# Carbon footprint report

# Lynk & Co 01 PHEV car

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*LCA, PHEV, carbon footprint, car*

# Contents

# 1 Introduction

## 1.1 About this report

This is the LCA report of the Lynk & Co 01 PHEV car carried out by IVL Swedish Environmental Research Institute on behalf of Lynk & Co.

The climate change impact is calculated using the life cycle assessment methodology where the most important information and result are found in the main chapters of the report, while the appendix contains the LCA reported according to the format specified in the ISO 14044 LCA standard. The methodology follows the ones published by Volvo Cars (Volvo Cars, 2021) and Polestar (Polestar, 2021) to the extent possible.

The outcome of this study is intended to be used for external communication and internal knowledge building.

## 1.2 What is LCA?

Life cycle assessments (LCA) investigate the environmental impacts related to a product or a system during its whole life cycle. This includes evaluating energy and resource consumption as well as emissions, from all life cycle stages including material production, manufacturing, use and maintenance, and end-of-life (Figure 1). LCA is a widely used and accepted method for studies of the environmental performance of various products and systems.


*Figure 1. Illustration of an LCA-system.*

# 2 Studied system

The climate change impact is assessed for the Lynk & Co 01 car, comparing different user behaviors and different electricity mix used to charge the vehicle. The study investigates the climate change impact along the vehicle life cycle. The system boundaries of the study are illustrated in Figure 2. Maintenance of the vehicle has been excluded and a sensitivity analysis is performed to explore the results using another functional unit and a different number of users and passengers in the vehicle. Future electricity grid mix scenarios are also explored to better capture the electricity grid mix when the car will be in operation.

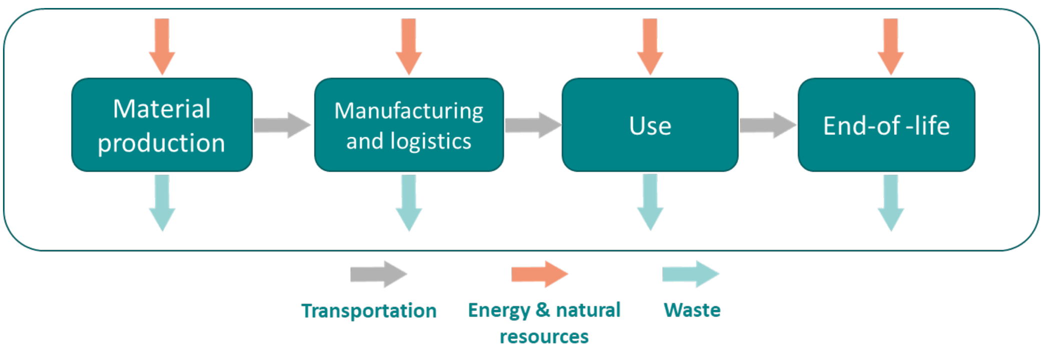


*Figure 2. Illustration of system boundaries.*

The car is a plug-in hybrid vehicle (PHEV) which means it has both a combustion engine as well as an electric motor and a Li-ion battery for propulsion. More technical information about the car can be found in Table 1.

*Table 1. Technical information about the studied car.*

| Product | Vehicle type | Total weight (kg) | Pure electric range (km) | Battery Chemistry | Battery weight (kg) | Battery energy (kWh) |
|---|---|---|---|---|---|---|
| Lynk & Co 01 | PHEV | 1897 | 69 | NMC 811 | 137 | 22 |

## 2.1 Raw material production

The material production phase is assessed using a bill of material (BOM) which defines the parts used in the vehicle and their respective weight and material composition. The information on material composition comes from suppliers through the International Material Data System (IMDS, 2023). A complete vehicle BOM typically consists of at least 10,000 different materials and to make the number of materials manageable in the LCA software, they are aggregated into approximately 45 material categories defined by Geely. Some material categories were however too aggregated to be useful in LCA modelling so some of them were disaggregated using the original detailed BOM. More details on specific material categories can be found in Appendix A.

The import of the BOM to LCA for expert software (LCA FE, formerly known as GaBi) is made in a specific mapping tool, called DfX BOM import. In the mapping, each material is connected to a specific life cycle inventory dataset and a manufacturing process dataset. A list of all used datasets can be found in Table 11 Appendix C.

The material composition of the car can be found in Figure 3. The car consists of a majority of steel and iron, followed by polymers and aluminium. Appendix A explains how each important material group has been modelled.

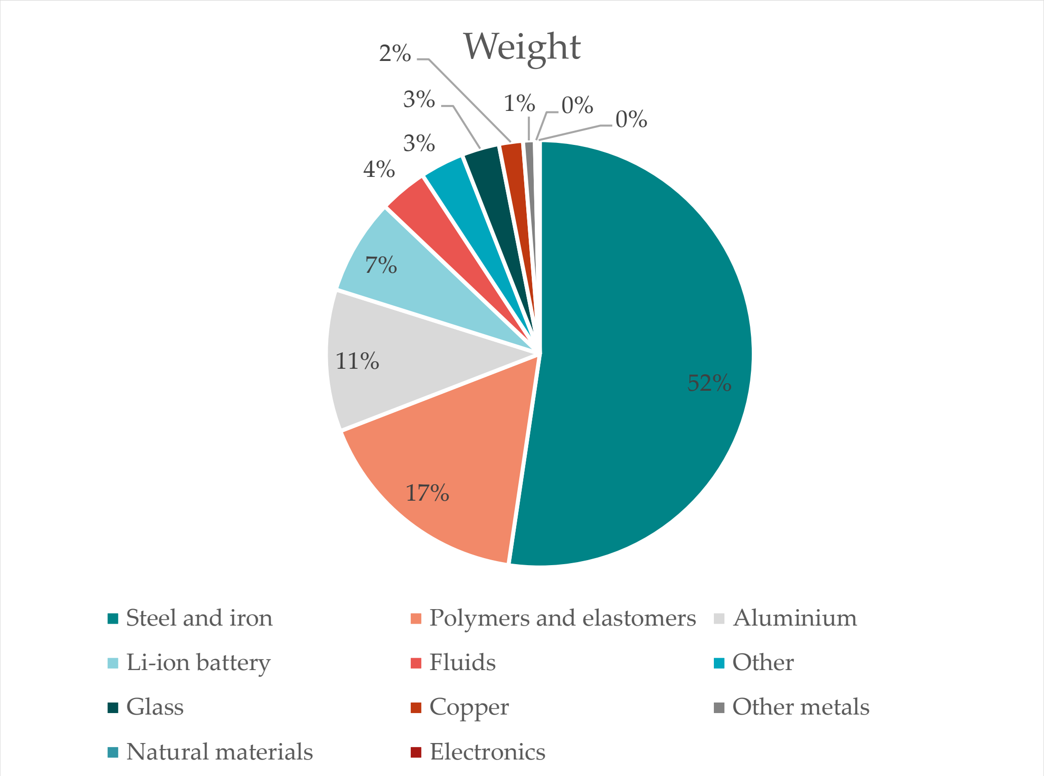


*Figure 3. Material composition of the car.*

## 2.2 Manufacturing

After the material production and component manufacturing has taken place, the car needs to be assembled and shipped to the customer. The assembly takes place in China and the car is then shipped to Europe to be used. Manufacturing and logistics data is valid for 2022. More information about the modelling can be found in Appendix A.

## 2.3 Use

The use phase data comes from the WLTP drive cycles (Worldwide Harmonized Light Vehicle Test Procedure used for certification of vehicles in the EU). Since Lynk & Co 01 is a plugin hybrid, the evaluation is done in two different drive cycles and they are named **combined** and **weighted combined** (presented in Table 2). In the combined drive cycle the vehicle is not charged from any external electricity sources, only electricity from regeneration is considered. In the cycle called weighted combined, external electricity and the combustion engine is powering the vehicle.

Since these are theoretical test cycles, care should be taken when interpreting the results. Most car users do not follow the behaviour of either the combined or weighted combined scenario, but rather a mix of them. The weighted combined cycle assumes a high degree of charging that might not be the case for the average PHEV user.

*Table 2. Information on the use phase.*

| Drive cycle | $CO_2$ emissions (tailpipe) | Fuel consumption (Petrol) | Electricity consumption | Description |
|---|---|---|---|---|
| **Combined** | 163 g $CO_2$/km | 7.2 L/100km | N/A | No external electricity source considered |
| **Weighted Combined** | 24 g $CO_2$/km | 1.0 L/100km | 185 Wh/km | Combination of external electricity and combustion engine |

## 2.4 Waste management

When the vehicle has reached its end-of-life, it is collected and sent for end-of-life treatment. When the car is collected, it is then assumed to go through dismantling and pre-treatment, see Figure 4. The first treatment step is disassembly to remove hazardous components and components that are candidates for specific recycling or reuse efforts. The disassembled parts are treated, and the remaining vehicle is shredded. Depending on material type, the resulting fractions go either to material recycling, incineration, or landfill. Any credit for recycling or reuse in another product system is excluded from the modelling since it follows the polluter pays principle/simple cut-off. This principle means that the first user of the material takes on the environmental burden of production and that the second user of the material only takes the environmental burden of recycling processes that need to be done in order to use the material again. More information about end-of-life can be found in Appendix A.

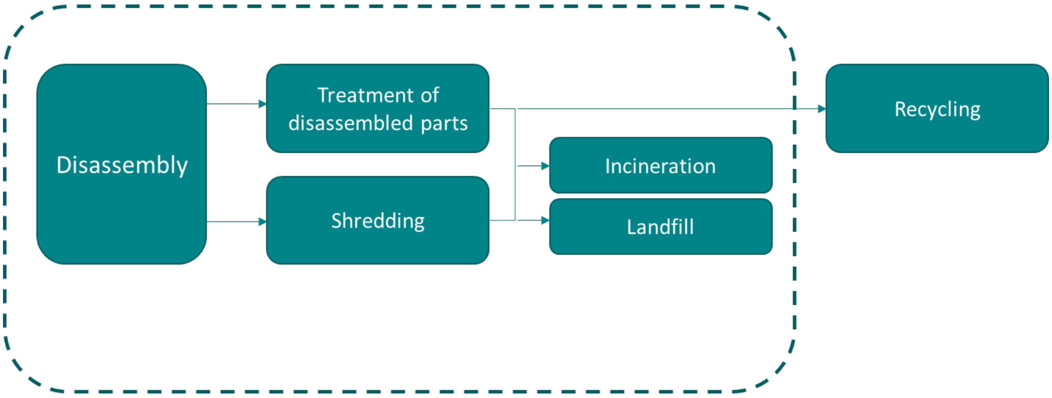


*Figure 4. End-of-Life boundaries.*

# 3 Results and discussion

The impact indicator studied is climate change impact which is based on the definition in CML2001 and updated in August 2016 (CML, 2016). The functional unit is one Lynk & Car 01 in operation the entire lifetime, which is defined as 200 000 km.

The results include different user behaviour (not charging at all compared to almost exclusively charging) and different electricity mixes which can be seen in Figure 5. **Combined** only uses external energy in the form of petrol and the **weighted combined** uses both petrol and electricity to power the vehicle. Since there are a lot of different electricity mixes that can charge a car on the European market, a selection has been made to illustrate an example of a worst-case (coal power), an average case (EU grid mix) and a best case (wind power).

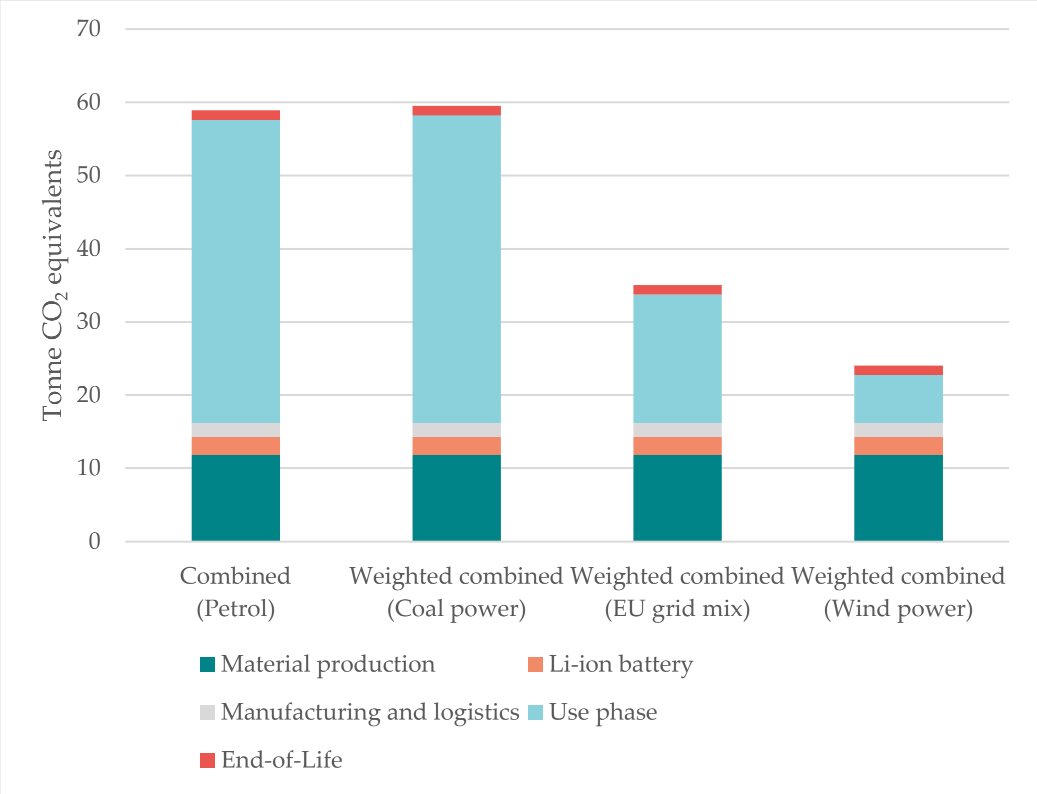


*Figure 5. Results per the functional unit of driving a Lynk & Co car for 200 000 km.*

Both combined and weighted combined (charged exclusively with coal power) show similar results, that the use phase contributes to a substantial portion of the impact on climate change from the whole life cycle (roughly 70%). When the car is charged with either the average European grid mix or wind power, the use phase impact is reduced to roughly 51% and 27% respectively. The importance of frequent charging and electricity mix used is evident and can direct PHEV users to make informed decisions. **Important to note that the weighted combined is a theoretical test cycle and shall not be interpreted as the exact behaviour of the average PHEV user, instead it should be interpreted as an example of a PHEV user that charges their car very frequently and rarely fuels their car with petrol.** The results are disaggregated and analyzed in more depth in Appendix A.

In Table 3, rounded numeric values of the results are presented.

*Table 3. Rounded results (Tonne $CO_2$ equivalents) per functional unit of driving a Lynk & Co car for 200 000 km.*

| Life cycle phase (fuel/electricity mix in the use phase) | Material production | Li-ion battery | Manufacturing and logistics | Use phase | EoL | Total |
|---|---|---|---|---|---|---|
| Combined (Petrol) | 12 | 2.4 | 2.0 | 41 | 1.3 | 59 |
| Weighted combined (Coal power) | 12 | 2.4 | 2.0 | 42 | 1.3 | 59 |
| Weighted combined (EU grid mix) | 12 | 2.4 | 2.0 | 18 | 1.3 | 35 |
| Weighted combined (Wind power) | 12 | 2.4 | 2.0 | 6.5 | 1.3 | 24 |

## 3.1 Sensitivity analysis

Sensitivity analysis in an LCA study is done to investigate and quantify certain important parameters and uncertainties. The choice of electricity mix used when driving the car was such an important parameter that it is presented already as the main results but there are some more interesting things to explore in a sensitivity analysis. First, it is investigated how the choice of functional unit affects the results and how the incorporation of occupancy in the car could be possible. A different functional unit is therefore explored, and two more scenarios are introduced to give examples of different kinds of car mobility, sharing and carpooling. Secondly, it is analysed how the electricity grid mix in Europe is projected to change during the next 10-15 years. Thirdly, an analysis of how going from primary aluminium to different shares of recycled aluminium would affect the results.

### 3.1.1 Sharing and carpooling

Since Lynk & Co is using a business model that also allows for sharing of the vehicle, this section will provide a further understanding of the environmental benefit of such a business model and how that relates to a carpooling and non-sharing scenario. Carpooling is here defined as a scenario where there are at least two passengers in the car at all times. However, the effects of sharing and carpooling cannot be evaluated using the current functional unit and another, which can take into account the number of passengers in the vehicle, must be used. The new functional unit for this analysis is "passenger kilometres", which means that the previous results have been divided by the lifetime distance (kilometres) and number of passengers. The same lifetime of the vehicle is assumed (200 000km) and Table 4 below describes the different scenarios of **no-sharing**, **sharing** and **carpooling**. The **no-sharing** scenario can be seen as the conventional use case, where someone is owning a car and it is only used by that person. In the **sharing** scenario two persons are sharing one car which means that the environmental burden of production is assumed to be divided by two persons instead of one in the no-sharing scenario, the car is still driven by only one person at the time. The **carpooling** scenario means that the environmental burden of both the production and use phase is divided by two passengers since this use case is defined as there is an average of two passengers travelling in a Lynk & Co vehicle together. Since there is a lack of real-world data on this matter, two have been assumed as a proxy to evaluate two hypothetical scenarios. This shall not be interpreted as a reflection of reality but rather an example of how the environmental burden could be allocated between users under different mobility scenarios.

*Table 4. Information about the analyzed theoretical scenarios.*

| Scenario | How is the environmental burden distributed? |
|---|---|
| **No-sharing** | The environmental burden from the whole life cycle is divided by one person (owner) |
| **Sharing** | The environmental burden of production is divided by 2 persons, and the use phase by 1 person |
| **Carpooling** | The environmental burden of the whole life cycle is divided by 2 persons |

The results for each scenario are illustrated in Figure 6. If a sharing concept could attract people to share one vehicle instead of having two vehicles, the environmental burden would be lower for both combined and weighted combined. It would also be a more efficient use of resources since only one vehicle needs to be produced to perform the same mobility services as two vehicles. However, the most efficient way, from a climate change perspective, is a Lynk & Co vehicle that can be used as a carpooling service. This would in theory, decrease the need for additional production of cars as well as the number of trips needed for the same mobility needs.

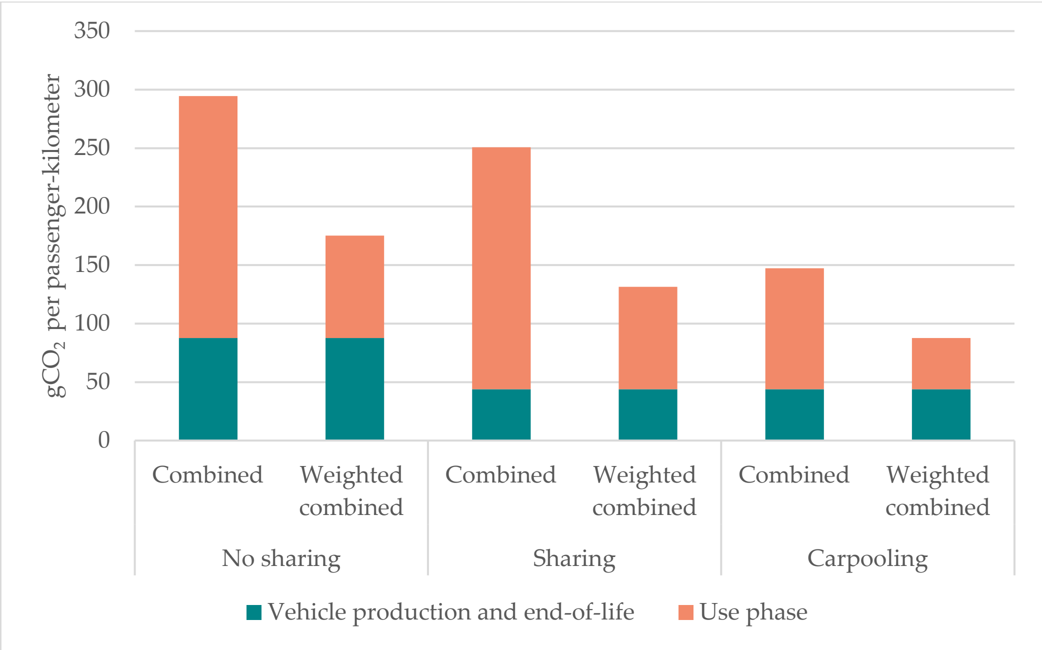


*Figure 6. Results per passenger kilometers for three different scenarios. The combined scenario uses petrol only and weighted combined use a majority of the EU electricity grid mix and a small share of petrol.*

### 3.1.2 Future electricity grid mix

As concluded in the above chapters, the environmental impact of the Lynk & Co 01 car is highly dependent on the use of low-carbon electricity. To get an understanding of the future performance of different electricity markets, the International Energy Agency (IEA, 2021) provides several different prognoses which have been implemented in the LCA FE software. In Figure 7, two scenarios for 2030 based on IEA prognoses are presented together with the already presented results for the Lynk & Co car driving on only petrol and driving with a majority of external electricity from the current average EU electricity grid mix. The two scenarios from IEA are **STEPS** (Stated Policies Scenario) and **SDS** (Sustainable Development Scenario). STEPS reflects current policies that are in place and those that are under development. SDS reflects what is needed to reach a global net zero by 2070 (with many countries reaching net zero much earlier) while achieving key energy-related SDGs (United Nations Sustainable Development Goals) related to universal energy access and clean air.


*Figure 7. Results for 200 000km driving with different electricity mixes, current and future.*

### 3.1.3 Recycled aluminium

Using recycled aluminium saves a significant amount of energy and reduces the impact on climate change as a consequence. Since the base case in this study assumes zero percent recycled aluminium due to lack of reliable data, this parameter is tested in a sensitivity analysis. To illustrate the impact of using recycled aluminium, two hypothetical cases are used. One where 30 % of the aluminium in the car comes from recycled content and one where 50 % comes from recycled content. This change could potentially decrease the total climate impact during the vehicle life cycle by 1.2 and 2 tonnes $CO_2e$ respectively (total for the whole life cycle ranges between 24-59 tonnes $CO_2e$). The two cases compared to the base assumption are presented in Figure 8. It compares the results for material production where the production of the battery, manufacturing, use and EoL is excluded.

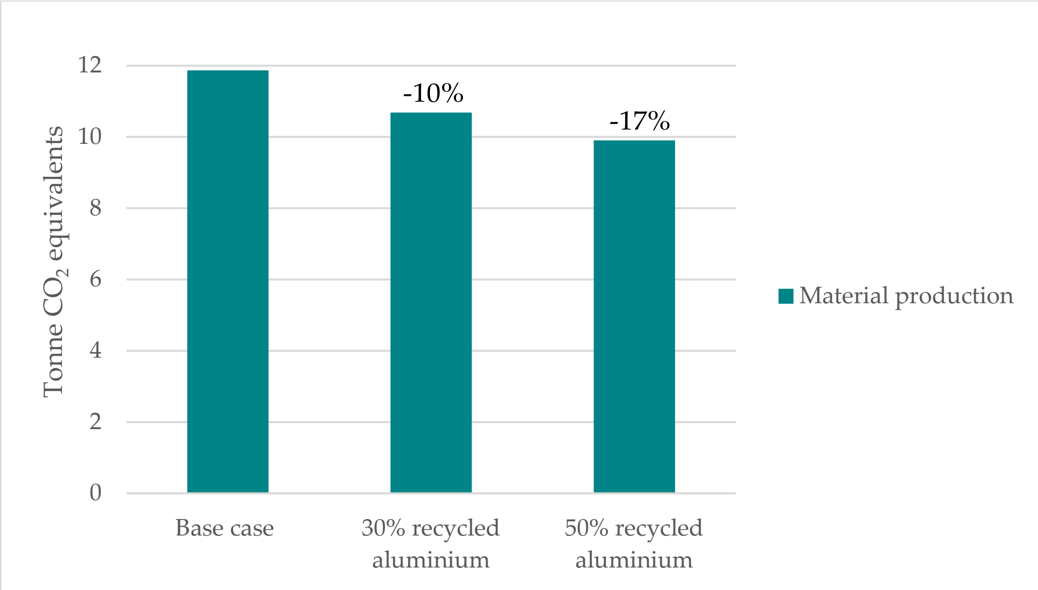


*Figure 8. Results of using more recycled aluminium in the vehicle.*

# 4 Conclusions and recommendations

The result of this study indicates that the climate change impact from the Lynk & Co 01 PHEV is highly variable depending on how much the user charges the car and what electricity mix is used. Not charging at all or charging solely with coal power indicates a climate change impact of roughly 59 tonnes of $CO_2$e. The impact on climate change when charging with wind power or the average European grid mix ranges from roughly 24-35 tonnes $CO_2$e.

It is important to thus remember that the PHEV's impact on climate change is highly variable depending on the individual user, but a general conclusion is that the use phase is the most important hot spot to tackle. How to tackle this could be making sure to inform customers on how to reduce their impact by choosing how much they charge and what kind of electricity mix they have access to. Informing and/or nudging customers to share their cars both in sharing services as well as carpooling to reduce the number of cars needed to fulfil the same mobility needs in a fleet is also important to make use of resources more efficiently.

Since the car will be used for around 10-15 years, the electricity grid mix in Europe will evolve and see an increased share of renewables. How much is unclear and that is why two different scenarios were presented, one to represent a more conservative scenario where already existing and decided policies are implemented and one scenario that represents what is needed to meet globally agreed targets.

While the use of the vehicle contributes to the majority of the climate change impact, material production is the second largest hot spot and becomes increasingly important when charging with renewable electricity. The following materials and components contribute the most:

- Aluminium
- Steel & iron
- Li-ion battery
- Polymers and elastomers

As the next steps, Lynk & Co could start working with suppliers to collect specific data and minimize their environmental impact on the materials and components mentioned above. It is also recommended to use the outcomes of this study to educate the users of the vehicle on the variability of the climate change impact of this car and nudge customers to use the vehicles efficiently, charge frequently and with fossil-free electricity whenever possible.

Lynk & Co could also start the work of implementing a systematic way to aggregate materials and substances from IMDS. The inclusion of maintenance in the next studies and investigation of the need for battery replacement is recommended.

# 5 References

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# Appendix A: LCA report

In this appendix is the LCA reported according to the format specified in the ISO 14044 standard. The 4 steps of the LCA report are goal and scope, inventory analysis, impact assessment and interpretation. In the appendix is the goal and scope and inventory analysis presented, while the interpretation of the result is found in the chapter result and discussion above.

## Goal and scope

In this chapter is the goal and scope of this LCA defined and explained. It is in this part of the report that the primary objectives of the study are listed and where the scope of the project is described. The goal and scope should act as guidelines to perform the assessment as well as help the reader of the report to understand key assumptions, system boundaries, limitations and other aspects influencing the results. Another important element of the goal and scope is the definition of the functional unit, which is the reference unit by which the inputs and outputs of the LCA are scaled.

### Goal

The goal of the study is to evaluate the carbon footprint of the Lynk & Co 01 car and identify hotspots where efforts to reduce the climate impact will matter the most. Another goal is to assess how different charging behaviour changes the impact on climate change and the outcome of this study is intended to be used as a basis for GHG protocol reporting, external communication and learning material for internal stakeholders at Lynk & Co.

### Scope

The study performed is a life cycle assessment (LCA) for greenhouse gas emissions only: a so-called carbon footprint. The study includes the vehicle life cycle from cradle-to-grave, starting with extracting and refining of raw materials and ending with the end-of-life of the vehicle.

Major assumptions, uncertainties and cut-offs are described more thoroughly below. The emissions from the life cycles of infrastructure are included when they are available in the LCA databases but no active data collection or modelling of infrastructure has been carried out in this study, such as charging infrastructure. Generic data, as opposed to supplier-specific data, are used for all the upstream processes, such as raw materials production and manufacturing processes.

The production data are for the current situation, which means that the carbon intensity of the electricity mix for driving is also historic, although it will change during the car's lifetime. The effect of this approach was tested in a sensitivity analysis. The inclusion of the sensitivity of the used electricity mix when charging the vehicle as well as the effects of car sharing and thus another functional unit is also explored in the report.

## Type of LCA

This methodology follows a strictly attributional approach considering the environmental impact category climate change on the detail level of a complete vehicle. An attributional LCA estimates the environmental impact that belongs to the studied system.

## Functional unit

A functional unit is used to relate the result to a fixed factor, to enable comparison of different cases based on the prerequisites of a certain function. This is important both when comparing results, but also important to understand in what cases the LCA results are valid as the results showing the environmental impacts are given in light of this function.

The desired function of a car is to transport passengers.

**Chosen functional unit: Use of the Lynk & Co 01 car driving 200 000km.**

The results are presented as kg $CO_2$-equivalents per functional unit.
The amount of material needed, weight, durability and use phase details all relate to being able to perform this function.

Alternative functional units are explored in a sensitivity analysis to be able to better capture the potential impact of car sharing which is closely related to the business model of Lynk & Co.

# Studied product systems

The study investigates the climate change impact of the Lynk & Co 01 car along its life cycle. The Lynk & Co 01 car is engineered and developed in Sweden by Cevt, designed in Sweden by Geely Design and produced by Lynk & Co in China. The system boundaries of the study are illustrated in Figure 9.

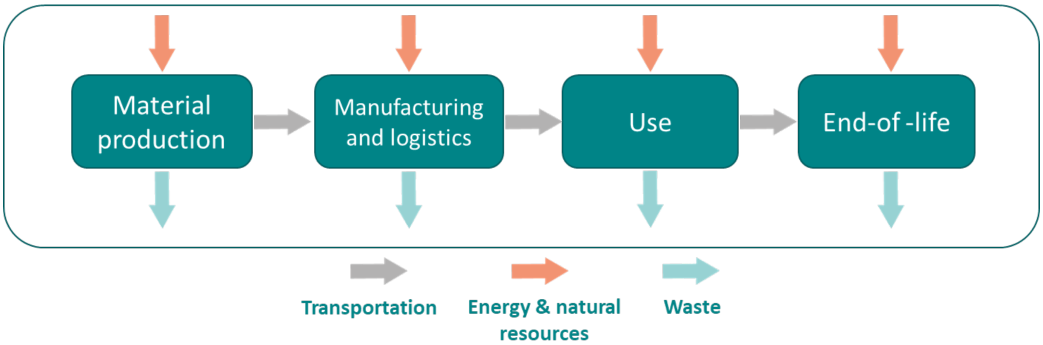


*Figure 9. System boundaries.*

The car is a plug-in hybrid vehicle (PHEV) which means it has both a combustion engine as well as an electric motor and a Li-ion battery for propulsion. More information about the car can be found in Table 5.

*Table 5. Technical specification of the car.*

| Product | Vehicle type | Total weight (kg) | Pure electric range (km) | Battery Chemistry | Battery weight (kg) | Battery energy (kWh) |
|---|---|---|---|---|---|---|
| Lynk & Co 01 | PHEV | 1897 | 69 | NMC 811 | 137 | 22 |

# System boundaries

In this section, the applied system boundaries of the LCA are specified. Aspects such as boundaries towards nature and geographical boundaries, as well as methodological aspects concerning system expansion and allocation, are defined and explained.

## Boundaries towards nature

This study is a cradle-to-grave assessment, which means that the whole value chain has been covered i.e. the production of fuels, electricity and raw materials are followed from the cradle where the natural resources (e.g. crude oil or uranium) are extracted from the ground. The life cycle also covers all relevant transportation as well as the end-of-life management of the products i.e. the "grave" in terms of the soil (after human activity has ceased), the air (e.g. emissions from combustion of fuels) or water (e.g. water emissions from wastewater treatment).

### Geographical boundaries

The material production is mostly modelled with average generic data representing a global scope as far as possible. The operation is assumed to take place in Europe where the vehicle is sold. Other electricity grid mixes as well as future ones will be explored in the sensitivity analysis since the variation is predicted to be large.

### System expansion

System expansion means that the systems are expanded to reflect the environmental benefit associated with for instance produced energy (electricity and heat produced in waste incineration of used products) and with recycled materials (produced in material recycling). System expansion is not applied in this study.

### Allocation

Often allocations are required in LCA studies. This is, for instance, relevant for multioutput processes generating several products and co-products, where it is necessary to distribute (allocate) the environmental impact between these. For this LCA, allocation is not applied (not needed) since the processes studied are not multioutput processes.

## Important methodology choices and key assumptions

The LCA has to a large extent been aligned with the general and common rules according to the requirements of ISO 14044:2006. In general, assumptions have been made conservatively as proposed by Volvo Cars (Volvo Cars, 2021) and Polestar (Polestar, 2021), in order not to underestimate the impact of uncertain data. Additional processes have been added to the model when needed to represent actual emissions more accurately. The inventory does not include:

- Processes at Lynk & Co such as business travels, R&D activities or other indirect emissions not directly linked to the product
- Lynk & Co infrastructure e.g., production and maintenance of buildings, inventories or other equipment
- Construction and maintenance of roads in the use phase
- Emissions from tyres and road wear in the use phase
- Maintenance of the vehicle in the use phase

## Selected impact categories

The impact indicator studied in the life cycle assessment is climate change impact, see Table 6. The indicator is based on the definition in CML2001 and updated in Aug 2016. For climate change impact, the impact from biogenic carbon dioxide is out of scope. This includes carbon dioxide sequestration of the raw materials as well as the impact of emissions at the end of life. The reason for excluding biogenic carbon dioxide emissions is that they are considered net zero over a longer period and will not impact the result.

*Table 6: Environmental impact categories.*

| Impact category | Category indicator | Reference |
|---|---|---|
| Global warming potential (GWP) | g $CO_2$ equivalents | CML2001 - Aug 2016 |

## Review procedure

This study and report have been internally reviewed and approved in accordance with IVL's audited and approved management system. No third-party review has been performed.

# Inventory

This section gives an overview of the data collection process, data and information collected and used in the analysis. In the first section is the data for material production presented. This is followed by a description of the data used to model manufacturing, operation and waste management. The modelling of the systems has been conducted using the LCA-software LCA FE (formerly known as GaBi).

# Material production

## Steel

As the most common material in a car, steel has a high importance in the assessment. However, it is quite difficult and time consuming to determine the route of processing the steel by simply analyzing the BOM and material names from suppliers. Therefore, Geely instead gave an engineering estimate for the share of hot rolled (20 %), cold rolled (10 %) and hot dip galvanized steel (70 %) in the car. All steel in the vehicle was then assumed to be rolled and stamped to desired thickness and shape in line with Volvo Cars and Polestars LCA methodology. The scrap generated in the processes of making the steel parts for the vehicle is included in the carbon footprint, since a cut-off is applied at the point of scrap being generated in the factory, the total footprint of generating the scrap is allocated to the vehicle. The material utilisation rate (MUD, the degree of utilised material of the total amount needed for producing a part) for the generic manufacturing process of steel stamping can be seen in Table 10.

## Aluminium

No information on the share of recycled aluminium has been possible to gather and thus has all the aluminium been modelled with primary production. This can be viewed as a worst-case scenario but is in line with Volvo Cars and Polestars LCA methodology. Based on information in the BOM, 27 % of the aluminium has been categorised as wrought and 73 % as cast. Aluminium that could not be classified as either cast or wrought has been assumed to be wrought and is included in the share presented above.

All wrought aluminium was assumed to go through the process of making aluminium sheets and the cast aluminium goes through a process for die casting.

The scrap generated in the processes of making the aluminium parts for the vehicle is included in the carbon footprint. The material utilisation rate (MUD) for the generic manufacturing processes of both cast aluminium and wrought aluminium can be seen in Table 10.

## Li-ion battery

Supplier data for the battery was not attainable during the data collection process and therefore database data had to be used. The Li-ion battery was separated from the BOM and modelled separately from the other materials and components, this was done since the dataset from ecoinvent 3.8 scaled based on the weight of the total NMC811 battery and not the individual materials in the battery. The dataset was adjusted to reflect the studied batteries energy density since the energy density of the battery was slightly different compared to the one documented in the ecoinvent dataset.

## Electronics

The material category "Electronics" includes printed circuit boards (PCBs) and the components mounted on them. It does not include chassis, cables or other parts that are present in electronic components. All materials that are used in electronic devices that are deemed not to be PCBs have been sorted into other categories, such as copper or different types of polymers. For the category "Electronics" a generic dataset from ecoinvent 3.8 has been used. This dataset represents the production of a lead-free, mounted PCB.

## Polymers and elastomers

The BOM from Geely only contained highly aggregated categories for polymers and elastomers which was too few to be able to assess adequately. Using a more detailed BOM, a share of specific polymers could be established, see Table 7 for polymers and Table 8 for elastomers.

*Table 7. Share of plastics classified as polymers.*

| Material | Share (%) |
|---|---|
| Polypropylene (PP) | 40 |
| Polyamide (PA) | 14 |
| Polyethylene (PE) | 14 |
| Acrylonitrile butadiene styrene (ABS) | 13 |
| Polycarbonate (PC) and PC/ABS | 12 |
| Polybutylene Terephthalate (PBT) | 5 |

| | |
|---|---|
| Polyethylene terephthalate (PET) | 1 |
| High-density polyethylene (HDPE) | 1 |

*Table 8. Share of rubbers classified as elastomers.*

| Material | Share (%) |
|---|---|
| Tyre rubber | 62 |
| EPDM | 26 |
| Silicon rubber | 5 |
| NR | 4 |
| CR | 1 |
| NBR | 1 |
| FKM | 1 |

Tyre rubber is modelled as a mix of Styrene-butadiene rubber (35 %), natural rubber (27 %) and carbon black (38 %).

All thermoplastics have been modelled using injection moulding while elastomers have been assumed to be vulcanized. A full list of additional manufacturing processes and the material utilization degree can be found in Table 10.

## Processing of other materials

There are materials for which data on processing is missing in the LCA databases used. In those cases, the material weight was doubled as an estimation for the processing and material losses (as proposed by Volvo Cars (Volvo Cars, 2021) and Polestar (Polestar, 2021)). This means that the manufacturing process is assumed to have the same carbon footprint as the production of the raw material itself. This has been applied only for minor materials (by weight).

## Electricity use in material production

A global average electricity mix has been applied for materials production and refining. This was modelled using statistics from the International Energy Agency

(IEA, 2022) and electricity production datasets in LCA FE, since there is no existing dataset for global electricity mix in that database. This electricity mix is used for a few partially aggregated processes in the LCA fo Experts databases where it is possible to add an electricity mix.

# Manufacturing and logistics

After the material production and component manufacturing has taken place, the car needs to be assembled and shipped to the customer. The following sections explain the data collection of this part of the life cycle.

## Manufacturing

The Lynk & Co 01 PHEV car is produced in the Geely factory in Yuyao China. The factory purchased hydropower from the grid in 2022 and produces electricity on-site using Solar PV. The total factory data for 2022 has been divided by the number of produced cars during the same year. The factory uses mainly electricity, natural gas and steam to produce the vehicles. Production and packaging waste as well as water use is included in the data collection.

## Logistics

Logistics data comes from Lynk & Co through both Geely and Volvo Cars which is involved in the production and transportation of the vehicle. The data is classified as transportation from tier 1 to the factory and from the factory to the port as well as transportation to Europe and distribution within Europe. The climate impact from logistics comes directly from Lynk & Co and has not been modelled by IVL.

# Use phase

The use phase data comes from the WLTP drive cycles (Worldwide Harmonized Light Vehicle Test Procedure used for certification of vehicles in the EU). Since Lynk & Co 01 is a plugin hybrid, the evaluation is done in two different drive cycles and they are named **combined** and **weighted combined**. In the combined drive cycle the vehicle is not charged from any external electricity sources, only electricity from regeneration is considered. In the cycle called weighted combined, external electricity and the combustion engine is powering the vehicle. Since these are theoretical test cycles, care should be taken when interpreting the results. Most PHEV users do not follow the behaviour of either the combined or weighted combined scenario, but rather a mix of them. The weighted combined cycle assumes a high degree of charging that might not be realistic for the average PHEV user.

The fuel and energy related GHG emissions associated with the actual driving of the vehicle are divided into two categories:

**Well-to-tank (WTT)** – Includes the environmental impact caused during the production and distribution of the fuel or electricity used. Data for fuel, when the combustion engine is in operation, is from LCA FE. Electricity production is modelled according to regional (global or EU28) grid mix or as a specific energy source (wind or coal).

**Tank-to-wheel (TTW)** – Includes the tailpipe emissions during use and are based on the WLTP driving cycle. These emissions are described in Table 9.

Data from the WLTP drive cycle was also used for electricity consumption when the electric motor is in operation (Table 9).

Additional charging losses (other than what is recorded in the WLTP drive cycles) are excluded, and tail-pipe emissions only include carbon dioxide emissions, methane and nitrous oxide emissions (CH4 and N2O) are excluded. CH4 and N2O contribute a minor fraction of total tailpipe GHG emissions and the exclusion of these emissions does not influence the conclusions of this study.

*Table 9. Specification on the use phase.*

| Drive cycle | $CO_2$ emissions | Fuel consumption (Petrol) | Electricity consumption | Description |
|---|---|---|---|---|
| Combined | 163 g $CO_2$/km | 7.2 L/100km | N/A | No external electricity source considered |
| Weighted Combined | 24 g $CO_2$/km | 1.0 L/100km | 185 Wh/km | Combination of external electricity and combustion |

# End of life

When the vehicle has reached its end-of-life, it is assumed to be collected and sent for end-of-life treatment. When the car is collected, it is assumed to go through dismantling and pre-treatment (shredding and specific component pre-treatment), see Figure 10. Material separation, refining or any credit for reuse in another product system is excluded from the modelling since it follows the polluters pay principle. The first treatment step is disassembly to remove hazardous components and components that are candidates for specific recycling or reuse efforts. The disassembled parts are treated, and the remaining vehicle is shredded. Depending on material type the resulting fractions go either to material recycling, incineration, or landfill.

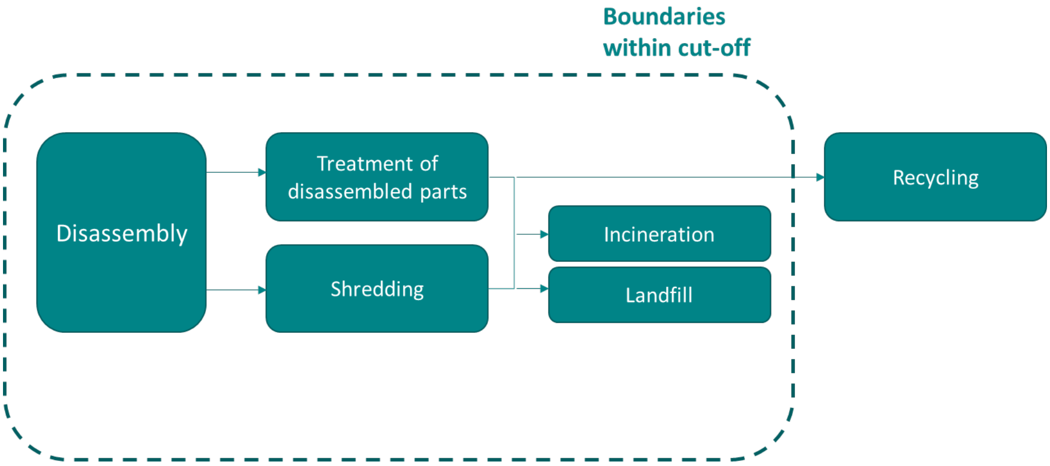


*Figure 10. End-of-life modelling.*

The metal fractions can be sent for further refining and in the end material recycling. The combustible part of the light fraction is incinerated with energy recovery. Non-combustible materials are landfilled. Assessment of material losses after shredding and refining are outside the system boundaries set by the cut-off approach.

In the disassembly stage, hazardous and/or valuable components are removed from the vehicle. These include:

- Batteries
- Fuel
- Wheels

- Liquids
- Oils
- Catalytic converter

Treatment of fuels, oils and coolants has been assumed to be incineration. The tyres are assumed to be salvaged for rubber recovery, and the lead batteries for lead recovery. The catalytic converter contains valuable metals and is disassembled for further recycling efforts. Oil filters are assumed to be incinerated. The Li-ion battery is assumed to be taken out of the vehicle and sent to recycling. All other parts of the vehicle are sent to shredding. In this process, the materials in the vehicle are shredded and then divided into fractions depending on different physical and magnetic properties. Electricity use during shredding is modelled based on information from ecoinvent. A transportation distance of 1 500km is used to model a proxy distance to a recycler. Shredding is assumed to occur at the same place as the dismantling.

# Detailed results

## Material production

Looking a bit closer into the contribution to climate change of each material category in Figure 11 we can see that the top five materials are: Aluminium, steel, Li-ion battery, Polymers and elastomers, and electronics.

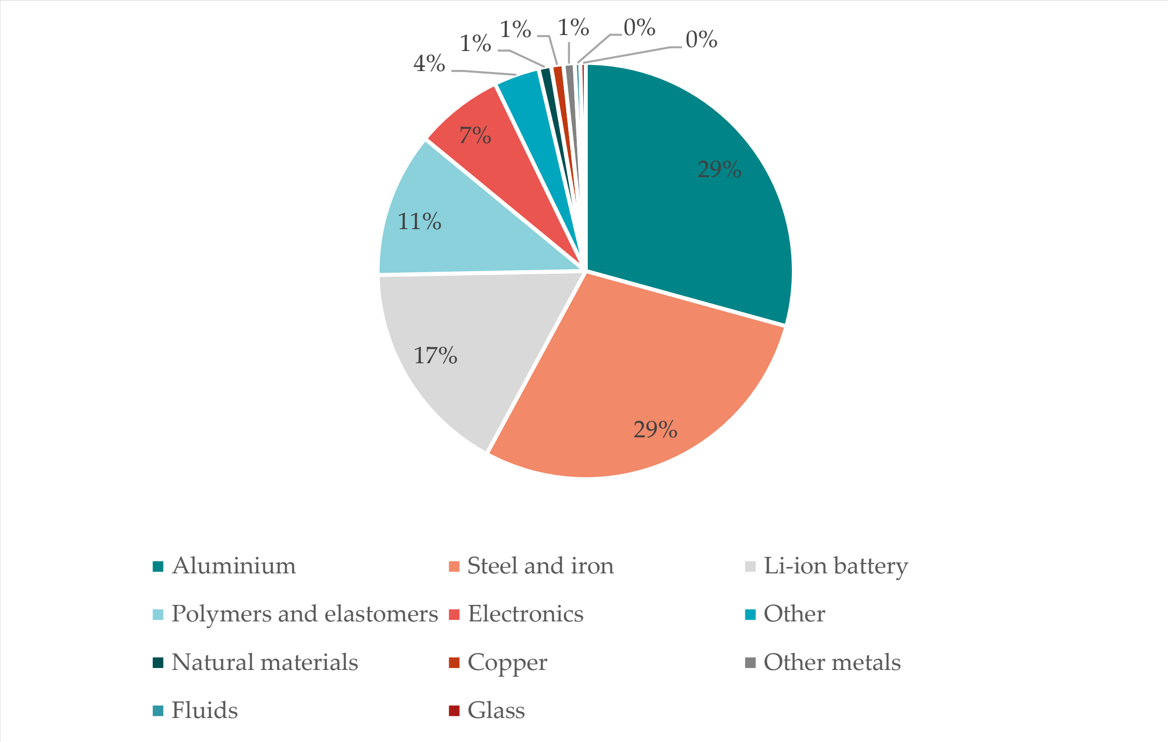


*Figure 11. Results for material and battery production.*

Aluminium has a relatively large impact on climate change and is highly dependent on the electricity mix used in the smelting process, which in this study is a global one. Modelling all the aluminium in the car as primary also contributes to the higher share since primary aluminium production has a higher impact than recycled aluminium. The effect of this choice is explored in the sensitivity analysis.

Steel and iron also have a high impact on climate change and this is mainly due to the use of unalloyed/low-alloyed steel in the car. Steel was assumed to be produced with the most common process route called Blast Furnace-Basic Oxygen Furnace (BF-BOF).

Battery has a large impact on climate change and the main contributors are the material production of active materials for the cathode and the energy demand in cell production.

Polymers contribute to roughly 11% of the impact of climate change and since there are a lot of different polymers and elastomers in this category there is no individual polymer or elastomer that is a huge hotspot. However, polyamide (PA), Polycarbonate (PC) and Polypropylene together contribute the most of all the polymers and tyre rubber for elastomers.

Electronics stands out a bit more in the results since there is such a small amount present in the vehicle itself but has a significantly larger share of the impact on climate change.

## Use phase

The environmental assessment of the use phase for the Lynk & Co vehicle is done according to WLTP (Worldwide Harmonised Light-Duty Vehicles Test Procedure), and since the use phase is the life cycle stage that consumes the most energy, the environmental impact of this stage will be highly dependent on which fuel or electricity that is used. To illustrate the variation of environmental impact, the impact of the two different drive cycles is shown in Figure 12. One can see a significant difference between **combined** and **weighted combined** when weighted combined is powered by wind and European grid mix. If the weighted combined is powered by electricity produced from coal, there is almost no difference between the two drive cycles.

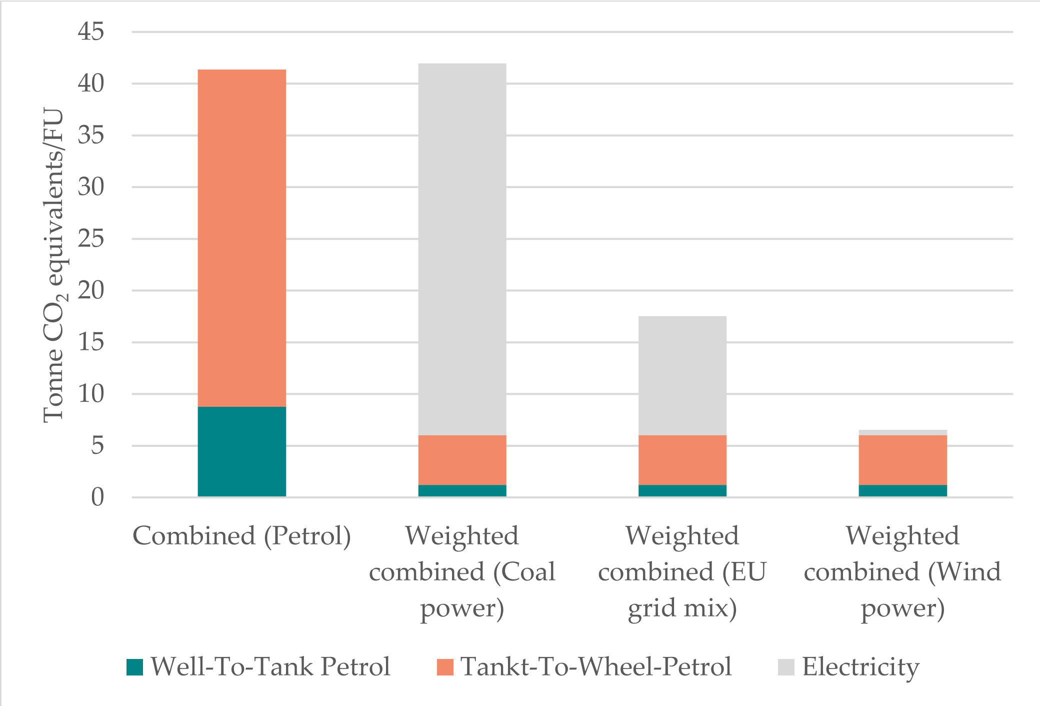


*Figure 12. Results for the use phase of the car.*

## Manufacturing and logistics

Manufacturing and logistics contribute to roughly two tonnes of $CO_2e$ combined where logistics alone stands for 90 % of the impact. That is mainly due to the logistics from China to Europe and transportation within Europe. Manufacturing stands for 10 % of the impact and it is natural gas used at the site that contributes to most of the impact since the electricity purchased comes from wind power and electricity produced from solar PV on site. If the purchased electricity would have been the average Chinese electricity grid mix, the electricity use would have been the major contributor and the total figure for manufacturing would have tripled.

## End-of-life

At the vehicle's end-of-life, the incineration of combustible materials and fluids stands for the majority of the climate change impact as can be seen in Figure 13. The total climate change impact for end-of-life is roughly 1.3 tonnes.

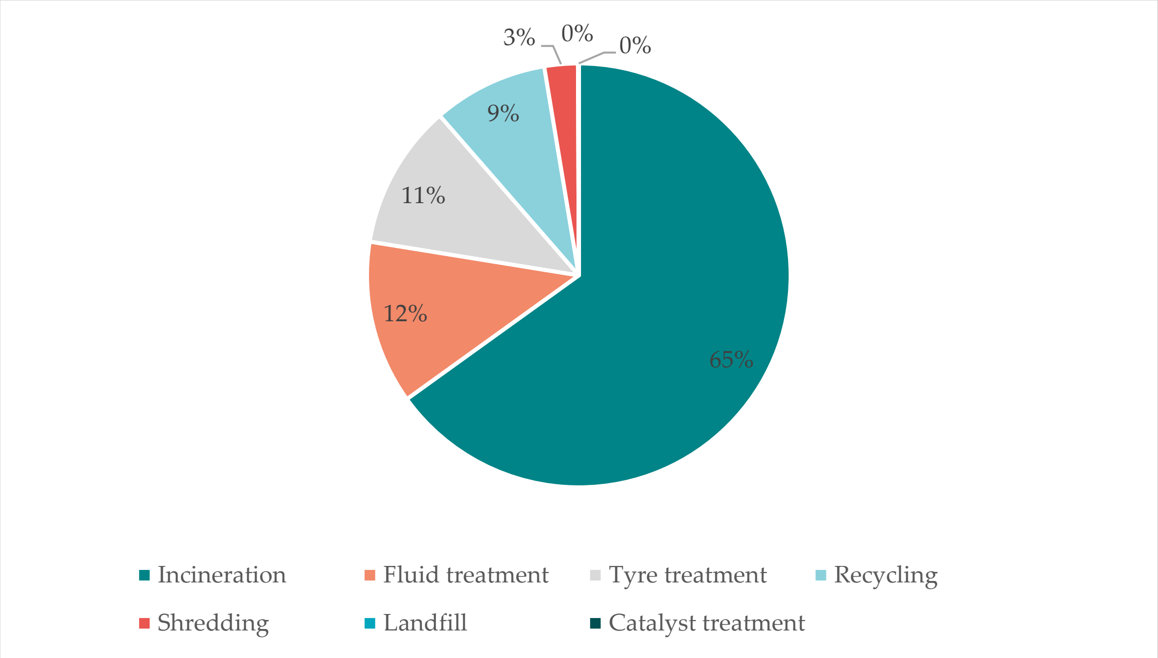


*Figure 13. Results for the End-of-Life treatment.*

# Appendix B. Details on inventory

This part of the appendix summarizes the list of component manufacturing.

*Table 10. Assumptions on component manufacturing.*

| Material | Assumption on component manufacturing | Comment | Material utilisation degree |
|---|---|---|---|
| Cast iron | No extra manufacturing processes | Chosen dataset already includes the production of a finished part | |
| Fluids | No extra manufacturing processes | Fluids are assumed to not need additional processing | |
| Elastomers | Vulcanisation | Vulcanisation of the rubber is needed | 70% |
| Electronics | No extra manufacturing processes | Chosen dataset already includes the production of a finished part | |
| Copper wire | No extra manufacturing processes | Assumed that processing is negligible | |
| Cast aluminium | Die-casting process | | 95% |
| Wrought aluminium | Rolling + sheet deep drawing | Aluminium sheet part production | 63% |
| Steel | Sheet deep drawing | Sheet is assumed in line with the conservative approach proposed by Volvo Cars and Polestar | 63% |
| Polymers | Injection moulding process | Assumed as a generic polymer processing | 97% |

| | | | |
|---|---|---|---|
| Other materials | Raw material weight x2 | Emissions from raw material production have been multiplied by two, to compensate for further unknown refining and component manufacturing | 50% |

# Appendix C. Database data and data creation

All database data used in the study is presented in Table 11.

*Table 11. Datasets used in LCA modelling.*

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| Adhesives, sealants | EU | Silicone sealing compound |
| Aluminium and aluminium alloys | GLO | Aluminium ingot - cradle to gate |
| | GLO | Aluminium ingot mix IAI 2015 |
| Brake fluid | GLO | market for diethylene glycol ecoinvent 3.8 |
| Cast aluminium alloys | GLO | Aluminium ingot - cradle to gate |
| | GLO | Aluminium ingot mix IAI 2015 |
| Cast iron with lamellar graphite / tempered cast iron | DE | Cast iron part (automotive) |
| | GLO | Electricity grid mix |
| | EU | Thermal energy from Natural gas |
| Cast iron with nodular graphite / vermicular cast iron | DE | Cast iron part (automotive) |
| | GLO | Electricity grid mix |
| | EU | Thermal energy from Natural gas |
| Cast iron | DE | Cast iron part (automotive) |
| | GLO | Electricity grid mix |
| | EU | Thermal energy from Natural gas |
| Cast magnesium alloys | CN | Magnesium Sphera |
| | DE | Magnesium die-cast part |
| Ceramics / glass | EU | Float flat glass |
| Coolant / other glycols | EU | Ethylene glycol |
| | EU | Ethylene glycol |
| Copper (e.g. copper amounts in cable harnesses) | EU | Copper wire |
| | EU | Copper Wire Mix |

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| | | |
| Copper alloys | GLO | Copper mix |
| | GLO | market for tin ecoinvent 3.8 |
| Duromers | DE | Epoxy Resin |
| | DE | Polyvinyl Butyral Granulate (PVB) |
| Elastomers / elastomeric compounds | DE | Ethylene Propylene Diene Elastomer (EPDM) |
| | DE | Natural rubber (NR) (excl. LUC emissions) |
| | DE | Nitrile butadiene rubber, incl. MMA |
| | DE | Styrene-butadiene rubber (S-SBR) mix |
| | DE | Chloroprene rubber (Neoprene) |
| | DE | Silicone rubber |
| | DE | Tyre rubber |
| | DE | Natural rubber (NR) (excl. LUC emissions) |
| | DE | Styrene-butadiene rubber (S-SBR) mix |
| | DE | Carbon black (furnace black; general purpose) |
| Electrics | GLO | Market for printed wiring board, surface mounted, unspecified, Pb free ecoinvent 3.8 |
| Electronics (e.g. pc boards, displays) | GLO | Market for printed wiring board, surface mounted, unspecified, Pb free ecoinvent 3.8 |
| Fuels | EU | Gasoline mix (regular) at refinery |
| Highly alloyed cast iron | DE | Cast iron part (automotive) |
| | GLO | Electricity grid mix |
| | EU | Thermal energy from Natural gas |
| highly alloyed | EU | Stainless steel |
| | EU | Stainless steel cold rolled coil (304) |
| Lacquers | EU | Solvent paint white |
| Lead | DE | Lead (99,995%) |
| Lubricants | EU | Lubricants at refinery |
| Magnesium alloys | CN | Magnesium Sphera |
| Modified organic natural materials (e.g. leather, wood, | EU | Modified organic natural materials |
| | EU | Kraftliner |

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| cardboard, cotton fleece) | EU | Leather |
| Nickel alloys | GLO | Nickel |
| NMC811 battery | GLO | Market for battery, Li-ion, NMC811, rechargeable, prismatic ecoinvent 3.8 |
| Other compounds (e.g. friction linings) | DE | Carbon black |
| | DE | Carbon black (furnace black; general purpose) |
| Other duromers | DE | Epoxy Resin (EP) Mix |
| | DE | Polyvinyl butyral granulate (PVB) |
| | GLO | Market for glass fibre ecoinvent 3.8 |
| Other fuels and auxiliary means | EU | Gasoline mix (regular) at filling station |
| Other special metals | EU | Copper Wire Mix |
| | DE | Lead |
| | GLO | Silver mix |
| | GLO | Gold (primary) |
| | GLO | Market for chromium ecoinvent 3.8 |
| | GLO | Market for permanent magnet, for electric motor ecoinvent 3.8 |
| | GLO | Market for tin ecoinvent 3.8 |
| Plastics (in polymeric compounds) | GLO | Market for acrylonitrile-butadiene-styrene copolymer ecoinvent 3.8 |
| | GLO | Market for polypropylene, granulate ecoinvent 3.8 |
| | GLO | Market for nylon 6 ecoinvent 3.8 |
| Platinum / rhodium | GLO | Platinum mix Sphera |
| Polyurethane (PU) | EU | Market for polyurethane, rigid foam ecoinvent 3.8 |
| Preservative | EU | Aromatics (BTX) at refinery Sphera |
| Refrigerant | GLO | Refrigerant R-1234yf |
| Steels / cast steel / sintered steel | GLO | Steel finished cold rolled coil worldsteel |
| | GLO | Steel hot rolled coil worldsteel |

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| | GLO | Steel hot dip galvanised worldsteel |
| Textiles (in polymeric compounds) | EU | Polyamide 6.6 fibres (PA 6.6) |
| | EU | Polyethylene terephthalate fibres (PET) |
| Thermoplastic elastomers | DE | Polybutylene terephthalate granulate (PBT) mix |
| | GLO | market for acrylonitrile-butadiene-styrene copolymer ecoinvent 3.8 |
| | GLO | market for polycarbonate ecoinvent 3.8 |
| | GLO | market for polyethylene terephthalate, granulate, amorphous ecoinvent 3.8 |
| | GLO | market for polyethylene, high density, granulate ecoinvent 3.8 |
| | GLO | market for polyethylene, low density, granulate ecoinvent 3.8 |
| | GLO | market for polypropylene, granulate ecoinvent 3.8 |
| | GLO | market for nylon 6 ecoinvent 3.8 |
| Thermoplastics | DE | Polybutylene terephthalate granulate (PBT) mix |
| | GLO | market for acrylonitrile-butadiene-styrene copolymer ecoinvent 3.8 |
| | GLO | market for polycarbonate ecoinvent 3.8 |
| | GLO | market for polyethylene terephthalate, granulate, amorphous ecoinvent 3.8 |
| | GLO | market for polyethylene, high density, granulate ecoinvent 3.8 |
| | GLO | market for polyethylene, low density, granulate ecoinvent 3.8 |
| | GLO | market for polypropylene, granulate ecoinvent 3.8 |
| | GLO | market for nylon 6 ecoinvent 3.8 |
| Titanium and titanium alloys | GLO | market for titanium ecoinvent 3.8 |
| unalloyed, low alloyed | GLO | Steel finished cold rolled coil worldsteel |
| | GLO | Steel hot rolled coil worldsteel |
| | GLO | Steel hot dip galvanised worldsteel |
| Underseal | EU | PVC adhesive (approximation) |

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| Unsaturated polyester (UP) | DE | Polyester Resin (unsaturated) (UP) |
| Washing water, battery acids | EU | Sulphuric acid (96% H2SO4) |
| Wrought aluminium alloys | GLO | Aluminium ingot - cradle to gate |
| | GLO | Aluminium ingot mix IAI 2015 |
| Wrought magnesium alloys | CN | Magnesium |
| Zinc alloys | GLO | Special high grade zinc only from Zn concentrate IZA |
| Thermal energy | EU | Thermal energy from Natural gas |
| | EU | Thermal energy from natural gas |
| | CN | Water (deionised) |
| | CN | Tap water from groundwater |
| | CN | Lubricants at refinery |
| | CN | CLubricants at refinery |
| Electricity | GLO | GLO: Electricity grid mix |
| | EU | Electricity from biogas |
| | EU | Electricity from geothermal |
| | EU | Electricity from hard coal |
| | EU | Electricity from heavy fuel oil (HFO) |
| | EU | Electricity from hydro power |
| | EU | Electricity from natural gas |
| | EU | Electricity from nuclear |
| | EU | Electricity from photovoltaic |
| | EU | Electricity from solar thermal |
| | EU | Electricity from waste |
| | EU | Electricity from wind power |
| Vehicle assembly | CN | Electricity from hydro power |
| | CN | Electricity from photovoltaic |
| | CN | Natural gas mix |
| | CN | Process steam from natural gas 85% |
| | CN | Tap water from surface water |
| | EU | Hazardous waste (statistical average) (no C, worst case scenario incl. landfill) |
| | EU | Municipal waste in waste incineration plant |

| Material name | Location | Dataset/Plan in LCA FE |
|---|---|---|
| | EU | Paper and board (water 0%) in waste incineration plant |
| | GLO | Truck-trailer, 34-40 t tot weight, MPL 27 t, Euro 6 |
| | EU | Biodiesel based on rape seed methyl ester (RME) |
| | EU | Diesel mix at refinery |
| End-of-Life | EU | Electricity grid mix 1kV-60kV |
| | DE | Waste incineration (plastics) |
| | GLO | Europe without Switzerland: treatment of waste mineral oil, hazardous waste incineration ecoinvent 3.8 |
| | GLO | treatment of used tyre ecoinvent 3.8 |
| | EU | Inert matter (Glass) on landfill |
| | EU | treatment of automobile catalyst ecoinvent 3.8 |

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*This report has been reviewed and approved in accordance with IVL's audit and approval management system.*