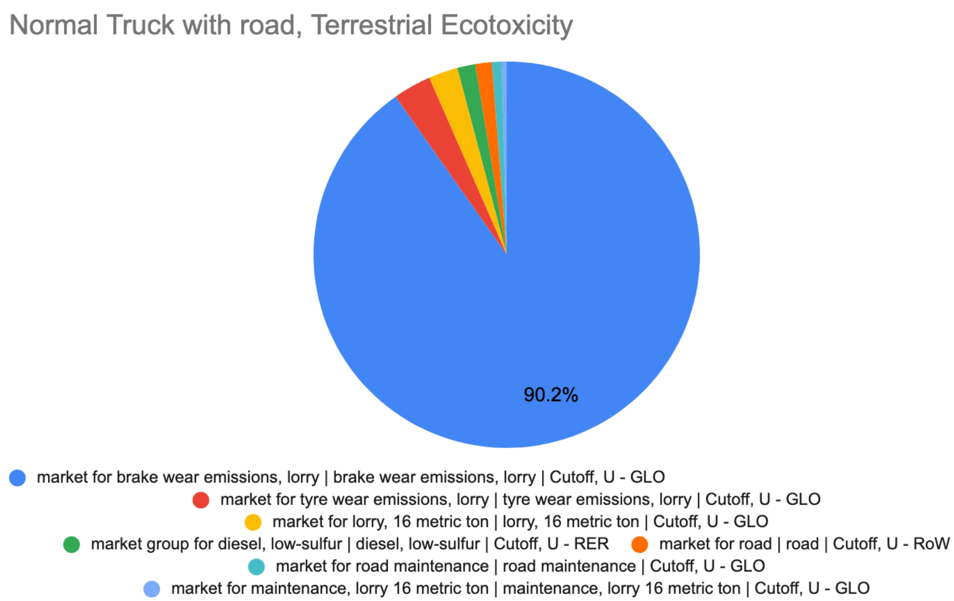

Interpretation of Results – Layer 1

1. **Most Impacted Environmental Category:** Terrestrial ecotoxicity stands out as having the highest impact in absolute terms for both vehicle types. The impact values are 2.43E+00 kg 1,4-DCB for LHVs and 2.21E+00 kg 1,4-DCB for normal trucks. Interestingly, this is one of the few categories where the LHV has a higher impact (about 14% more) than normal trucks.
2. **Eco-hotspots:**

- For Normal Trucks: Fuel consumption is the major contributor to most impact categories, followed by lorry production. This is evidenced in the contribution trees shown in the Annex (Figures 13-16).
- For LHVs: While fuel consumption is lower (24% less than normal trucks), brake wear emissions are 1.5 times higher than in normal trucks, which contributes significantly to the terrestrial ecotoxicity impact.

Interpretation of Results – Layer 2

1. **Most Impacted Environmental Category:** Terrestrial ecotoxicity remains the most impacted category in absolute terms, with values of 2.50E+00 kg 1,4-DCB for LHVs and 2.26E+00 kg 1,4-DCB for normal trucks.

2. **Eco-hotspots:**

- For Normal Trucks: Similar to Layer 1, fuel consumption remains the major contributor.
- For LHVs: With the inclusion of road infrastructure, land use impact increases significantly due to the 20% higher road usage required for LHVs.
- This is the only category where LHVs have higher impacts in Layer 2 (8.67E-03 m2a crop eq) compared to normal trucks (7.38E-03 m2a crop eq).

Greener Alternatives

1. **For LHVs:** Improve brake systems to reduce brake wear emissions, which would lower the terrestrial ecotoxicity impact.
   - Optimize road usage and design to minimize the additional land use requirements, which is currently 20% higher than normal trucks.
   - Consider road materials and construction methods that reduce environmental impacts, as the inclusion of road infrastructure increases LHV impacts
2. **For Normal Trucks:** Focus on fuel efficiency improvements, as fuel consumption is the major contributor to environmental impacts.
   - Improve production processes for the trucks themselves, as lorry production is the second highest contributor
3. **System-level Recommendations:** Maintain a steady modal share of road transport (around 72%) while increasing the share of LHVs within road transport.
   - Monitor and manage the potential increase in overall freight transport volume, as the study shows that a 30% increase in transport volume would negate the environmental benefits of using LHVs