Inclusive and sustainable smart cities (CISI)

Towards the measurement of electromobility in international trade

Ira Ronzheimer - José Durán Lima
Cristóbal Budnevich - Matthew Gomies

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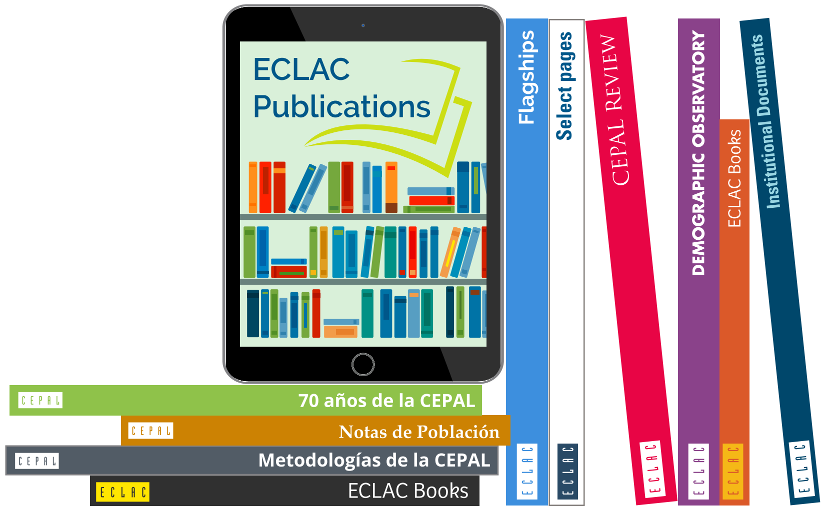

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Towards the measurement of electromobility in international trade

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This document was prepared by Ira Nadine Ronzheimer, José Durán Lima and Matthew Gomies, staff of the Regional Integration Unit of the International Trade and Integration Division of the Economic Commission for Latin America and the Caribbean (ECLAC), and Cristóbal Budnevich, consultant with the same division, as part of the activities of the ECLAC project "Inclusive and sustainable smart cities in the framework of the 2030 Agenda for Sustainable Development in Latin America and the Caribbean", implemented by ECLAC with the support of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The authors wish to thank Niklas Lindig, Sebastian Herreros, and Daniel Cracau for their support in conducting the preliminary research and review of the manual. This document was presented at the virtual workshop "Measuring electromobility in international trade", organized by Sergio Arboleda University in Bogotá. Civil engineers, engine engineers, and specialists in the automotive sector participated in the workshop.

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Summary

This document has been prepared within the context of the project "Inclusive, sustainable, and smart cities within the framework of the 2030 Agenda for Sustainable Development in Latin America and the Caribbean", implemented by the Economic Commission for Latin America and the Caribbean (ECLAC) with the support of the German Corporation for International Cooperation (GIZ). The project primarily focuses on implementing electromobility in Latin American cities' transport systems as a sustainable alternative in the context of climate change.

The methodology presented in this document aims at estimating the productive capacity of Latin America in the context of electromobility in urban transport based on trade flows. By tracing export flows of electric buses and their inputs both in the region and at the global level, the main suppliers and buyers can be identified and Latin America's participation in global value chains can be assessed. The overall goal is to identify how Latin American countries can take part in electromobility value chains and increase the value added of their exports.

The core of the methodology is based on the disaggregation of both an electric (battery-run) bus and a conventional (diesel-run) bus into their elaborated and semi-elaborated parts and raw materials using the 2017 edition of the Harmonized Commodity Description and Coding System. In this respect, the methodology identifies the quantity requirements of all raw materials needed to build a bus. The different products required were also allocated to clusters such as the bus body, battery and engine, among others, to analyze trade in the respective clusters' products.

Besides the identification of required inputs, their prices have been estimated based on global trade flows in order to determine the cost structure of an electric bus. This allows the identification of products with high value added in their elaboration processes. Finally, based on input prices and required quantities, the share of the required products' international trade that goes into the production of electric buses was estimated.

Introduction

In recent years, interest in electromobility —and specifically the electrification of public transport— has greatly increased in Latin America and the Caribbean (LAC), driven by the urgent need to decarbonize its economy and reduce pollution levels. The electrification of public transport poses several challenges to the region, including those related to the cost and availability of electric buses and the required support infrastructure. At the same time, LAC is a key supplier of raw materials needed to produce electric buses and has abundant sources of sustainable energy needed for the operation of electric vehicles.

While the LAC region relies extensively on imports of electric buses from the rest of the world, there is interest in exploring options for greater regional production. To evaluate regional manufacturing capacity, this document presents a methodology based on the Harmonized Commodity Description and Coding System (HS), a standard international trade classification. Based on the identification of elaborated and semi-elaborated components as well as the raw materials required to produce electric buses, the methodology allows mapping trade flows within and outside the region. Whereas the proposed methodology focuses on electric buses, it includes conventional diesel-run buses as a benchmark. Three component vectors (for elaborated inputs, semi-elaborated inputs, and natural resources) are defined for each bus type. The component vectors will be used to analyze the value chains of electric and conventional diesel buses.

The labor and capital costs involved in the production of a bus are excluded from the following analysis, same as the services included in the production process. Software such as monitoring systems (battery management systems, CAN: Controller Area Network, among others) may represent an important share of the total value of a bus, especially of electric and hydrogen buses.

This document has been prepared in the context of the project "Inclusive, sustainable, and smart cities within the framework of the 2030 Agenda for Sustainable Development in Latin America and the Caribbean", implemented by ECLAC with the support of GIZ. The main objectives of this collaboration are: i) to estimate the demand for electromobility in Latin American cities and facilitate its implementation; ii) to promote regional supply to meet the potential demand for electromobility; and iii) to promote a dialogue between stakeholders of sustainable urban mobility and the region's suppliers of buses and their inputs.

I. Electromobility in Latin America: an overview

As of April 2022, and based on information available for 11 countries, it is estimated that there were nearly 117,000 buses operating in urban passenger transport in the LAC region, of which about 113,500 (97%) were conventional diesel-run buses. Electric buses accounted for the remaining 3%, of which 68% require batteries and 32% are trolleybuses. Overall, the regional penetration of battery electric buses is only 1.9%, with Barbados, Chile and Colombia showing the highest penetration (see Table 1).

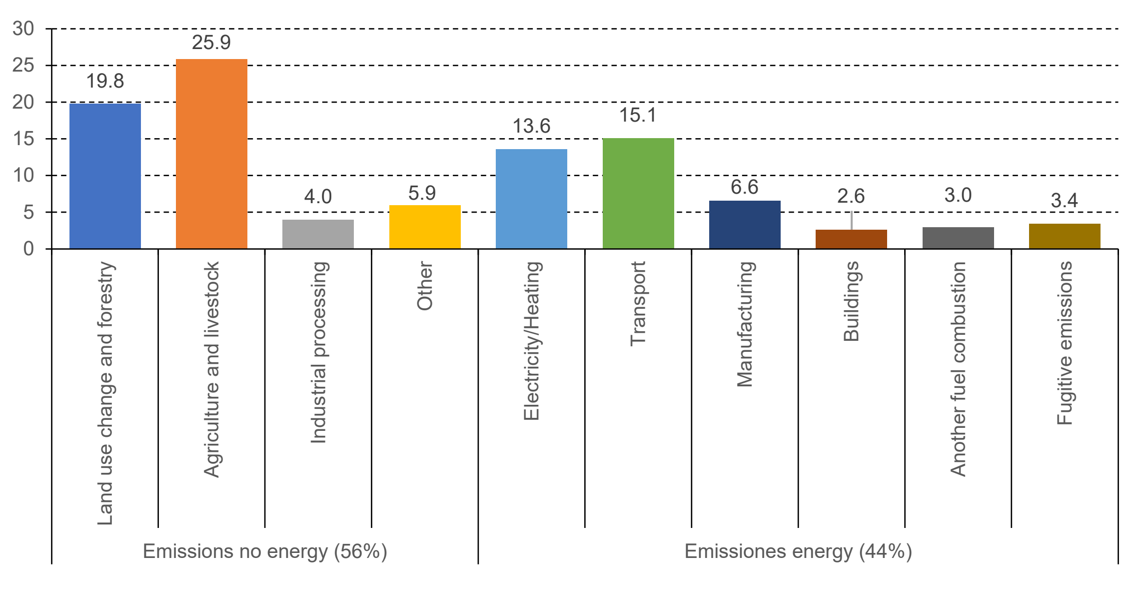
Table 1
LAC (11 countries): fleet of urban transport buses as of April 2022

Countries	Type of Bus (No of units)				Penetration		
	Total (1)=(2)+(3)+(4)	Diesel (2)	Electric (3)	Trolley (4)	Diesel (5)=(2/1)	Electric (6)=(3/1)	Trolley bus (7)=(4/1)
Argentina (4 cities)[a]	23 604	23 507	20	77	99.6	0.1	0.3
Barbados (Bridgetown)	283	250	33	0	88.3	11.7	0.0
Brazil (6 cities)[b]	19 010	18 662	46	302	98.2	0.2	1.6
Chile (2 cities)[c]	9 557	8 738	789	30	91.4	8.3	0.3
Colombia (3 cities)[d]	14 566	13 401	1 165	0	92.0	8.0	0.0
Ecuador (2 cities)[e]	8 430	8 240	21	85	97.7	0.2	1.0
Mexico (2 cities)[f]	17 347	16 791	48	508	96.8	0.3	2.9
Paraguay (Asunción)	2 249	2 247	2	0	99.9	0.1	0.0
Peru (Lima)	15 449	15 448	1	0	100.0	0.0	0.0
Uruguay (2 cities)[g]	3 246	3 212	36	0	99.0	1.0	0.0
Venezuela (R.B.)	3 000[h]	2 955	0	45	98.5	0.0	1.5
Latin America and the Caribbean (11 countries)	116 741	113 451	2 161	1 047	97.2	1.9	0.9

Source: Authors, based on World Population Review (2022), E-Bus Radar (2021), Ministerio de Energía Chile (n.d) & Centro Tecnológico de Transporte, Tránsito y Seguridad Vial (2016).
[a] Includes information for Santa Fe, Mendoza, Cordoba, and the Buenos Aires Metropolitan Area (AMBA); [b] Includes information for Campinas, São Paulo, Brasilia, Maringá, Volta Redonda and Bauru; [c] Includes information for Santiago and Valparaíso; [d] Includes information for Bogotá, Medellín and Cali; [e] Includes information for Guayaquil and Quito; [f] Includes information for Mexico City and Guadalajara; [g] Includes information for Montevideo and Canelones; [h] Information circa 2019, obtained from: Paez-Pumar (2018).

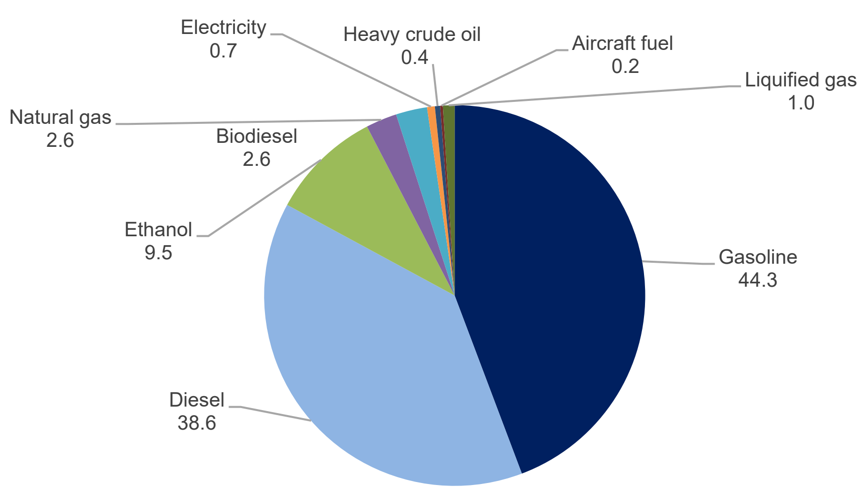
Energy generation represents 44% of total greenhouse gas (GHG) emissions in LAC, and within this group, emissions from transport reach 15%. Transport emissions exceed those generated by electricity and heating, and more than double those generated by the manufacturing industry (see Figure 1). Fossil fuels (gasoline and diesel) account for 83% of total fuels used by the transport sector (see Figure 2).

Figure 1
LAC: share of greenhouse emissions, by sector, 2018
(In percentages)



Source: Samaniego, Alatorre, van der Borght and Ferrer (2021), Overview of Nationally Determined Contribution updates in the run-up to COP 26, ECLAC.

Figure 2
LAC: fuels used by the transport sector by product, 2018
(In percentages)



Source: Own elaboration based on UNEP (2021).

Alternatives to reduce transport GHG emissions include reducing the fleet of conventional buses and replacing them with electric buses, trolleybuses, natural gas buses, or hydrogen buses (see Table 2 for a comparison of the different bus types). The following section briefly discusses the operation of these different bus types.

Table 2
Comparison of different types of buses

Type of Bus	Power source	Penetration potential in the LAC region	Advantages	Disadvantages
Diesel Fuel Bus	Compression-ignition engine	Already established system with infrastructure in place	Lower purchase price Technically mature systems (therefore, lower safety concerns compared to more recent technologies such as electric buses) Easy handling of fuel distribution via truck or pipeline	Higher CO_2 emissions than other types of buses More complex technical requirements than other types of buses Noisy during operation
Electric Bus (battery-run)	Fully battery-run bus (assuming a lithium battery)	Old diesel buses could be retrofitted Potential to generate renewable energy in the region for the operation of bus fleets	Zero emissions during bus operation Lower technical complexity Many core inputs can be found in large amounts in LAC (copper, lithium, graphite, among others) and can be reused or recycled Low noise level during operation	Relatively expensive buses High upfront costs for charging infrastructure necessary High CO_2 emissions for producing batteries Charging takes longer than re-fueling of gas, diesel, and hydrogen Little precise data on the durability of batteries since the technologies are not yet technically mature
Overhead Line Bus	Bus containing batteries (lithium-batteries) charged almost constantly with the use of a pantograph	Option for hybrids: Electric or retrofitted buses can be upgraded Overhead line buses are in use in some LAC countries (Chile, Mexico, among others)	Zero emissions during bus operation Smaller battery sizes Hybrid options allow the use of battery and overhead lines as energy sources for operation depending on infrastructure Long life cycles Low noise level during operation	Complex overhead line infrastructure is necessary Existing pantograph heads (graphite blocks) have a maximum service life of 1,000 km and need to be replaced regularly Relatively expensive
CNG/LNG Bus	Spark-ignition engines running on CNG/LNG	Depend on special infrastructure (natural gas stations) Option to retrofit existing diesel-run buses by adding gas fuel system and spark-ignition system	Proven and technically mature systems Relatively clean combustion with mainly water and CO_2 as products High octane rating (around 120) Can be mixed with CO_2 neutral biogas Combination with hydrogen production by pyrolysis is possible Low noise level during operation	Not fully CO_2 emission-free Relatively complex technical requirements compared to electric buses Cryogen temperature handling and control systems necessary for LNG bus (safety concerns) High-pressure systems for CNG bus
Hydrogen Fuel-Cell Bus	Bus containing lithium-batteries and fuel cells that convert hydrogen into energy stored in the batteries	Old diesel buses could be retrofitted	Power-to-gas system can be established to support energy infrastructure, an opportunity for low-cost compressed hydrogen distribution when using the existing natural gas network Smaller Li-Ion batteries are required resulting in lower CO_2 emissions Low noise level during operation	Very high upfront investment in the required infrastructure Low energy density when using compressed hydrogen Need for relatively more expensive green hydrogen (currently, most hydrogen is made from CNG due to cost advantages) Very high pressures; up to 700bar.

Source: Own elaboration.

One of the reasons why diesel-run buses are used extensively in the LAC region is their low cost compared to electric buses. In addition, the technology used to produce conventional buses is largely available in the region, as well as the infrastructure to fuel them (gas stations). Moreover, the diesel bus technology has a high safety level due to the low risk of fire at normal temperature and pressure. However, diesel-run buses also have several disadvantages. First, they produce more CO_2 emissions than electric buses, and air pollution emitted by combustion vehicles may cause lung diseases among the exposed population.[1] Also, the technical requirements for the production and maintenance of diesel buses are more complex and costly than for electric buses. Finally, conventional diesel buses are noisy, thus contributing to noise pollution.

Among the advantages of electric buses are that they are less technically complex, more reliable, and safer than all other types of buses. Also, some of the main inputs for their production (iron ore, aluminum, copper, lithium, and graphite) can be found in large quantities in LAC. Moreover, 95% of them can be reused or recycled (Alcover, 2021). Some disadvantages of electric buses are their higher prices compared to conventional buses and the need for investments in charging infrastructure, which is much less developed in the region than is the case for conventional buses. Additionally, there are indications that the production of electric batteries generates high CO_2 emissions (overall carbon emissions range of 59-119 kg CO_2-eq/kWh battery according to Emilsson and Dahllöf (2019). The electric battery technology is still maturing, and charging takes longer than refueling gas, diesel, and hydrogen. However, well-planned infrastructure would likely ease this problem. Another point worth mentioning is the possibility of retrofitting, i.e., the conversion of conventional buses into electric buses by changing the necessary parts and installing an electric battery.

Overhead line buses (trolleybuses) are another viable option. They can be permanently charged using a pantograph or combined with a battery. The latter case provides these buses with greater versatility as it allows them to bypass parts without the overhead line infrastructure. They are also less pollutant than diesel-run buses and have been used in the past as a clean alternative. Conventional buses can be converted into trolleybuses through retrofitting. Like electric buses, the initial cost of trolleybuses is higher than that of conventional buses. Moreover, they are highly dependent on the existence and maintenance of the required infrastructure.

Another alternative are natural gas-run buses. Their emission levels are lower than those of a diesel bus and they can run on natural gas or biogas, making them more sustainable. However, their system is more complex than that of an electric bus, and there are safety risks due to the flammable nature of the fuel used. Conventional diesel-run buses can also be retrofitted into buses running on natural gas.

An additional alternative is provided by hydrogen buses. They emit significantly less CO_2 than conventional diesel buses and can be more versatile and complementary to gas buses, as they could take advantage of the natural gas transport system, i.e., take advantage of cisterns (180-200 bar) and gas pipelines (< 100bar in a transport network). However, the technology of hydrogen buses is still under development and there are few hydrogen-run buses operated globally. Furthermore, this type of bus is the most expensive one compared to the other types presented previously due to the low maturity of the technology.

The following sections of the document only elaborate on electric and diesel buses as resource constraints only allowed to focus on these types of buses.

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[1] The World Health Organization recently reported that billions of people breathe unhealthy air, recommending building safe and affordable public transport systems and pedestrian-friendly and cycle-friendly networks; in addition, it suggested implementing stricter vehicle emissions and efficiency standards (WHO, 2022).

II. Methodology

The goal of this methodology is to develop a list of all components necessary to produce both an electric and a conventional (diesel-run) bus. The selection of components was based on the 2017 edition of the HS developed by the World Customs Organization (WCO). The HS is widely applied in the analysis of global trade data because it provides a common nomenclature for the classification of traded goods. Based on the suggested list of identified HS products (also referred to as the *component vector*), it will be possible to analyze international trade flows related to electromobility. This approach allows the identification of the main countries trading electric buses and their parts and establishing the main related value chains.

The methodology developed here seeks to fill a gap in the literature. The 2012 edition of the HS did not have a separate code for electric buses, which were grouped in the category Other under the code 870290.[2] With the update to the 2017 edition, the code 870240 was introduced for fully electric vehicles for the transport of 10 or more persons (see Table 3).[3] No further amendments were made in the 2022 edition of the HS, which entered into force on January 1, 2022.

[2] The HS is updated every five years. Trade flows between 2013 and 2016 were registered in the HS 2012 edition.

[3] The WCO documented this change as follows: *"The structure of heading 87.02 has been redrafted and renumbered to provide separately for hybrid electric and plug-in hybrid vehicles and for all-electric motor vehicles, respectively".* See http://www.wcoomd.org//media/wco/public/global/pdf/topics/nomenclature/instruments-and-tools/hs-nomenclature-2017/2016/table_i_trp1712_en_rev1.pdf?db=web.

Table 3
Tariff codes for buses in the HS 2012 and 2017

A. HS 2012

HS code	Product description
8702	Motor vehicles for the transport of ten or more persons, including the driver
870210	With compression-ignition internal combustion piston engine (diesel or semi-diesel)
870290	Other

B. HS 2017

HS code	Product description
8702	Motor vehicles for the transport of ten or more persons, including the driver
870210	With only compression-ignition internal combustion piston engine (diesel or semi-diesel)
870220	With both compression-ignition internal combustion piston engine (diesel or semi-diesel) and electric motor as motors for propulsion
870230	With both spark-ignition internal combustion piston engine and electric motor as motors for propulsion
870240	With only electric motor for propulsion
870290	Other

Source: WCO (2015, 2017).

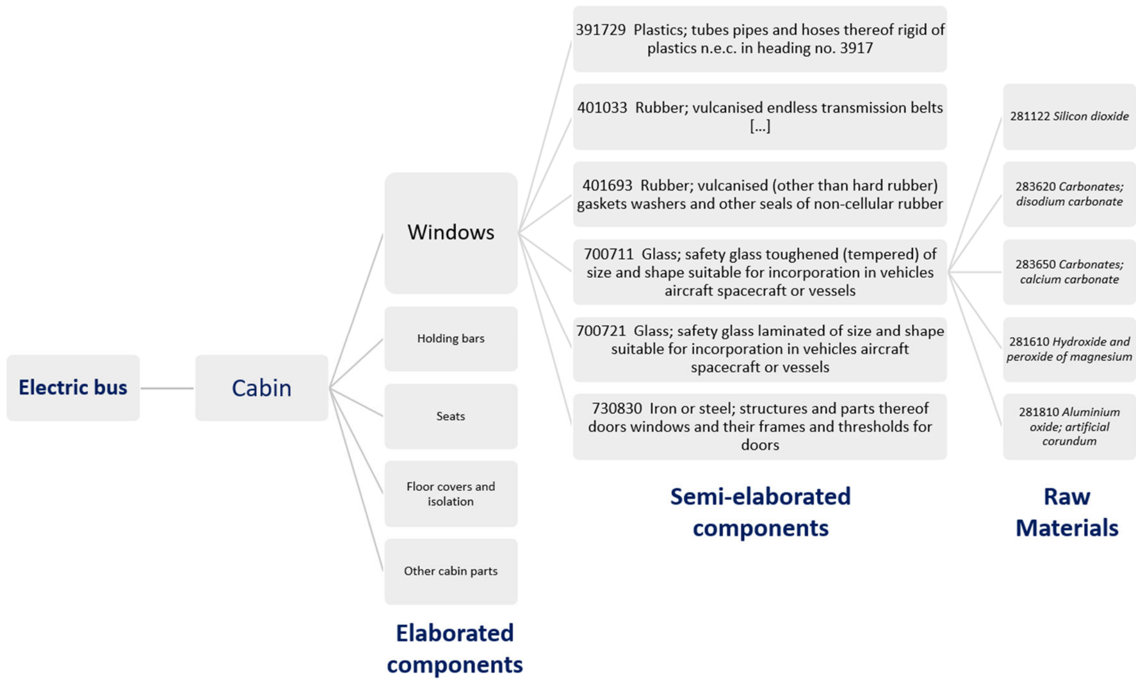
Although the HS 2017 edition introduced a specific code for electric buses, there are no separate codes for parts and components of electric and conventional buses. For this reason, it was necessary to construct a methodology of vectors that includes the parts and pieces required for the assembly of both an electric bus and a conventional bus.

It should be noted that other more aggregate approaches, such as the compilation of supply and use tables or the preparation of input-output tables, also lack the required disaggregation at the product-level. Some matrices display the automotive sector with a greater level of detail, differentiating transport vehicles from the products of the aeronautical industry and other transport equipment. However, the final products and intermediate goods required for the assembly of a bus in its different stages (from raw materials to the elaboration of more complex intermediate inputs such as electrical, electronic, or other types of parts and pieces) are not traced. This gap underlines the need to obtain a product breakdown that can be used for the identification of the cost functions involved in the production of a bus, bearing in mind that there are parts and pieces that are used by both conventional and electric buses.

The proposed methodology was developed through an interactive and iterative process of reviewing studies and consulting experts, mainly mechanical engineers, engine technicians, and representatives of the design and development fields of automotive companies.

An integral part of the methodology is the definition of product clusters (for example, the battery cluster groups all the components required to build a battery). The components identified in each cluster include different elaboration levels (elaborated and semi-elaborated inputs, and raw materials). Diagram 1 shows the disaggregation of windows, which belong to the cabin cluster. While windows are assigned to the elaborated components, their inputs such as rubber and glass belong to the semi-elaborated components. These can in turn then be disaggregated into their raw materials, as illustrated in the case of glass that is made of silicon dioxide and aluminum, among other inputs. Each HS code is uniquely assigned to one elaboration level.

Diagram 1
The three component vectors of a bus window



Source: Own elaboration.
Note. HS codes refer to HS 2017.

The list of all products and their corresponding HS codes from all clusters that are classified as elaborated components is referred to as elaborated component vector (the vectors for the remaining elaboration levels are referred to as semi-elaborated components and raw materials vector).

The component vectors are based on the HS 2017 edition at the six-digit level.[4] This is the latest HS edition for which trade data are available, since the 2022 edition only entered into force in January 2022. Regarding the changes made in the update of the HS 2017 (to HS 2022) in the subsection of vehicles, the following change in components require being mentioned: a new subheading 870822 has been created to provide for windows for the motor vehicles of Chapter 87.[5]

HS section 17 (*Vehicles, Aircraft, Vessels and Associated Transport Equipment*) includes Chapter 87 (*Vehicles other than railway or tramway rolling stock, and parts and accessories thereof*). Chapter 87 covers both the final product (the buses) and the parts required for its production, such as clutches, engines, gearboxes etc. (see Table 4).

[4] No changes were made in the codes of the identified components regarding the update from the HS 2012 to HS 2017. Therefore, all codes are identical in both editions.

[5] For further information see: http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/instruments-and-tools/hs-nomenclature-2022/table-i_en.pdf?la=en.

Table 4
Examples of inputs for vehicles in HS chapter 87

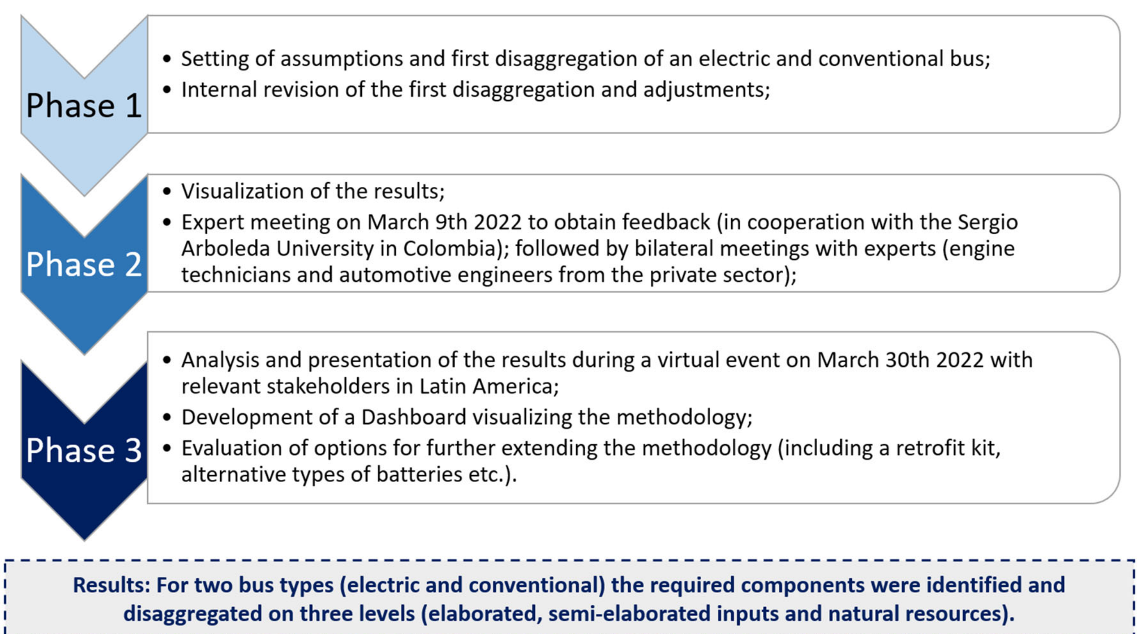
HS code	Product description
8708	Parts and accessories of the motor vehicles of headings 8701 to 8705:
870810	Bumpers and parts thereof
870821	Safety seat belts
870830	Brakes and servo-brakes; parts thereof
870840	Gear boxes and parts thereof
870850	Drive-axles with differential, whether or not provided with other transmission components, and non-driving axles; parts thereof

Source: OMC (2017).
Note. HS codes refer to HS 2017.

Other sections of the HS that contain parts and inputs required to produce a bus are *mineral products* (Section 5), *products of the chemical or allied industries* (Section 6), *plastics and articles thereof, rubber and articles thereof (Section 7), and base metals and articles of base metal* (Section 15). Sections of the HS that provide parts to a minor extent are *machinery and mechanical appliances, electrical equipment, parts thereof, sound recorders and reproducers, television image, and sound recorders and reproducers, and parts and accessories of such articles* (Section 16), and *optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; […] clocks and watches; musical instruments; parts and accessories thereof* (Section 18).

Diagram 2 sums up the different phases of the development of our proposed methodology. Those phases are explained in greater detail below.

Diagram 2
Steps of development of a methodology for trade in conventional and electric buses



Source: Own elaboration.

The first phase required the development of a general approach, as the methodology had to be set up from scratch. Regarding the construction of the component vector, a top-down approach was adopted. The first step was to break down each bus type into its main structures (bus body, motor etc.). All these elaborated components have been identified in the HS and used to construct the elaborated components vector. As a second step, elaborated components were in turn disaggregated into their own components (for example, magnets that form part of the motor) which were grouped in the semi-elaborated vector with their respective HS codes. Finally, semi-elaborated components were disaggregated into their raw materials. These have then been listed with their corresponding HS codes. The result consisted of a list of codes that ranged from elaborated products to raw materials.

To complement the top-down approach and ensure the completeness of the vectors, a bottom-up approach was used that included revising the entire HS to ensure all parts have been included. The second section of this document discusses in more detail these breakdown sections for the different bus types.

As a first step in the construction of the vector for the bus types, a reference bus model was selected (as explained in the assumptions sections). Then, the complete list of HS codes at the six-digit level was reviewed and all the elaborated parts required have been selected and categorized into different clusters (for example, wheels belong to the bus cabin cluster, battery cells belong to the battery cluster etc.). For large clusters, sub-clusters have been introduced to better organize the parts within one cluster (e.g. other cabin parts represent a sub-cluster of the cabin cluster including fire extinguishers, windscreen wipers etc.).

The second step was to assign weights (in kilograms) to the identified parts. Using the weights of the components, it was possible to compute the cluster weights. The total weight of all clusters was double-checked against the total weight of the bus. This was followed by the identification of the semi-elaborated parts in the HS. All elaborated parts have been disaggregated into the semi-elaborated inputs (for example, the bus body as elaborated part has been disaggregated into steel structures, aluminum plates, rubber, and other parts) and been assigned weights, too. Afterwards, the semi-elaborated parts have been disaggregated into their raw materials, whereby the required raw materials have also been assigned weights (e.g. the steel structures have been disaggregated into iron ores). As the product disaggregation process is very research-intensive and consequently, time-consuming, not all elaborated and semi-elaborated products have been disaggregated. The goal was set to disaggregate all components with a weight of more than 50 kg. Additionally, it is important to mention that some elaborated and semi-elaborated parts required were not included in the HS. For these products dummies were introduced. For example, there is no code in the HS for battery cases.

In a third step, all the products in the HS were identified that represent extremely small parts (screws, valves, steel alloys, lamps etc.) that could not be quantified as they are likely already included in the weights of the parts they belong to (such as screws in a motor). In order not to overestimate the weight, they were grouped in the generally necessary parts cluster without any weight assignments. The products belonging to the generally necessary parts cluster have not been disaggregated.

The main sources consulted were webpages of components' manufacturers (e.g. ZF Fahrzeugteile AG for the axles) and suppliers of spare parts for buses and trucks. Some parts are identical for buses and trucks (e.g. driver's seat, wheels, axles, brakes and steering systems); therefore, truck parts provide a good indication of the weight of bus parts. Moreover, there is more information available on truck spare parts.

The first version of the component vectors was subject to an internal analysis within the ECLAC team and was further discussed at an expert meeting convened to obtain feedback on the assumptions used for the disaggregation process. The expert meeting "Measuring electromobility in trade" took place on March 9t, 2022, in cooperation with experts from the private sector and University Sergio

Arboleda in Colombia.[6] The feedback obtained from participating experts and from further consultations with specialist engineers confirmed the reliability of the disaggregation exercise. The final version of the applied methodology was presented during an electromobility workshop held on March 30, 2022, that included actors from the private and public sectors.[7] This marked the successful conclusion of Phase 2.

A. Underlying assumptions

Input requirements for the construction of a bus were defined using the Mercedes-Benz Citaro city bus as the reference (see Image 1). The Citaro has both diesel-run and electric (battery-run) versions. Nowadays, the electric version is not operating in LAC cities, probably due to the cost difference with the Chinese manufacturers' models. However, the Citaro was selected due to the relatively high availability of technical information about its two versions compared to other models. Moreover, the variation in the components and materials used in different bus models is expected to be rather low, thus using a different reference model would likely have led to similar results. An exception might be the battery system, as the type of battery can vary with the bus model. Therefore, we chose a battery type that is commonly used (for details see the battery section below).

Image 1
Citaro bus model

Source: Sagar (2018).

The following subsection points out the basic characteristics and assumptions made regarding the different bus types, as summed up in Tab. 5. Both bus types are assumed to have a length of 12 m and to transport up to 80 passengers at a time. More cluster-related or product-related assumptions are made in the respective subsections of the following breakdown structure chapter.

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6 For more information see https://www.cepal.org/es/eventos/webinario-midiendo-la-electromovilidad-comercio-internacional-caso-buses-electricos.

7 For more information see https://www.cepal.org/es/eventos/webinario-dialogo-publico-privado-electromovilidad-america-latina-asia.

Table 5
Summary of assumptions made

Bus type	Model	Power source	Battery	Capacity / Performance	Capacity (*number of passengers*)	Length (*meters*)	Expected lifetime (*years*)	Purchase cost (*dollars*)
Electric Bus (exclusively battery-run)	eCitaro	Electricity	NMC111 with 10 modules	243 kWh	80	12	20[1]	750 000
Diesel Bus [benchmark]	Citaro	Diesel	-	220 kW	80	12	-	425 000

Source: Own elaboration based on official company information (Mercedes-Benz 2018, 2019b), Knote (2017) & Center for Transportation and the Environment (n.d).
[1]The battery is not expected to last 20 years, battery lifetime is still under assessment.

General assumptions on disaggregation of main semi-elaborated products into raw materials

To be able to break down all semi-elaborated parts of buses, some assumptions were required; depending on the final use of the product, its composition can vary slightly. For instance, glass and rubber can have many different products as raw inputs depending on the final use. Thus, the assumptions made to complete the raw material vector can be summarized as follows:

- Different types of glasses and rubbers that are part of the buses as semi-elaborate products were disaggregated using a unique formula even if the descriptions and codes in the six-digit HS vary.[8]
- Parts of the bus that are made of iron or steel were assumed to be 100% made of iron. This is because even if they were made of steel, iron would represent around 99% of the total mass of steel (Universidad Nacional de La Plata, n.d.).
- Products made of plastics have two disaggregations according to the HS product description (see Annex 1).
- It is assumed that the battery electrolyte consists solely of lithium, as the literature (Li et al., 2016; Fácil Electro, 2018) suggests that this component is basically lithium salt dissolved in organic solvents that cannot be identified using the six-digit HS (further elaborated in the respective section below).

Main semi-elaborated products' disaggregation criteria

According to Britannica (n.d), commercial glasses can be divided into soda-lime silica glasses and special glasses, the former being the most common. These glasses are made of three main materials: Sand (about 75% of silicon dioxide or SiO2), limestone (around 10% of calcium carbonate or CaCO3) and roughly 15% of sodium carbonate (Na2CO3). Glasses may also contain magnesium (magnesium oxide or MgO), and about 2 percent aluminum (aluminum oxide or Al2O3). The exact values used can be seen in Annex 1, Tab. A.2.

The second product in Table A1.2 corresponds to magnets, which are disaggregated using the information published by E-Magnets UK (n.d.). Magnets contain different metals and minerals in various proportions according to the type of magnet. The average between the upper and lower values of the interval was taken. It is worth mentioning that neodymium and dysprosium do not have a direct identification in the HS at the six-digit level, due to their specificity. In other words, neodymium and dysprosium are included in the HS code "Earth-metals rare; scandium and yttrium whether or not

[8] There are at least 5 types of rubber included in the bus, but description according to the HS vary very slightly, thus as a simplifying assumption all of them were disaggregated using the same shares. The same applies to glasses that are part of the bus.

intermixed or interalloyed" that has the code number 280530. However, to identify them individually, their ten-digit HS codes 2805300020 and 2805303030, respectively, are required.

The third input is carbon, which in its most primitive form is found as graphite. Although natural graphite is defined as the input required to produce this intermediate good, it is the most traded good in the form of graphite worldwide in recent years according to the six-digit HS according to UN Comtrade.

The fourth semi-elaborated product are vulcanized rubbers used in buses. The disaggregation is generalized for simplicity using the tire as a reference. According to Castro (2008) and Scrap Pollution Prevention Infohouse (n.d),[9] a bus tire contains natural rubber, synthetic rubber, black carbon, steel alloys, fibers, softeners, oxides, antioxidants, among others, which are identified in Tab. A.2.

Finally, the fifth category includes the various plastic components used in the manufacturing of a bus. Due to the low relative weight of these components, they are assumed to consist entirely of the most used component in this category, which according to Infinitia Industrial Consulting (2021) is polypropylene.

The following section points out some general assumptions with respect to the two bus types.

As mentioned above, the Mercedes-Benz eCitaro is used as a reference model here. It is a zero-emission vehicle operated with a lithium battery with nickel-manganese-cobalt cathode and graphic anode (NMC-111, Mercedes-Benz, 2018). The eCitaro may contain 6, 8, or 10 batteries. In our methodology, it is assumed that 10 batteries are included, which implies the bus has 243 kWh battery capacity. Other e-bus manufacturers, such as BYD, employ Lithium-Iron-Phosphate batteries (Chen, 2022). As BYD-made buses are currently more common in LAC, the battery cluster might just be replaced with a cluster that assumes a Lithium-Iron-Phosphate battery. With ten battery modules, the all-electric Citaro weighs around 13.44 tons. In conjunction with a gross vehicle weight of 19.5 tons, this corresponds to a payload of more than six tons (Sustainable Bus E-Magazine, 2020).

The conventional Citaro uses an internal combustion engine as an energy source and runs on diesel (Mercedes-Benz, 2019b). It has a net weight of 11.41 tons (Tschakert, 2013).

[9] More details in: https://p2infohouse.org/ref/11/10504/html/intro/tire.htm (consulted in February 2022).

III. Breakdown structures

A. Common breakdown structures

While conventional and electric buses differ in their propulsion systems, four of the breakdown structures or clusters identified are assumed to be the same for both buses (see Table 6).

Table 6
Common breakdown structures of a conventional and an electric bus

Type of bus	Clusters						
	Cabin	Drivetrain	Engine	Bus body	Electronics	Other add. Clusters	Generally necessary parts
Conventional diesel bus Electric bus	Same			Same	Same	Fuel system Battery	Same

Source: Own elaboration.

The next section explains in more detail the clusters common to all buses and then those which are specific to different bus types.

1. Bus body

The bus body (also referred to as frame) is assumed to be equal for all bus types. It consists of a welded square tube steel frame, bumpers, and rubber. The bus body is assumed to weigh 5,000 kg and represents 37.3% of the total curb weight of the bus. The frame is understood as the outer shell of the bus without any interior parts like seats or floors (see Image 2). Windows are considered as parts of the cabin cluster. Wheels are assigned to the drivetrain cluster. Note that the HS code for vehicle bodies,[10] which includes buses, is rather broad and includes a relatively large range of vehicles (cars, tractors, and buses).

[10] The code is 870790: "Vehicles; bodies (including cabs) for the motor vehicles of heading no. 8701, 8702, 8704 or 8705".

Image 2
Example of a bus shell

Source: Turbosquid (n.d).
Note. This is the shell of an intercity bus as no image could be found for a transit (inner city) bus.

There was no information available on the total weight of the bus body or frame, which is why its weight was estimated based on the weight of the car body of a Mercedes-Benz GLA. The relation between the weight of the car body and the total mass was mirrored on the eCitaro, assuming a similar relation between the weight of the car body and total weight. Furthermore, the total mass of the eCitaro was known and the deduction of the aggregated weights of all parts except the car body was used to confirm the estimation made before. Unfortunately, it was not possible to confirm the weight of the car body using external sources.

The bus body of the eCitaro is primarily made of steel sheets (Goergler, 2014); therefore, it represents the material assumed for the raw material vector. In the past, bus frames have been made of steel because it is relatively cheap and easy to bend. Furthermore, steel plates are used to cover the surfaces of the bus body.

The frame cluster only includes the structural steel parts of the chassis, while other parts such as wheels and the motor(s) belong to other clusters. In the HS, the chassis includes the motor (870600 "Chassis; fitted with engines for the motor vehicles of heading no. 8701 to 8705"). Therefore, this HS code is not directly included in any of the vectors, while the parts of the chassis are included. To still include the code, it has been assigned to the generally necessary parts cluster.

The paint used for the bus has been excluded from the analysis. Usually, cataphoretic immersion priming (KTL), an electro-chemical process, is used for coating the complete body shell (Mercedes-Benz, 2019b). This water-based paint protects the vehicle against corrosion because the paint coat is applied everywhere to the body with uniform thickness.

Results bus body

The bus body does not have any sub-clusters because it contains only few parts. The products of the different vector levels have been fully disaggregated (see Table 7).

Table 7
Disaggregation of the bus body cluster

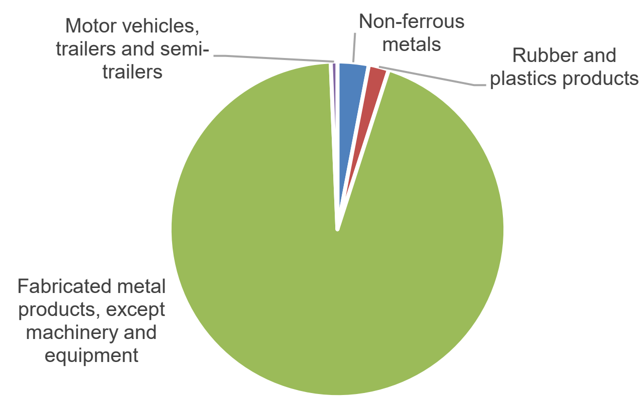
Vector Level	Number of products	Weight in kg	Percentage of disaggregated products
Elaborated	7	5 600	100%
Semi-elaborated	4	5 600	100%
Raw materials	25	5 600	-
Summary	36	5 600	100%

Source: Own elaboration.
Note. Column 4 refers to the percentage of the total mass of the products that were disaggregated into their semi-elaborated parts and raw materials. A value of 100% implies that all (semi-)elaborated parts have been disaggregated, while a value of 0% states that none of the parts has been disaggregated.

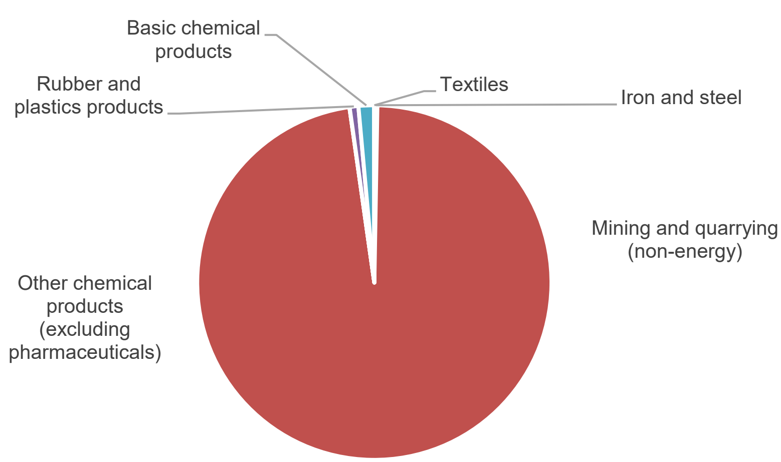
Figure 3 exhibits the economic sectors of the inputs for the different vectors in the bus body cluster by weight (the entire list of inputs can be found in the annex). The elaborated parts vector consists only of the bus body, which belongs to the sector Motor vehicles, trailers, and semi-trailers.

Figure 3
Economic sectors associated with the parts required for body bodies by level of product elaboration
(Percentages as a fraction of the cluster's total weight)

A. Semi-elaborated parts vector



B. Raw materials vector



Source: Own elaboration.

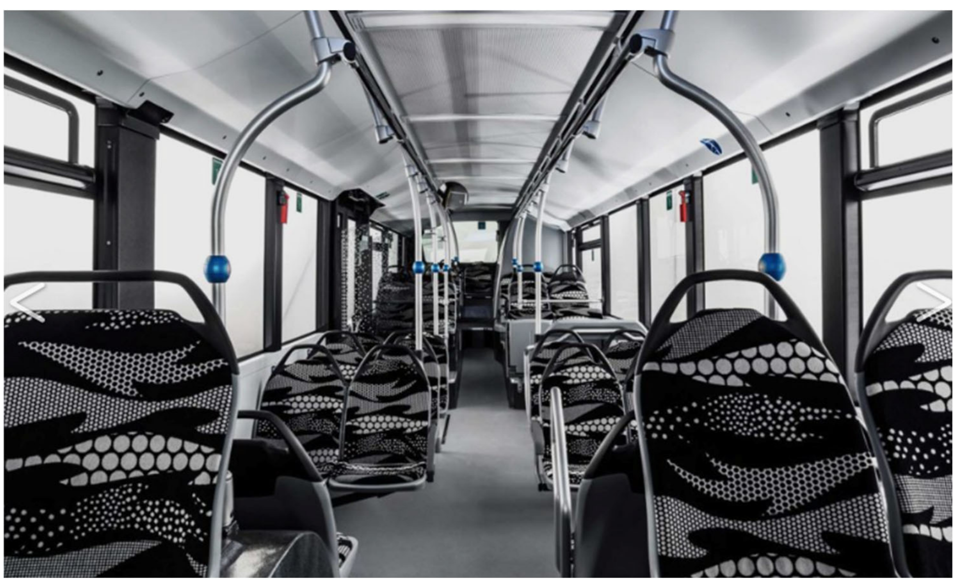
2. Bus cabins

The bus cabins are assumed to be the same for both bus types since they share the same requirements in terms of passenger capacity, safety, and comfort. The bus cabin cluster consists of two sub-clusters: the passengers' cabin (see Image 3) and the driver's cabin. Electric devices like an air conditioning system, cash registers, and outside lighting are listed in the electronics cluster. The steering wheel and pressure-air system, which allows the bus to kneel down, facilitating the entry of passengers, belong to the drivetrain cluster.

The cabin cluster consists of:

- Driver's seat, passenger seats and holding bars.
- Side and back windows are made of 1-layer safety glass (to be breakable in case of an emergency) and a laminated, two-layer safety windscreen with frames (windows are assumed to be made of soda-lime glass).
- Floor, ceiling, walls and covers, including heat/noise insulation.
- Automatically opening and closing doors, operable by the driver or a passenger, including frame and safety opening/closing system.
- Side mirrors for driver.
- Safety parts like fire extinguishers, locks.
- Lighting system (inside the cabin).

Image 3
Bus cabin of the Citaro



Source: Sagar (2018).

Results (bus cabin)

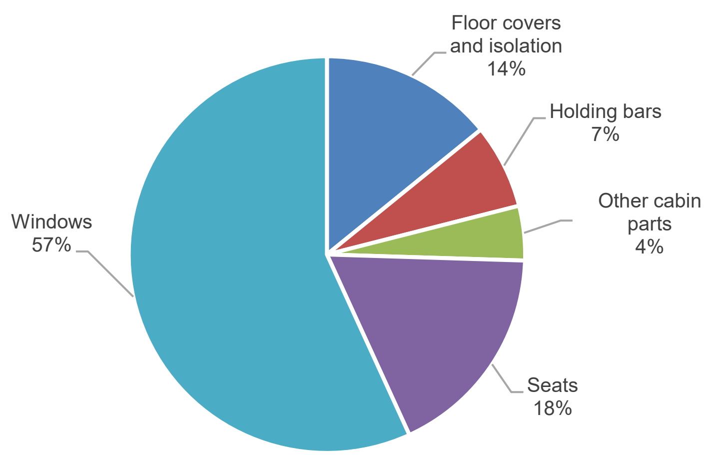
The products of the different vector levels have been fully disaggregated (see Table 8). The bus cabin consists of only five sub-clusters (see Figure 4).

Table 8
Disaggregation of the cabin cluster

Vector Level	Nb. of products	Weight in kg	Percentage of disaggregated products
Elaborated	11	1 727.5	96%
Semi-elaborated	15	1 650.6	99%
Raw materials	28	1 627.5	-
Summary	54	1 727.5	94%

Source: Own elaboration.
Note. Column 4 refers to the percentage of the total mass of the products that were disaggregated into their semi-elaborated parts and raw materials. A value of 100% implies that all (semi-)elaborated parts have been disaggregated, while a value of 0% states that none of the parts has been disaggregated.

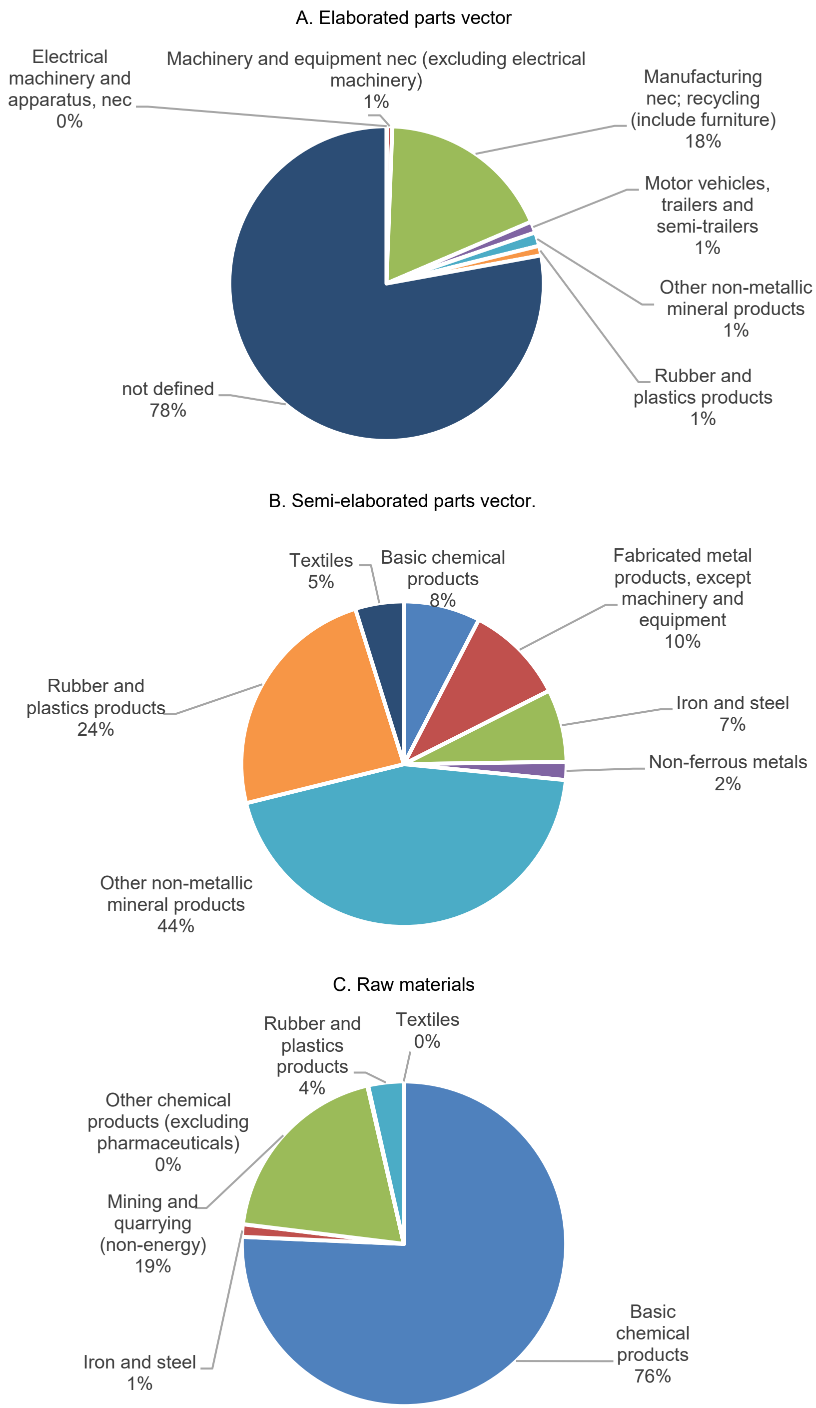
Figure 4
The subclusters of the bus cabin cluster



Source: Own elaboration.

Figure 5 on the next page exhibits the sectors of the inputs for the different vector in the bus cabin cluster by weight (the entire list of inputs can be found in the annex).

Figure 5
Economic sectors associated with the parts required for bus cabins by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.
Note. As the elaborated parts vector contains dummies due to missing HS codes for windows, holding bars and floor covers and isolation, no assignment to an economic sector can be made for these products.

3. Electronics

The electronics cluster includes, besides the air conditioning and heating system, many small and light-weighted inputs. One-quarter of the entire cluster is made up of the cables (insulated electric conductors) that link the different parts with the controlling system. The remaining elaborated products (parts) contained in the electronics cluster are:

- Engine control system.
- Cable harness.
- Air conditioning and heating system for cabins.
- Automatic door controllers.
- Suspension system.
- Drivetrain management system.
- On-board computers, surveillance and displaying systems for driver and passengers.
- Driving assistance systems for the driver.
- Lighting system (outside).

Results (bus electronics)

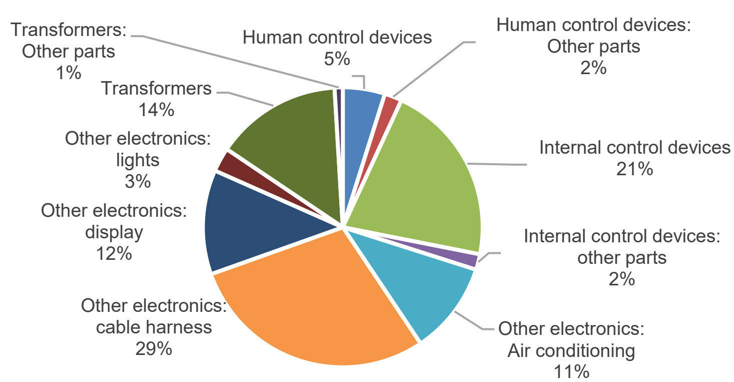
The products of the different vector levels have fully been disaggregated (see Tab. 9). The electronics cluster consists of 10 sub-clusters (see Figure 6).

Table 9
Disaggregation of the electronics cluster

Vector Level	Nb. of products	Weight in kg	Percentage of disaggregated products
Elaborated	35	1 656.6	47%
Semi-elaborated	18	782.3	82%
Raw materials	12	638.5	-
Summary	65	1 656.6	39%

Source: Own elaboration.
Note. Column 4 refers to the percentage of the total mass of the products that were disaggregated into their semi-elaborated parts and raw materials. A value of 100% implies that all (semi-)elaborated parts have been disaggregated, while a value of 0% states that none of the parts has been disaggregated.

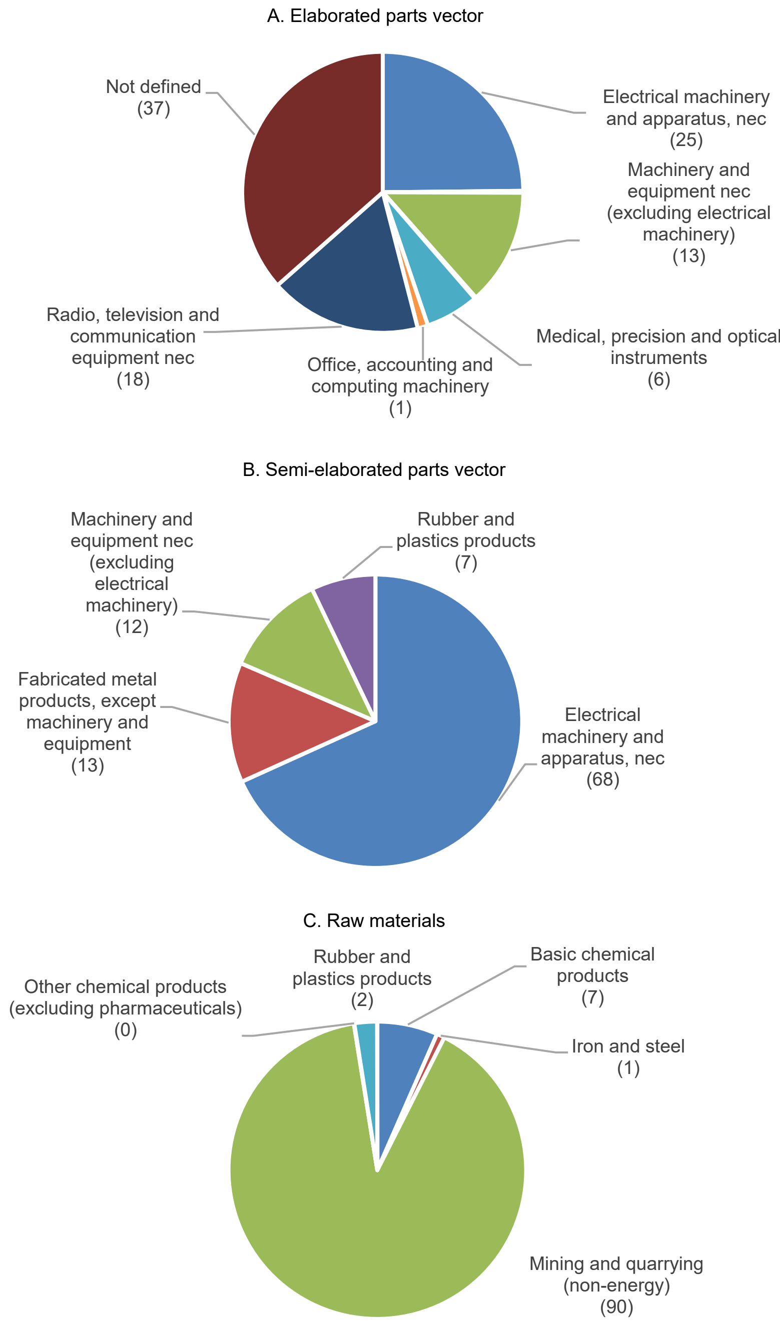
Figure 6
Subclusters of the electronics cluster



Source: Own elaboration.

Figure 7 exhibits the sectors of the inputs for the different vector in the electronics cluster by weight (the entire list of inputs can be found in the annex).

Figure 7
Economic sectors associated with the parts required for bus electronics by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

4. Generally necessary parts

Table 10 lists all parts that are contained in most buses, but which are hard to quantify, partly because they are already included in the weights of other, larger components (for example, screws and bolts in a motor). For completeness, these parts are listed here, but they do not enter the analysis as they mainly represent parts of minor weight and value.

Table 10
Generally necessary parts

SA 2017	Product description
220110	Waters; mineral and aerated including natural or artificial (not containing added sugar or other sweetening matter nor flavoured)
220710	Undenatured ethyl alcohol; of an alcoholic strength by volume of 80% vol. or higher
340399	Lubricating preparations; other than for the treatment of textile and similar materials not containing petroleum oils or oils obtained from bituminous minerals
392630	Plastics; fittings for furniture coachwork or the like
401610	Rubber; vulcanised (other than hard rubber) moulded rubber mats and mats of non-rectangular shape made by cutting from the piece of cellular rubber
730451	Steel alloy (not stainless steel); seamless cold-drawn or cold-rolled (cold-reduced) tubes pipes and hollow profiles of circular cross-section
731511	Chain; articulated link roller of iron or steel
731600	Iron or steel; anchors grapnels and parts thereof
731812	Iron or steel; threaded wood screws other than coach screws
731813	Iron or steel; threaded screw hooks and screw rings
731815	Iron or steel; threaded screws and bolts n.e.c. in item no. 7318.1 whether or not with their nuts or washers
731816	Iron or steel; threaded nuts
731819	Iron or steel; threaded screws bolts and nuts n.e.c. in item no. 7318.1
731821	Iron or steel; non-threaded spring washers and other lock washers
731822	Iron or steel; non-threaded washers excluding spring and lock
731823	Iron or steel; non-threaded rivets
731824	Iron or steel; non-threaded cotters and cotter-pins
830110	Padlocks; (key combination or electrically operated) of base metal
830230	Mountings fittings and similar articles; for motor vehicles of base metal
848110	Valves; pressure reducing for pipes boiler shells tanks vats or the like
848190	Taps cocks valves and similar appliances; parts thereof
848230	Bearings; spherical roller bearings
848240	Bearings; needle roller bearings
848250	Bearings; cylindrical roller bearings n.e.c. in heading no. 8482
848280	Bearings; n.e.c. in heading no. 8482 including combined ball/roller
848291	Bearings; parts balls needles and rollers
848299	Bearings; parts (other than balls needles and rollers)
848330	Bearing housings not incorporating ball or roller bearings and plain shaft bearings
850450	Electrical inductors; n.e.c. in heading no. 8504
853610	Electrical apparatus; fuses for a voltage not exceeding 1000 volts
853620	Electrical apparatus; automatic circuit breakers for a voltage not exceeding 1000 volts
853669	Electrical apparatus; plugs and sockets for a voltage not exceeding 1000 volts
853990	Lamps; parts of the lamps of heading no. 8539
854110	Electrical apparatus; diodes other than photosensitive or light emitting diodes
854121	Electrical apparatus; transistors (other than photosensitive) with a dissipation rate of less than 1W
854129	Electrical apparatus; transistors (other than photosensitive) with a dissipation rate of 1W or more
854140	Electrical apparatus; photosensitive including photovoltaic cells whether or not assembled in modules or made up into panels light emitting diodes
854160	Crystals; mounted piezo-electric
854190	Electrical apparatus; parts for diodes transistors and similar semiconductor devices and photosensitive semiconductor devices
854232	Electronic integrated circuits; memories
854239	Electronic integrated circuits; n.e.c. in heading no. 8542
854290	Parts of electronic integrated circuits
854370	Electrical machines and apparatus; having individual functions not specified or included elsewhere in this chapter n.e.c. in heading no. 8543
854390	Electrical machines and apparatus; parts of the electrical goods of heading no. 8543
854420	Insulated electric conductors; co-axial cable and other co-axial electric conductors
854520	Carbon brushes; with or without metal used for electrical purposes
854890	Electrical parts of machinery or apparatus; n.e.c. in chapter 85
870829	Vehicles; parts and accessories of bodies other than safety seat belts
870899	Vehicle parts and accessories; n.e.c. in heading no. 8708
902990	Meters and counters; parts and accessories for revolution and production counters taximeters mileometers pedometers and the like; speed indicators tachometers (excluding heading no. 9015) stroboscopes
903220	Regulating or controlling instruments and apparatus; automatic manostats
903289	Regulating or controlling instruments and apparatus; automatic other than hydraulic or pneumatic

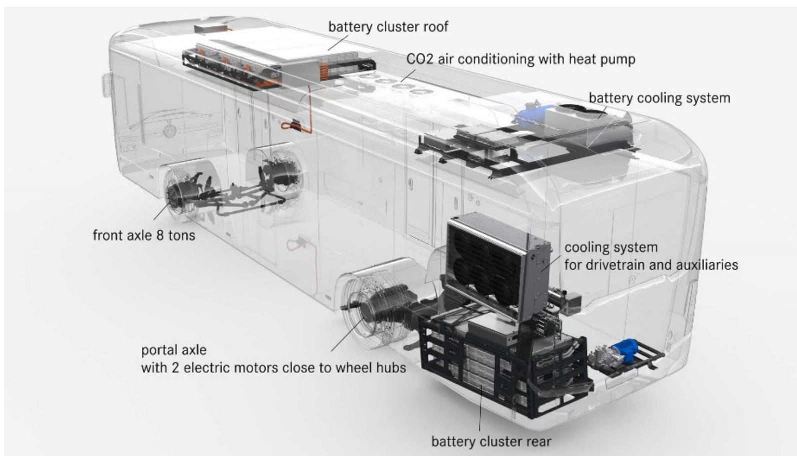
SA 2017	Product description
903290	Regulating or controlling instruments and apparatus; automatic parts and accessories
940190	Seat; parts
940370	Furniture; plastic
870600	Chassis; fitted with engines for the motor vehicles of heading no. 8701 to 8705

Source: Own elaboration.

B. Electric bus:eCitaro

The eCitaro is the battery-electric bus used as reference model. It is similar to the conventional Citaro but with modular modifications and substitutions that make it a zero-emission vehicle (see Image 4). As the implementation of electric buses has different requirements as compared to their conventional counterparts, Box 1 sums up the upfront investments related to operating electric buses.

Image 4
The arrangement of the eCitaro's main components



Source: Sagar (2018).

Box 1
Costs and upfront investment requirements related to the operation of electric buses

Introducing electric buses requires relatively high upfront investments (see Table 1). It has been argued that in the short to medium run, the purchase and operation of electric buses can only cover its costs if the investment is supported by public funds that help to reduce costs due to economies of scale. Another point of concern is the uncertainty related to the battery life, which makes the transition to electromobility appear risky (Knote, 2017).

Table 1
Costs related to the introduction of electric buses

Product	Initial Investment Requirement	Cost / KM	Uncertainty	Deadweight
Vehicle without battery	Moderate-high	High	Moderate	Very high
Batteries	Very high	Very high	Very high	High
Replacement batteries	Very high	Very high	Very high	High
Chargers	High	Moderate	Moderate	High
Installation Cost	Moderate-high	Low	Low	Low
Charging stations	High-very high	Moderate	Moderate	High
Cost of connection	High	Low	Low	Low
Maintenance cost	Moderate	Low	Low	Low
Training cost	Low	Low	Low	Low
Construction cost	Moderate-high	Low	Low	Low

Source: Taken from Knote et al. (2017).

1. Electric engine

The engine disaggregation includes the electric motor itself, rotor/stator with copper windings and permanent magnets, and a temperature and voltage management system. The eCitaro's two electric motors (motors and engine are used interchangeably), called ZF CeTrax, with a weight of 295 kg per motor (ZF Friedrichshafen AG, 2020), are directly mounted on the wheel hubs of the portal axle (see Image 5). The axle itself is part of the drivetrain cluster. Each motor has an output of 125 kW, making a total of 250 kW (ZF Friedrichshafen AG, 2021a). Note that the total weight of the electric engine cluster is equal to 584.1 kg (instead of two times 295 kg) as 5.9 kg were assigned to an instrument for measuring or checking voltage current resistance (HS code 903039) that has been assigned to the electronics cluster.

Image 5
eCitaro's electric motor (ZF CeTrax)

Source: Thoma (n.d).

The motors used are permanent magnet synchronous motors (PSM). These are highly efficient motors, also at a low-speed range, making it particularly suitable for stop-go traffic typical of urban areas, while enabling greater range per battery charge.

Results (Motor)

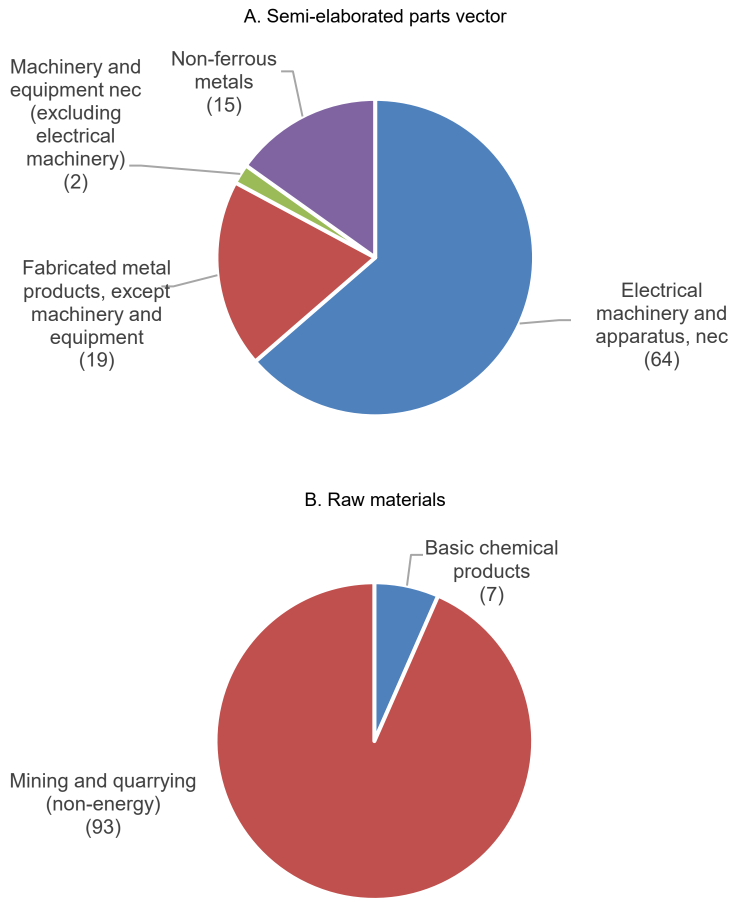
The electric motor cluster has no defined subclusters. The products of the different vector levels have fully been disaggregated (see Table 12). Similar to the bus body cluster, the elaborated vector of the engine cluster only includes the engine itself, which belong to the sector Machinery and equipment nec. (excluding electrical machinery). The semi-elaborated parts and raw material clusters include inputs from diverse economic sectors (see Figure 8, the entire list of inputs can be found in the annex).

Table 12
Disaggregation of the motor cluster

Vector Level	Nb. of products	Weight in kg	Percentage of disaggregated products
Elaborated	1	584.1	100%
Semi-elaborated	7	584.1	100%
Raw materials	7	584.1	-
Summary	15	584.1	100%

Source: Own elaboration.

Figure 8
Economic sectors associated with the parts required for electric motors by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

2. Drivetrain

The disaggregated drivetrain consists of:

- Air suspension system (air springs);
- Wheels (six wheels assumed);
- Brakes (disc brakes are assumed);
- Steering mechanism (connected to the steering wheel);
- Drive-axles (front and portal axles);
- Steering system (includes steering column, angular gear, power steering pump and steering system).

The eCitaro's drivetrain includes the suspension system and the steering system that is connected to the electro-motors and the steering wheel (see Images 6A and 6B). The two electric motors are mounted on the portal axle, a ZF AVE 130 (see Image 6C),[11] which is in the back of the bus. The front axle is a ZF 82 RL EC axle with a weight of 482 kg (Mercedes-Benz, 2021, see Image 6D).

The entire portal axle unit with two water-cooled asynchronous electric motors, control arms, springs and shock absorbers, weighs 1,220 kg (Mercedes-Benz, 2021; ZF Friedrichshafen AG, 2021a). The motors with a total weight of 590 kg are not considered to be part of the drivetrain cluster but belong to the motor cluster. Therefore, the weight of the portal axles is assumed to be 630 kg.

Additionally, electric buses are provided with regenerative braking systems that allow them to recuperate energy. The so-called electropneumatic brake system includes disc brakes and wear-free brakes that allow the recuperation of energy during braking (ZF Friedrichshafen AG, 2021b). Furthermore, the air suspension system serves to provide driving comfort for drivers and passengers. It is also capable of raising and lowering the vehicle, referred to as kneeling. This lowers the physical barrier for passengers to access the bus.

It remains to be mentioned that the bus is assumed to have six wheels, so no additional spare wheel is included. The gained space from the combustion engine, clutch, and the gearbox (which are not required by electric buses) are used to house battery modules (ZF Friedrichshafen AG, 2021b).

In addition to the axles itself, ZF Friedrichshafen AG provides inverters and control units including the appropriate software that informs the driver about the current state of the motor and battery system (ZF Friedrichshafen AG, 2021b). Services such as IT products also represent crucial input parts of electric buses. Box 2 sums up the most relevant points in this respect.

Box 2

Services as an input for electric buses

The adoption of an electric bus fleet needs to be understood as a part of a complex system that needs diverse services to operate smoothly and which is context-dependent and geography-dependent. Examples of the services required are travel assistance, management systems, design of strategic plans, maintenance or repair of the fleet, associated IT services, and funding, among others.

Services associated to electric buses can be divided into two categories. Firstly, there are services embedded in the bus itself and which are fundamental for its operation (for instance, IT services like Battery Management Systems (BMS)). BMSs are real-time systems controlling vital functions for the safe and optimal operation of the electrical energy storage system in electric vehicles. These functions include monitoring of temperatures, voltages and currents, maintenance scheduling, battery performance optimization, battery data collection/analysis, among others (Vezzini, 2014). Secondly, there are services that facilitate the inclusion and permanence of electric buses into the transport systems, such as maintenance or repair services. As this document focuses on the inputs required to produce electric buses, the first category of services will be elaborated on in more depth.

There is scarce publicly available information about the services contained in a bus. For example, while the BMS is essential for the bus to work properly, no specific information could be obtained about the most widely used types of BMS. The lack of information also stems from the fact that highly technological services are probably intellectual property of the bus manufacturing firm and are thus meant to be kept within the firm. As a result, measuring trade in services in the context of electromobility remains very difficult.

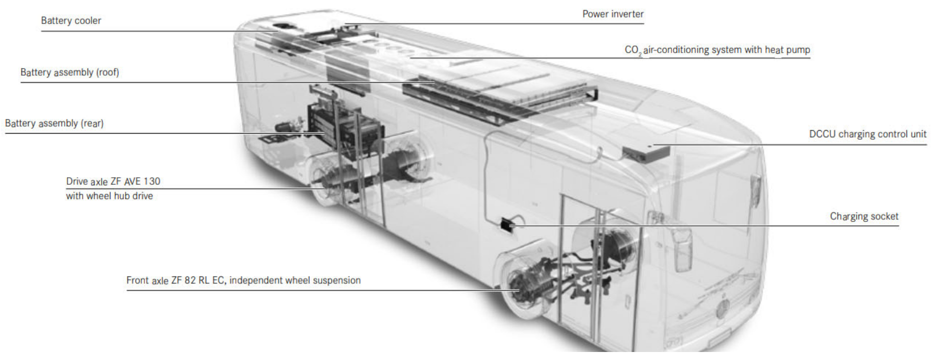
Source: Own elaboration.

[11] The axle ZF AVE 130 is now sold under the name AxTRAX AVE.

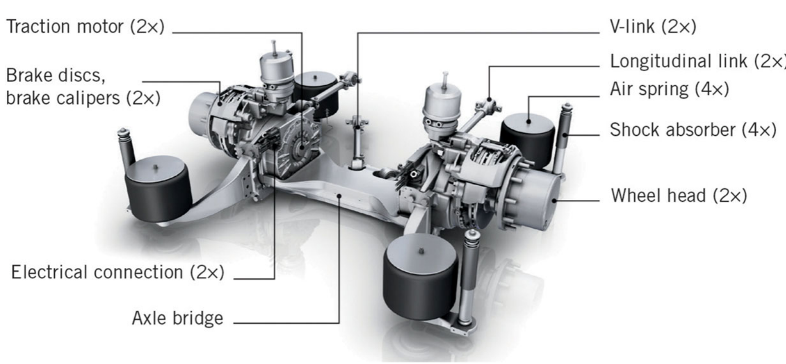
Image 6
eCitaro's drive train and portal axle with motors

A. eCitaro's drivetrain

B. eCitaro axles



C. eCitaro's electric portal axle (ZF AVE 130)



D. eCitaro's front axle (ZF 82 RL EC)

Source: Gross et al. (2015), ZF (n.d.a., n.d.b), Mercedes-Benz (2018).
Note. The two electric motors mounted on the portal axle are not considered parts of the drivetrain cluster but of the engine cluster.

Results (Drivetrain)

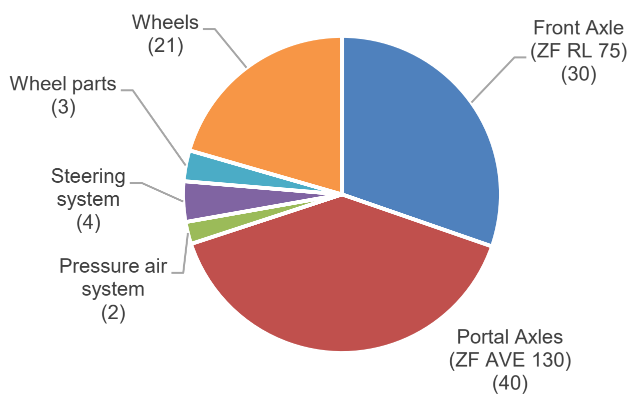
The products of the different vector levels have been disaggregated to a large extent (see Table 13). To the products without further disaggregation into their raw materials belong valves and tubes pipes as well as brake lining pads. Overall, the electronics cluster consists of six subclusters (see Figure 9).

Table 13
Disaggregation of the drivetrain cluster

Vector Level	Number of products	Weight in kg	Percentage of disaggregated products
Elaborated	7	1 589.6	100%
Semi-elaborated	19	1 589.6	98%
Raw materials	24	1 556.1	-
Summary	50	1 589.6	98%

Source: Own elaboration.

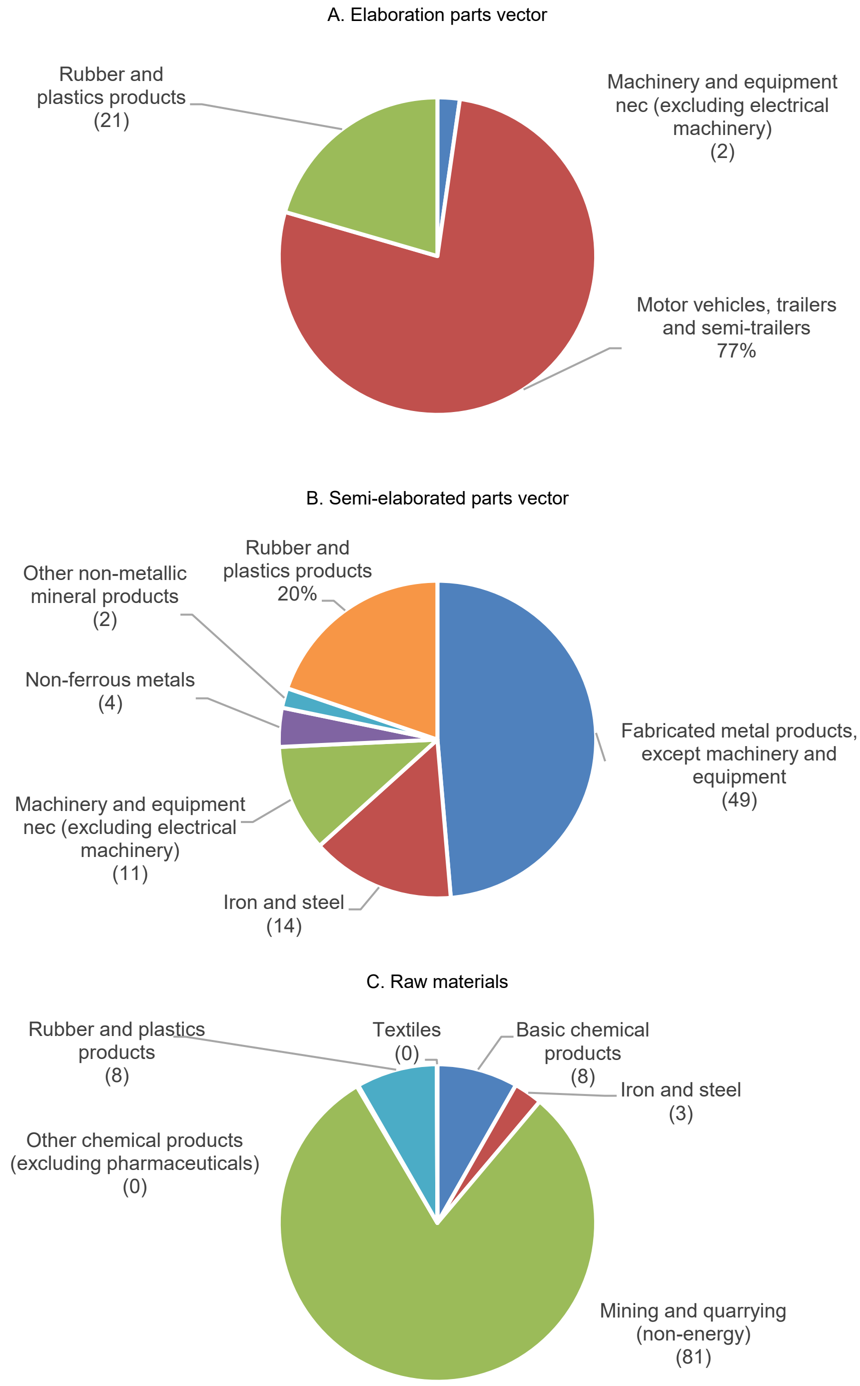
Figure 9
The subclusters of the drivetrain cluster



Source: Own elaboration.

Figure 10 exhibits the sectors of the inputs for the different vector in the drivetrain cluster by weight (the entire list of inputs can be found in the annex).

Figure 10
Economic sectors associated with the parts required for electric drivetrains by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

3. Battery

The battery cluster basically consists of heat exchangers, the battery cells, and the battery housing. Regarding the type of battery, we assume a Nickel, Manganese and Cobalt (NMC-111) battery with 10 modules. Total battery capacity is estimated to be 243 kWh (Forster, 2019). There were two reasons for assuming this battery type: firstly, it is the most common battery currently in use (Olivetti et al., 2017), and secondly, it is employed by our reference model, the eCitaro. Box 3 exhibits overall information on bus batteries and alternatives to NMC batteries.

Box 3
General information on batteries and alternatives to NMC batteries

The battery is a crucial part of the electric bus and is one of the main determinants of its autonomy. Increasing the number of battery modules rises input costs but also extends autonomy, presenting transport companies with a tradeoff. Furthermore, battery-charging times are longer than refilling times for conventional diesel buses, so potentially an increased number of drivers and e-buses may have to be deployed to meet demand. These are additional variables that determine the choice of the number of battery modules as well as battery types (Knote, 2017). Batteries represent an important part of the value of a bus: they may account for up to 40% of the value created during the manufacturing of the vehicle (IAA Mobility, 2020). The replacement of the battery of an electric bus is assumed to have a cost of approximately 180,000 Euros (Knote, 2017).

Other battery types on the market are lithium ferro phosphate and lithium titanate oxide batteries (see Table 1). The bus supplier BYD uses lithium ferro phosphate batteries (Chen, 2022).

Table 1
Comparison of different battery types

Battery type	NMC	Solid state	Lithium ferro phosphate	Lithium titanate oxide
Charging capacity	Good	Fair	Good	Very good
Range	Fair	Very good	Poor	-
Service life	Fair	Very good	Fair	Good
Summary	Good compromise between range and quick charge capability. Different operating concepts possible (hydrogen, overhead line)	Ideally suited for overnight charging concepts with long tours thanks to its long operating range	Similar to NMC but with worse range at the same weight. Irregular cell aging	Only suitable for route charging concepts with very short distances and fast recharging

Source: Redaktion E-Engine (2021).

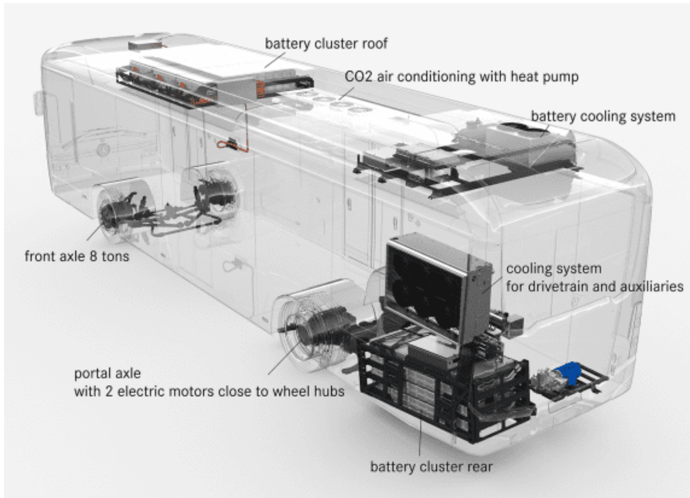
Each module weighs 254 kg (AKASOL, 2021), which implies a total assumed weight for the battery cluster of 2,540 kg. As the battery modules include electronics that are accounted for in the electronics cluster (e.g. cables), the clusters total weight was reduced by 17.6 kg to 2,522.4 kg. Still, for electronical parts a share of 2% (56 kg) was reserved in the battery cluster, including semiconductors among other parts.

Four battery modules are installed in the rear and six on the top of the bus (see Image 7A). Each battery module is made up of 15 cell modules, together with a control unit for monitoring purposes and as a means of balancing the charge of the battery cells. Each separate cell module houses 12 battery cells (Mercedes-Benz, 2018; see Image 7B).

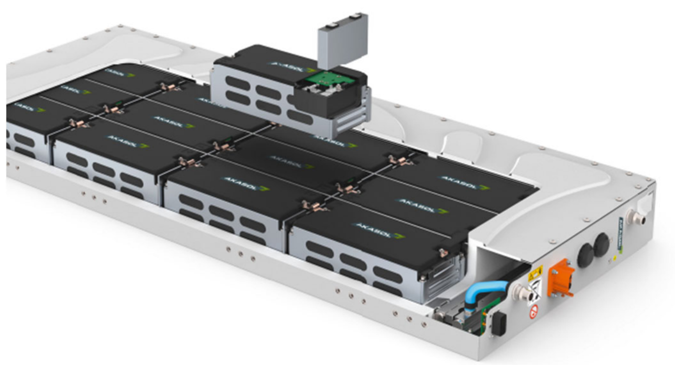
The company AKASOL produces the eCitaro’s battery system, referred to as Akasystem OEM PRC. It includes a lithium-ion battery cell manufactured by Samsung. Furthermore, it is a modular solution with integrated tubes and heat exchange units for cooling the lithium cells while charging or discharging. It has an efficient water-cooling, which guarantees stable tempering at 25 degrees and is essential for meeting the bus’s life expectancy (AKASOL, 2018). Under perfect conditions, the eCitaro has a range of 280 km, which is reduced to 170 km when using air conditioning (Mercedes-Benz, 2019a). Table 16 sums up the technical specifications related to the battery employed in eCitaros.

Image 7
Battery employment in the eCitaro

A. Battery in the eCitaro



B. Battery module



Source: AKASOL (2021) & Sheppard (2018).

Table 14
Battery performance indicators

Item	Value	Unit
Cell connection in module	12	Slp
Capacity[a]	50	Ah
Energy[a]	33	kWh
Technology	Li-Ion NMC	-
Nominal voltage[a]	655	V
Voltage (max.)	756	V
Voltage (min.)	540	V
Discharging power max. (IOs)[b]	150	kW
Charging power max. (10s)[b]	100	kW
Continuous power discharge (RMS)[b]	100	kW
Continuous power charge[b]	45	kW
Internal HV-Fuse	200	A
Power consumption in standby mode	8	W
Cycle life[c]	>3.000	cycles

Source: Taken from AKASOL (2021).
[a]0,33C reference discharge cycle.
[b]Depending on SOC and temperature.
[c]Depending on individual user profile, especially DoD, temperature, and power.

The eCitaro can be charged using a fast depot charging technology with 150 kW in 1.5-2.5 h (Forster, 2019). In this methodology, the charging system was omitted. The following paragraphs resume the setup and disaggregation of the battery cluster.

In our estimation, battery cells have a weight of 1,760 kg while the cases and other battery parts for all 10 battery modules weigh 780 kg (based on Deutsche Rohstoffagentur, 2021, see Table 15).

Table 15
Weight distribution of battery inputs and parts
(In percentages)

Component	Material	Percentage of the total weight
Housing	Steel or aluminum	20-25
Cathode	NMC, NCA, LFP or LMO	25-35
Anode	Graphite	14-19
Electrolyte	Lithium salt in an organic solution	10-15
Cathode collector foil	Aluminum	5-7
Anode collector foil	Copper	5-9
Separator	PP, PE plastic	1-4
Additives	Russ, silicon, etc.	-

Source: Deutsche Rohstoffagentur (2021).

The disaggregation of battery cells used as a reference the shares suggested by Weyhe and Yang (2018), Li et al. (2016) and Research Interfaces (2018) are summed up in table 16. For steel, copper, aluminum, plastics, circuits, and carbon (graphite) semi-elaborated products the shares suggested in table 19 were used for their mass (weight) calculation. Similarly, from table. 17 it is assumed that the 12% corresponding to electrolytes (plus the additional share of lithium corresponding to the 2% of the weight from that same table) is assigned to lithium oxide and hydroxide, since electrolytes is basically lithium salt is dissolved in organic solutions that have not been matched with an HS code (Li et al, 2016). Thus, the share of lithium in a battery cell it is assumed to be 14% of its total weight. (246.4 kilograms, see Table 16). Too visualize a further tracing of the different degrees of processing of lithium check box 3.

Table 16
Primary inputs required to produce the eCitaro's battery cells (ten modules)
(In kilograms)

HS 2017	Description of the required product	Requirement
282520	Lithium oxide and hydroxide	246.4
730890	Iron or steel; structures and parts thereof n.e.c. in heading 7308	316.8
741999	Copper; articles n.e.c. in heading no. 7419	123.2
761699	Aluminum; articles n.e.c. in heading 7616	35.2
392010	Plastics; plates sheets film foil and strip (not self-adhesive) of polymers of ethylene non-cellular [...]	70.4
853400	Circuits; printed	17.6
854590	Carbon; lamp carbons battery carbons and other articles of graphite or other carbon [...]	281.6
260500	Cobalt ores and concentrates	222.9
260200	Manganese ores and concentrates including ferruginous manganese ores and concentrates [...]	222.9
260400	Nickel ores and concentrates	222.9
	Total	1 760

Source: Own elaboration based on Research Interfaces (2018), Li et al. (2016) and Weyhe & Yang (2018).

Table 17
Battery inputs by battery part
(In percentages)

Part	Resource	LCO	NMC	LMO
Cell housing	Steel	19	18	19
	Aluminum	0	0	0
	Plastics	1	1	1
Anode	Carbon	16	16	16
	Copper	8	7	8
Cathode	Manganese	0	6	8
	Lithium	2	2	2
	Cobalt	19	6	0
	Nickel	0	4	0
	Aluminum	4	3	4
	Iron	0	0	0
	Phosphorus	0	0	0
	Titanium	0	0	0
	Oxygen	10	9	13
	Others	5	11	13
Separator	Plastics	3	3	3
Electrolyte	Solvent	14	12	14
Sum		100	100	100

Source: Taken from Weyhe & Yang (2018).

To establish the mass content of the metal's cobalt, manganese, and nickel, we assumed an NMC-111 battery for the bus, since it is the most common battery in the market (Li et al., 2016; Olivetti et al., 2017). Consequently, the remaining weight from the disaggregation exercise (explained in the previous paragraph) was assigned to these metals in equal proportions (Research Interfaces, 2018). Thus, each of these three metals would weigh 222.9 kg in the battery cell component. As these core materials are included in a range of HS codes, depending on their level of elaboration, Box 4 provides information on the relevant codes to consider for each input material.

Box 4
Disaggregation of HS codes for key raw materials required in battery production: Lithium, cobalt, nickel, manganese, and graphite

Lithium

Lithium is a crucial raw material in the battery value chain. An electric bus with 10 battery modules requires a total of 246.4 kg of lithium. In the raw materials vector, we assumed the HS code 282520 as lithium. However, as Table 1 reveals, there exist multiple codes determining the different stages of elaboration of lithium, thereby reflecting different steps on the value chain. Therefore, it is important to not focus on only one HS code of lithium, but to consider that it might be traded in different stages of processing. This might be also true for other raw materials, but in case of lithium it is even more relevant (LaRocca, 2020).

Table 1
HS Codes used in lithium trade

Form of lithium (process stage)	HS code	Description	Source(s) type
Unprocessed lithium minerals (raw stage 1)	253090	Other mineral substances, not elsewhere specified or included	Mine extraction
	-	Lithium rich salt concentrates	Brine extraction
Processed lithium chemicals (raw stage 2)	283691	Lithium carbonate	Lithium rich ores and salt concentrated
	282520	Lithium oxide and hydroxide	Lithium rich ores or lithium carbonate
Refined lithium compounds	282739	Chlorides, not elsewhere specified or included	Lithium carbonate
	282690	Other Fluorides, fluorosilicates, fluor aluminates and other complex fluorine salts	Various lithium compounds, such as lithium chloride, lithium hydroxide, or lithium fluoride
	280519	Akali metals, other than sodium	Lithium chloride

Source: LaRocca (2020), HS 2017.

Cobalt

Cobalt is another key input in battery production. Under our assumptions, an e-bus requires 222.9 kg of cobalt. Like Lithium, in the case of cobalt different stages of processing can be distinguished in the HS (see Table 2). In the raw materials vector, HS code 260500 was used to include cobalt as an input.

Table 2
HS codes used in cobalt trade

Form of cobalt (process stage)	HS code	Description	Source(s) type
Unrefined raw cobalt ores and concentrates	260500	Raw ores and concentrated obtained as byproduct from nickel and copper mining operations	-
Refined cobalt oxides and hydroxides	282200	Refined product processed from cobalt ores and concentrates	-
Refined unwrought cobalt	810520	Refined cobalt product processed from cobalt ores and concentrates	-

Source: Matthews (2020), HS 2017.

Nickel

Nickel is another key input in batteries. In this respect, only premium nickel with a high level of purity is suitable for battery production. Table 3 sums up the HS codes of nickel products.

Table 3
HS codes used in nickelt trade

Form of nickel (process stage)	HS code	Description	Source(s) type
Unprocessed raw materials	260400	Nickel ores and concentrates	Mining extraction from laterites
	282540	Nickel oxides and hydroxides	Mining extraction from laterites
Unprocessed raw materials	283324	Sulphates; of nickel	Mining extraction from sulfides
Processed nickel	750110	Nickel; nickel mattes	Refining of nickel and production of nickel pellets and other intermediates
	750120	Nickel; oxide sinters and other intermediate products of nickel metallurgy	
Intermediate nickel products with low level of processing	750210	Nickel; unwrought not alloyed	-
	750220	Nickel; unwrought alloys	-
	750400	Nickel; powders and flakes	-
Waste	750300	Nickel; waste and scrap	-
Nickel products	750511	Nickel; bars rods and profiles not alloyed	-
	750512	Nickel; bars rods and profiles of nickel alloys	-
	750521	Nickel; wire not alloyed	-
	750522	Nickel; wire of nickel alloys	-
	750610	Nickel; plates sheets strip and foil not alloyed	-
	750620	Nickel; plates sheets strip and foil of nickel alloys	-
	750711	Nickel; tubes and pipes not alloyed	-
	750712	Nickel; tubes and pipes of nickel alloys	-
	750720	Nickel; tube and pipe fittings	-
	750810	Nickel; cloth grill and netting of nickel wire	-
	750890	Nickel; articles thereof n.e.c. in item no. 7508.1	-

Source: Own elaboration based WCO (2017)

Manganese

Manganese is another crucial input in batteries. Furthermore, the trend is aiming towards a reduction of the cobalt content and an increase of the manganese or nickel content due to relative prices of the metals Weimer et al., 2019). The relevant HS codes in this context are exhibited in Table 4.

Table 4
HS codes used in manganese trade

Form of Manganese (process stage)	HS Code	Description	Source(s) type
Unprocessed raw materials	260200	Manganese ores and concentrates including ferruginous manganese ores and concentrates with a manganese content of 20% or more calculated on the dry weight	Mining extraction from open pits
	282010	Manganese dioxide	
	282090	Manganese oxides; excluding manganese dioxide	
Manganese alloys/intermediate products	720211	Ferro-alloys; ferro-manganese containing by weight more than 2% of carbon	Ferromanganese and silicomanganese are produced by the smelting of ores in a blast or electric furnace
	720219	Ferro-alloys; ferro-manganese containing by weight 2% or less of carbon	
	720230	Ferro-alloys; ferro-silico-manganese	
	722720	Steel alloy; bars and rods hot-rolled in irregularly wound coils of silico-manganese steel	
	722820	Steel alloy; bars and rods of silico-manganese steel	
	722920	Steel alloy; wire of silico-manganese steel	
	722990	Steel alloy; wire of materials other than silico-manganese steel	
Waste	811100	Manganese; articles thereof including waste and scrap	-
Manganese products	850680	Cells and batteries; primary manganese dioxide	-

Source: Own elaboration based on Brittanica (n.d.) & Adjei, Gajigo & Mutambatsere (2011).

Graphite

Graphite will play an essential role in decarbonizing the transportation sector as it is one of the main components that comprises an EV battery. Either natural or artificial graphite serve as an input to produce batteries. Although, the carbon footprint of artificial graphite is significantly higher relative to the graphite found naturally. Table 5 shows the different process stages of graphite in the HS (Ritoe et al., 2022).

Table 5
HS codes used in graphite trade

Form of graphite (process stage)	HS code	Description	Source(s) type
Unprocessed raw materials	250410	Graphite; natural in powder or in flakes	Mining extraction
	250490	Graphite; natural in other forms excluding powder or flakes	Mining extraction
	380110	Graphite; artificial	produced from oil or coal-based needle coke
Intermediate graphite products with low level of processing	380120	Graphite; colloidal or semi-colloidal	graphite suspended in water, alcohol, petroleum oil, castor oil, glycerin, or other liquids,
	380190	Graphite or other carbon-based preparations; in the form of pastes blocks plates or other semi-manufactures	-
	681510	Stone articles and other mineral substances non-electrical articles of graphite or other carbon	-
Graphite products	690310	Refractory ceramic goods; containing by weight more than 50% of graphite or other forms of carbon or of a mixture of these products excluding those of siliceous fossil meals or similar earths	-
	854590	Carbon; lamp carbons battery carbons and other articles of graphite or other carbon with or without metal of a kind used for electrical purposes	-

Source: Own elaboration based on Ritoe et al. (2022) & Glodeanu, F. (2016).

Results (battery)

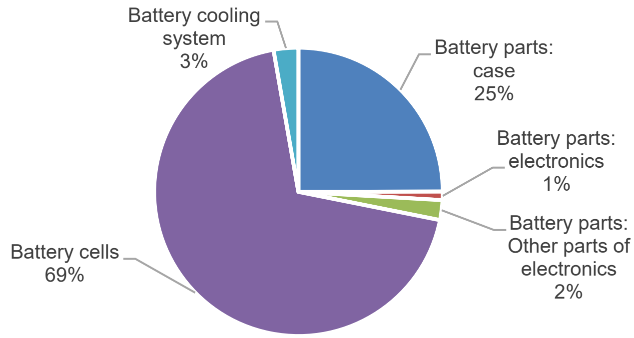
The products of the different vector levels have been fully disaggregated (see Table 18). The battery cluster consists of five subclusters (see Fig. 11).

Table 18
Disaggregation of the battery cluster

Vector Level	Nb. of products	Weight in kg	Percentage of disaggregated products
Elaborated	3	2 522.4	100
Semi-elaborated	12	2 522.4	100
Raw materials	9	2 515.2	-
Summary	24	2 522.4	100

Source: Own elaboration.

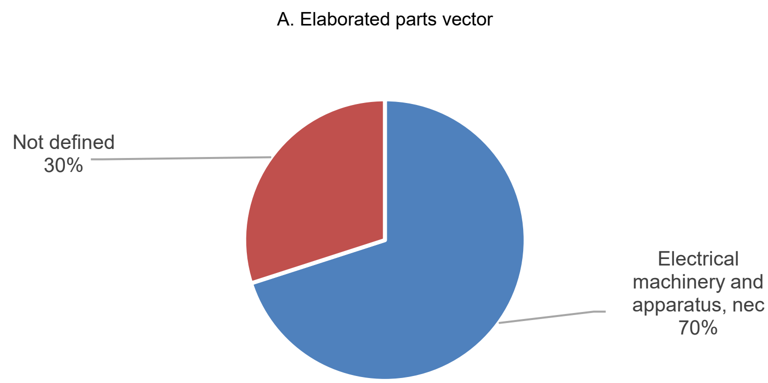
Figure 11
The subclusters of the battery cluster

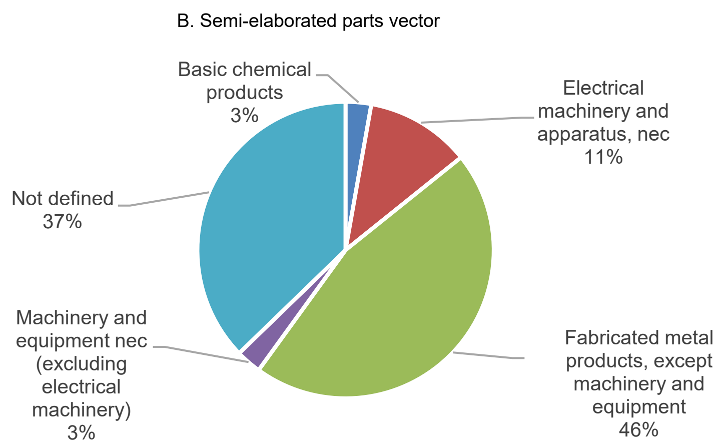


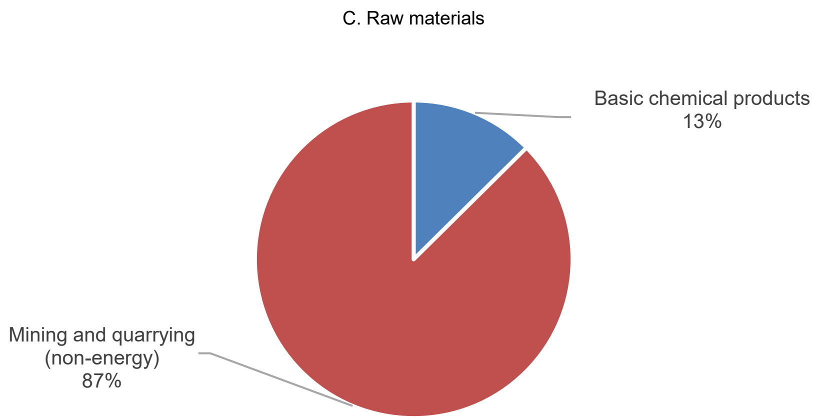
Source: Own elaboration.

Figure 12 exhibits the sectors of the inputs for the different vector in the battery cluster by weight (the entire list of inputs can be found in the annex).

Figure 12
Economic sectors associated with the parts required for bus battery by level of product elaboration
(Percentages as a fraction of the cluster's total weight)







Source: Own elaboration.
Note. For battery cases, the cooling system and electronic parts of the battery the HS does not include defined codes. Therefore, dummies have been introduced that cannot be mapped to economic sectors.

C. Conventional bus: Citaro with an internal combustion engine

This chapter characterizes the Citaro model that is based on internal combustion processes, referred to as a conventional or diesel bus.

1. Conventional diesel engine

The conventional diesel engine system (also referred to as motor) consists of:

- Intake air pressurizing system via a turbocharger.
- Engine block of cast iron with integrated cooling canals, camshaft, and cylinders.
- Transmission belts for an electric generator, lubricant pump.
- Cooling medium cooling system.
- Chain transmission system for crankshaft.
- Exhaust gas filtering system and exhaust pipe including the muffler.
- Smoke detector and motor control system.

Image 8
Citaro's engine OM 936 h

Source: Mercedes-Benz (2019b).

Results (conventional motor)

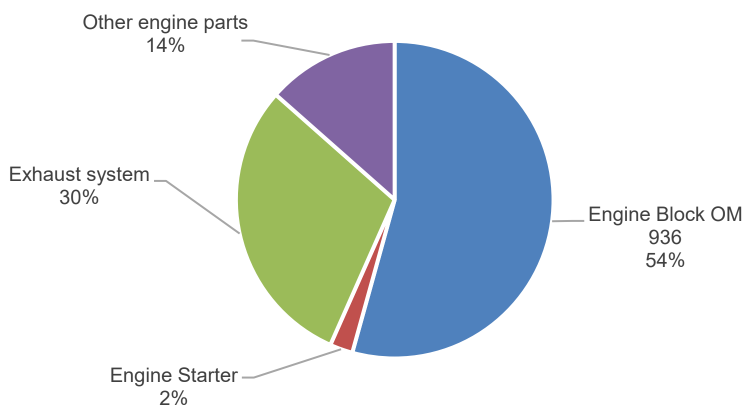
The products of the different vector levels have fully been disaggregated (see Table 19). The engine cluster consists of four sub-clusters (see Figure 13).

Table 19
Disaggregation of the conventional motor cluster

Vector Level	Nb. of products	Weight in kg	Percentage of disaggregated products
Elaborated	7	1 113.0	98
Semi-elaborated	14	1 087.0	93
Raw materials	21	1 012.0	-
Summary	42	1 113.0	91

Source: Own elaboration.

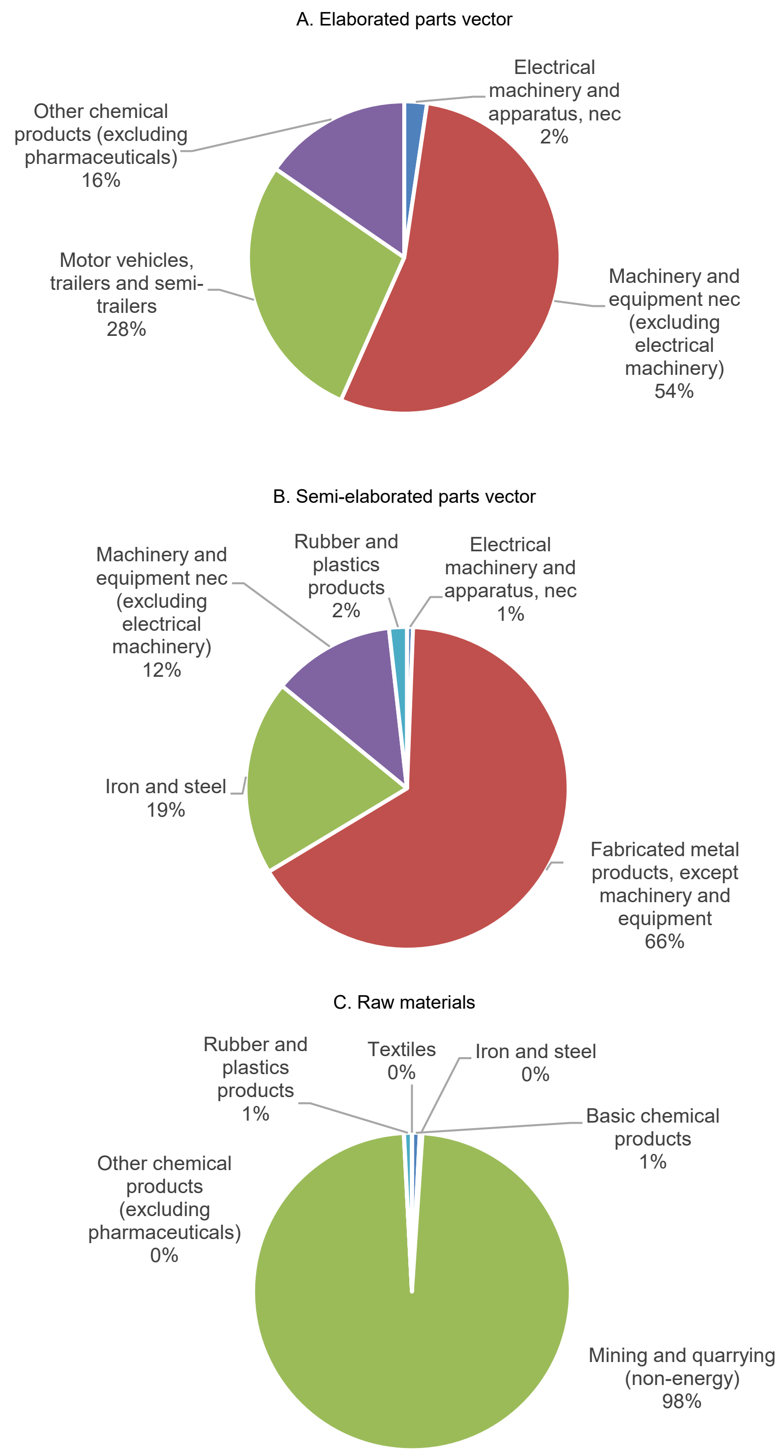
Figure 13
Subclusters of the conventional motor cluster



Source: Own elaboration.

Figure 14 on the next page exhibits the sectors of the inputs for the different vector in the conventional motor cluster by weight (the entire list of inputs can be found in the annex).

Figure 14
Economic sectors associated with the parts required for the diesel engine by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

2. Conventional drivetrain

The conventional drivetrain includes all systems necessary to provide a proper mechanical transmission from engine to road. It also includes the suspension system and the steering system that is connected to the automatic gear shifting management and the steering wheel. It consists of:

- Air suspension system to provide proper driving comfort for drivers and passengers. It is also capable of raising and lowering the vehicle.
- Gearbox/es for translation of torque.
- Wheels and brakes.
- Steering mechanism (connected to the steering wheel).

Results (drivetrain)

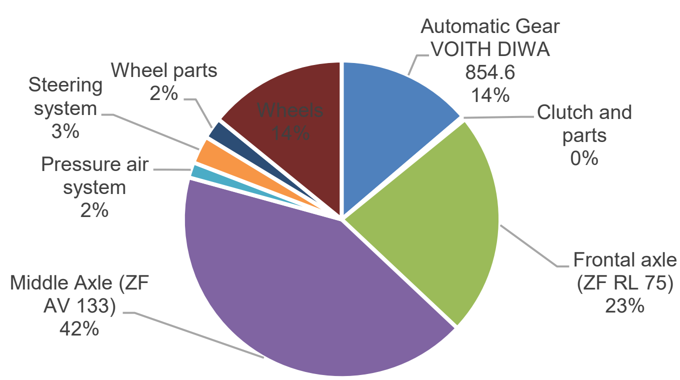
The products of the different vector-levels have fully been disaggregated (see Table 20). The drivetrain cluster consists of eight sub-clusters (see Figure 15).

Table 20
Disaggregation of the conventional drivetrain cluster

Vector Level	Number of products	Weight in kg	Percentage of disaggregated products
Elaborated	8	2 303.4	100
Semi-elaborated	20	2 294.9	97
Raw materials	15	2 226.0	-
Summary	43	2 303.4	97

Source: Own elaboration.

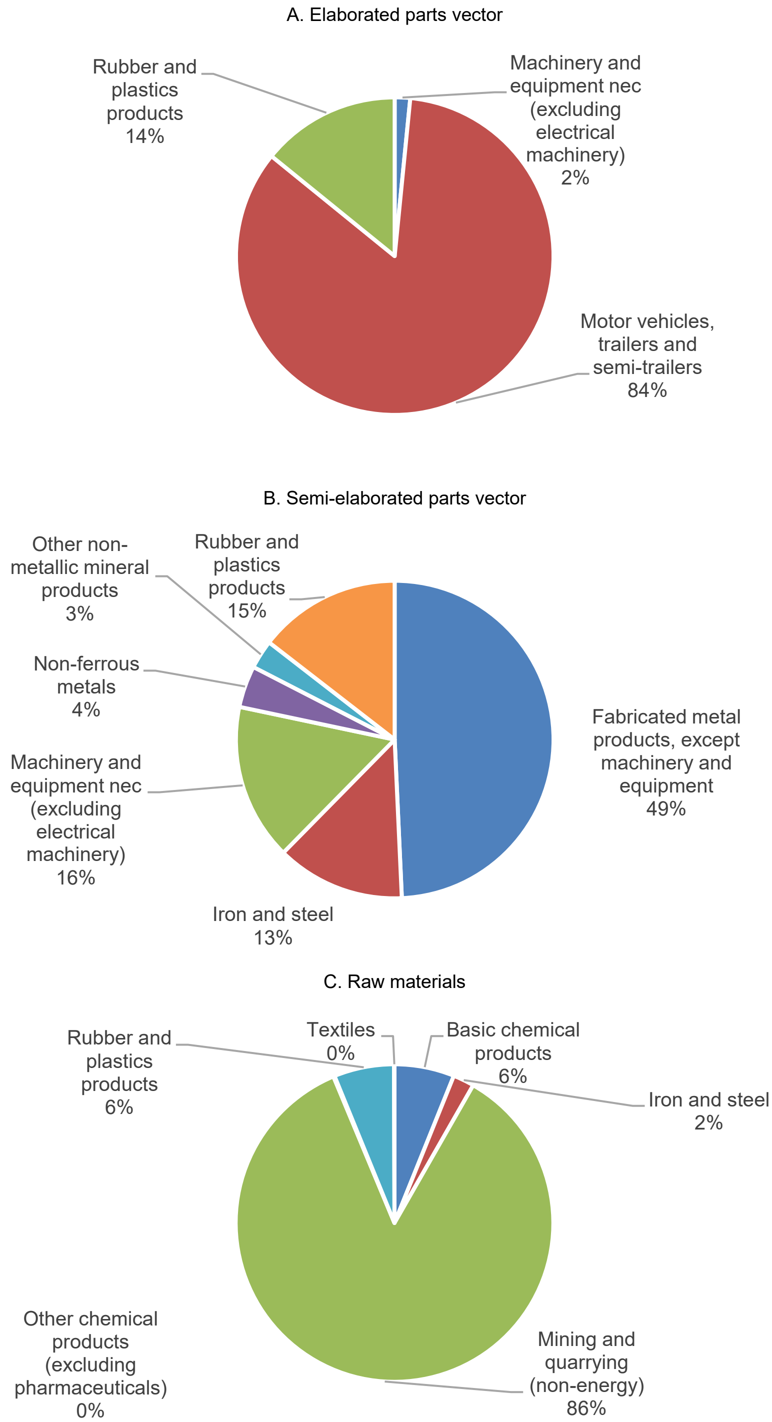
Figure 15
Subclusters of the conventional drivetrain cluster



Source: Own elaboration.

Figure 16 exhibits the sectors of the inputs for the different vector in the drivetrain cluster by weight (the entire list of inputs can be found in the annex).

Figure 16
Economic sectors associated with the parts required for the conventional drivetrain by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

3. Diesel fuel sistem

The diesel engine fuel system consists of:

- Tank (including filling hose).
- Pumps for transporting and pressurizing the fuel (common-rail system) including fuel filters.
- Valves, thermometers, and manometers for controlling and surveying the system.

Results (Fuel Tank)

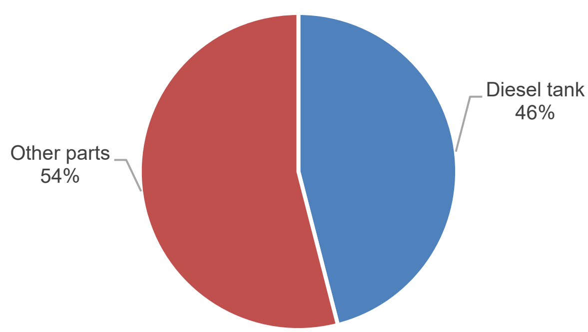
The products of the different vector-levels have fully been disaggregated (see Table 21). The fuel tank cluster consists of two sub-clusters (see Figure 17).

Table 21
Disaggregation of the fuel tank cluster

Vector Level	Number of products	Weight in kg	Percentage of disaggregated products
Elaborated	2	135.0	100
Semi-elaborated	7	135.0	80
Raw materials	9	108.0	-
Summary	18	135.0	80

Source: Own elaboration.

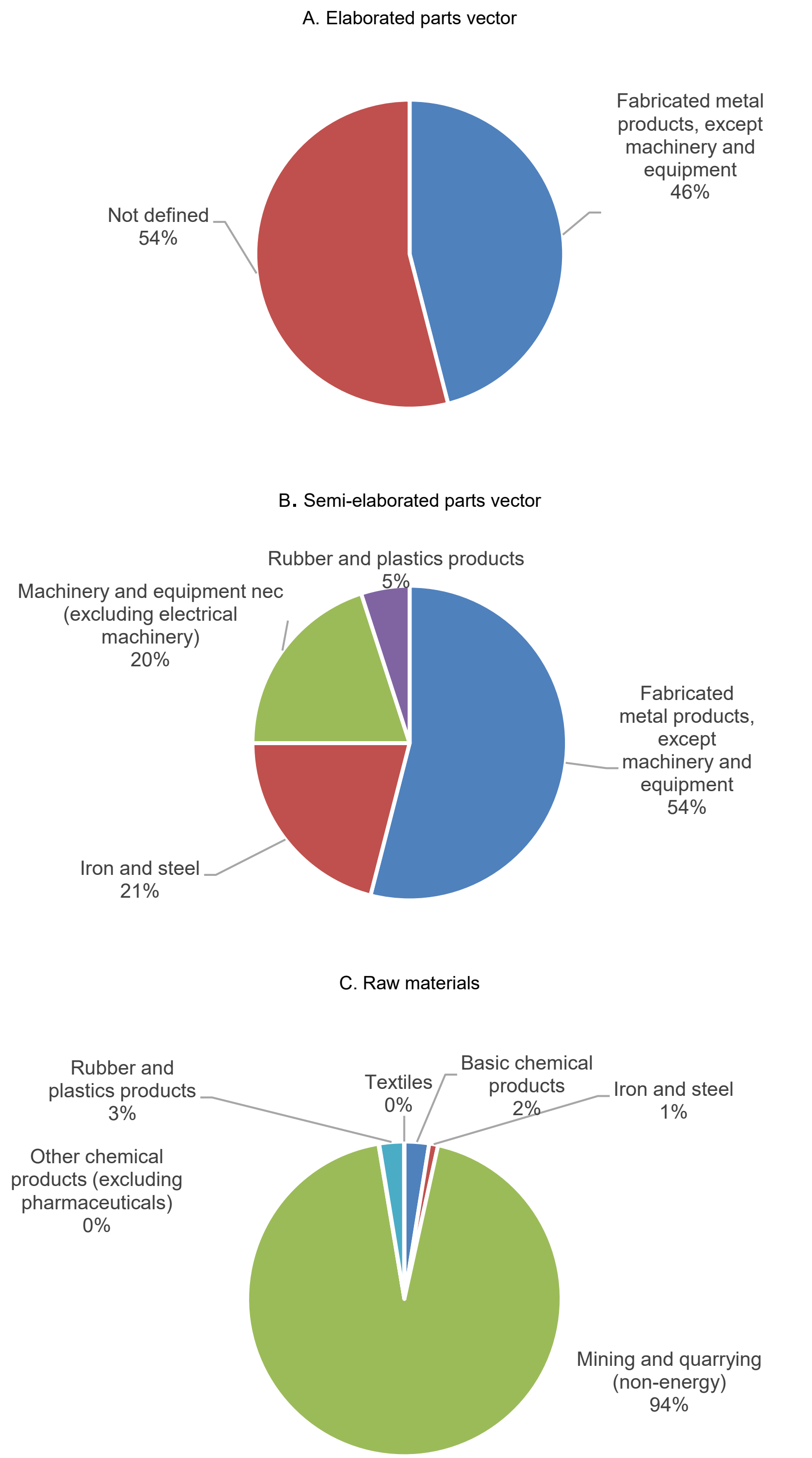
Figure 17
The subclusters of the fuel tank cluster



Source: Own elaboration.

Figure 18 exhibits the sectors of the inputs for the different vector in the fuel tank cluster by weight (the entire list of inputs can be found in the annex).

Figure 18
Economic sectors associated with the parts required for the conventional drivetrain by level of product elaboration
(Percentages as a fraction of the cluster's total weight)



Source: Own elaboration.

IV. Aggregated Results

This section sums up the aggregated results for both bus types that have been provided at the cluster level in the previous sections.

Electric Bus

The electric bus has been disaggregated to a large extent: 91.5% of its total mass has been disaggregated into its raw materials. The cluster with the lowest level of disaggregation is the electronics cluster (see Table 22) due to the complexity of its components.

Table 22
Weights and disaggregation by cluster and vector-level for the electric bus
(Weights in kilograms)

Cluster	Vector Level	Number of products	Weight	Percentage disaggregated	Percentage not disaggregated
Bus body	Elaborated	7	5 600.0	100	0
	Semi-elaborated	4	5 600.0	100	0
	Raw materials	25	5 600.0	-	-
	Total	36	5 600.0	100	0
Battery	Elaborated	3	2 522.4	100	0
	Semi-elaborated	12	2 522.4	100	0
	Raw materials	9	2 515.2	-	-
	Total	24	2 522.4	100	0
Motor	Elaborated	1	584.1	100	0
	Semi-elaborated	7	584.1	100	0
	Raw materials	7	584.1	-	-
	Total	15	584.1	100	0
Cabin	Elaborated	11	1 727.5	96	4
	Semi-elaborated	15	1 650.6	99	1
	Raw materials	28	1 627.5	-	-
	Total	54	1 727.5	94	6
Drivetrain	Elaborated	7	1 589.6	100	0

Cluster	Vector Level	Number of products	Weight	Percentage disaggregated	Percentage not disaggregated
	Semi-elaborated	19	1 589.6	98	2
	Raw materials	24	1 556.1	-	-
	Total	50	1 589.6	98	2
Electronics	Elaborated	35	1 656.6	47	53
	Semi-elaborated	18	782.3	82	18
	Raw materials	12	638.5	-	-
	Total	65	1 656.6	39	61

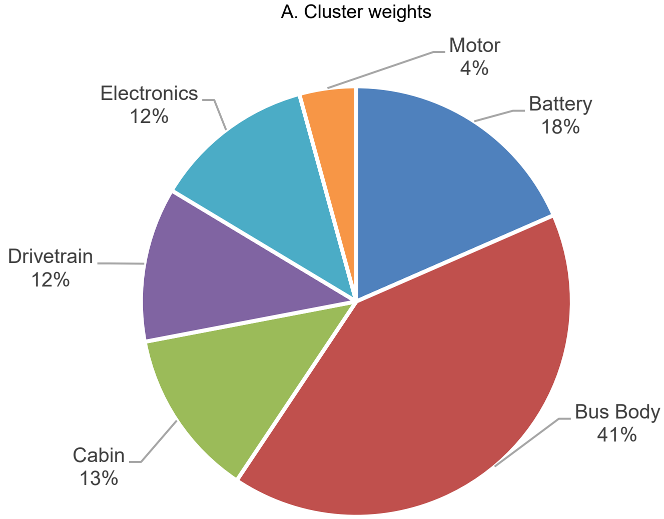
Source: Own elaboration.

Regarding the main sectors that provide inputs to produce an electric bus, the analysis must distinguish between the different vector levels. In case of the elaborated parts vector, the most important sector is the Motor Vehicles, Trailers and Semi-trailers sector (50 %) followed by the Electrical machinery and Apparatus sector (16 %). It is important to note that 20 % of the mass in the elaborated parts vector has not been assigned to a sector, because dummy products have been introduced in case no HS code exists (for example, there is no HS code for holding bars).

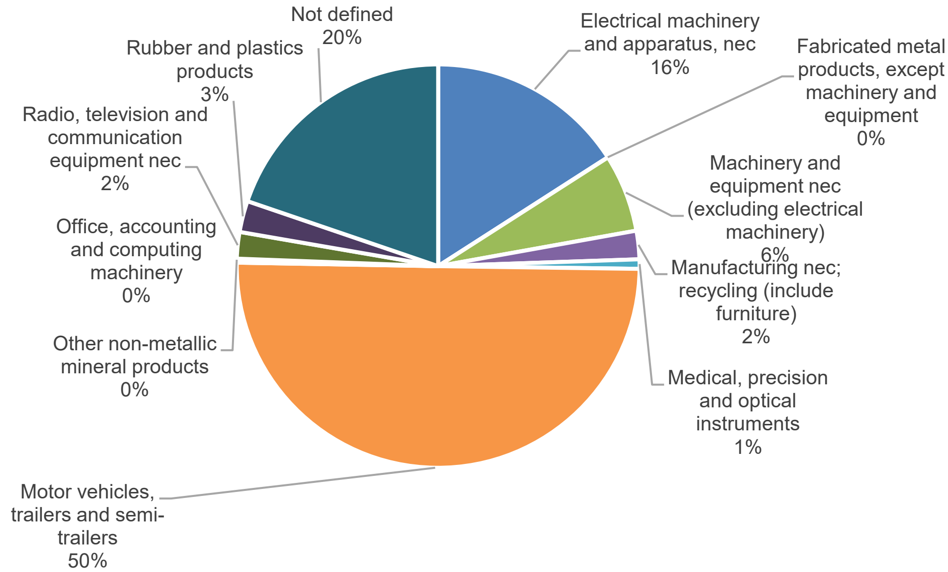
The semi-elaborated parts vector is dominated by the Fabricated Metal Products sector (60 %), followed by the Electrical Machinery and Apparatus sector (9 %), Rubber and Plastics Products (7 %) and various other sectors. Finally, the raw materials vector mainly consists of products belonging to the Mining and Quarrying (non-energy) sector (82 %) and the Basic Chemical Products Sector (15 %).

Figure 19
Associated economic sectors by vector-level to produce the electric bus
(Weights in kilograms)

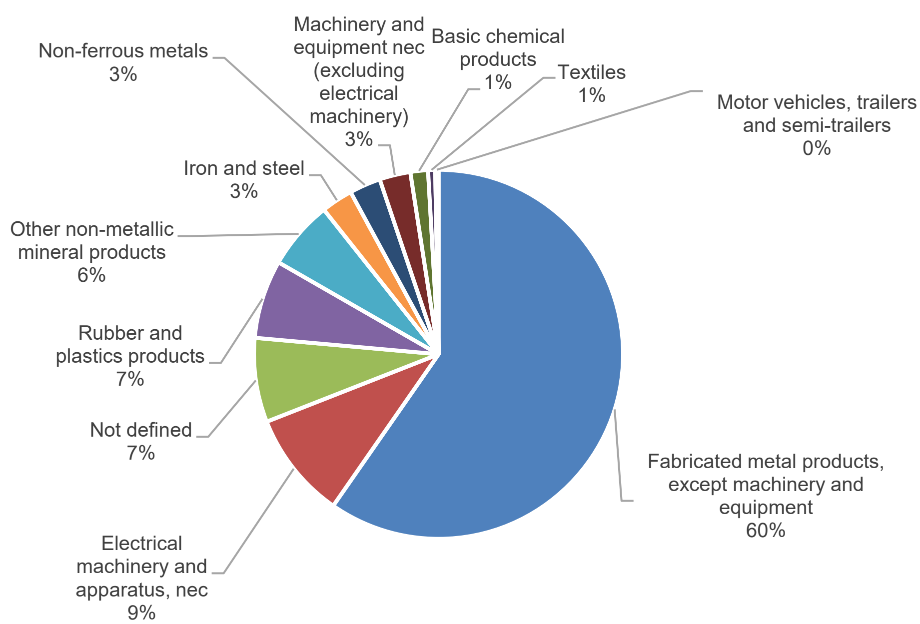
A. Cluster weights



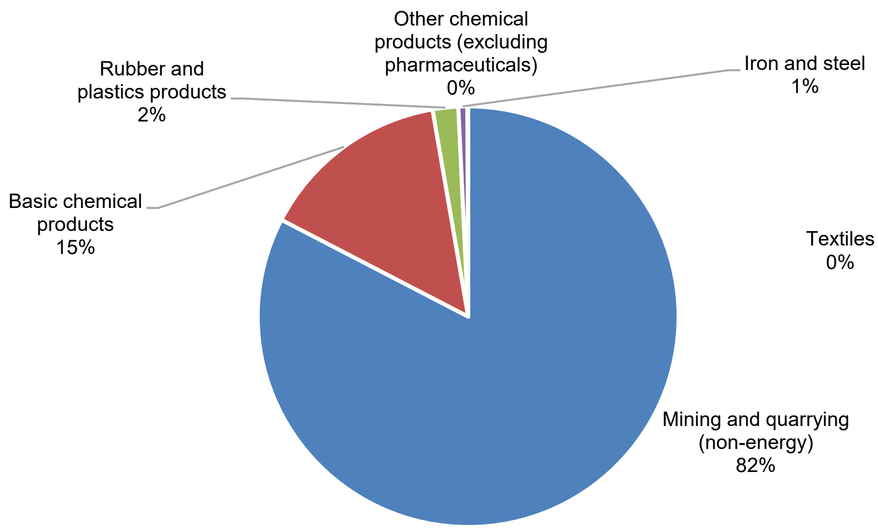
B. Elaborated parts vector with inputs aggregated by sector



C. Semi-elaborated parts vector with inputs aggregated by sector



D. Raw materials with inputs aggregated by sector



Source: Own elaboration.
Note. The sectors labelled "not defined" result from dummy codes introduced for products that have not been defined by the HS (for example Holding Bars in the Cabin cluster).

Conventional bus

The conventional bus has also been disaggregated to a large extent: 89.4% of its total mass has been disaggregated into its raw materials. Same as in the case of the electric bus, the cluster with the lowest level of disaggregation is the electronics cluster (see Table 23) due to the complexity of its components.

Table 23
Weights and disaggregation by cluster and vector-level for the electric bus
(Weights in kilograms)

Cluster	Vector Level	Number of products	Weight	Percentage disaggregated	Percentage not disaggregated
Bus Body	Elaborated	35	5 600	100	0
	Semi-elaborated	18	5 600	100	0
	Raw materials	25	5 600	-	-
	Summary	78	5 600	100	0
Fuel Tank	Elaborated	2	135.0	100	0
	Semi-elaborated	7	135.0	80	20
	Raw materials	9	108.0	-	-
	Summary	18	135.0	80	20
Motor	Elaborated	7	1 113.0	98	2
	Semi-elaborated	14	1 087.0	93	7
	Raw materials	21	1 012.0	-	-
	Summary	42	1 113.0	91	9
Cabin	Elaborated	11	1 727.5	96	4
	Semi-elaborated	15	1 650.6	99	1
	Raw materials	28	1 627.5	-	-
	Summary	54	1 727.5	94	6
Drivetrain	Elaborated	8	2 303.4	100	0
	Semi-elaborated	20	2 294.9	97	3
	Raw materials	15	2 226.0	-	-
	Summary	43	2 303.4	97	3

Cluster	Vector Level	Number of products	Weight	Percentage disaggregated	Percentage not disaggregated
Electronics	Elaborated	35	1 656.6	47	53
	Semi-elaborated	18	782.3	82	18
	Raw materials	12	638.5	-	-
	Summary	65	1 656.6	39	61

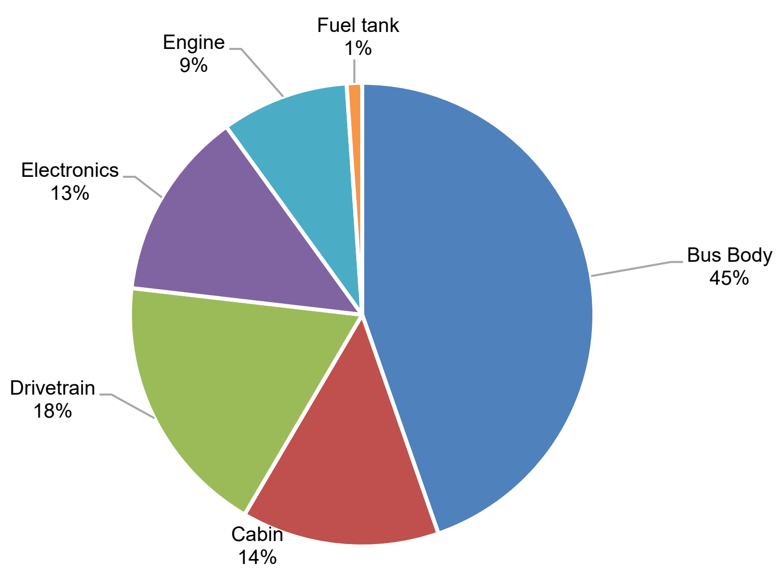
Source: Own elaboration.

The cluster which accounts for the largest share of total bus weight is the bus body (45% of total mass), followed by the drivetrain (18%), the cabin (14%), electronics (13%), the motor (9%), and the fuel tank (1%; see Figure 20A).

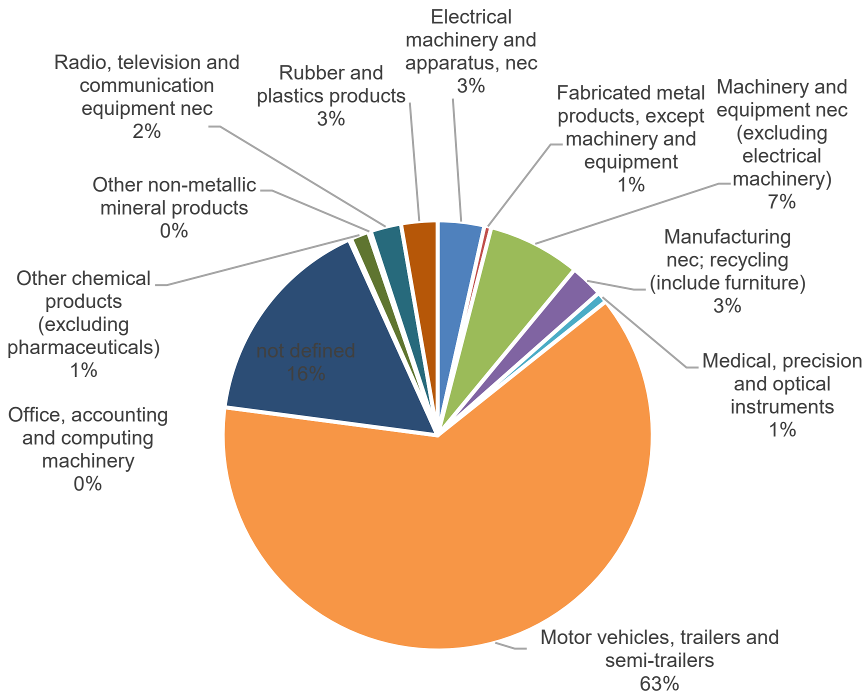
In the case of the elaborated parts vector, the most important sector is Motor Vehicles, Trailers and Semi-trailers (63 %) followed by the Machinery and equipment sector (7 %). 16 % of the mass in the elaborated parts vector has not been assigned to a sector. The semi-elaborated parts vector is dominated by the Fabricated Metal Products sector (65 %), followed by the sectors Rubber and Plastics Products (8 %) and the Other non-metallic mineral products (7 %) and various other sectors. Finally, the raw materials vector mainly consists of products belonging to the Mining and Quarrying (non-energy) sector (83 %) and the Basic Chemical Products Sector (13 %).

Figure 20
Associated economic sectors by vector-level to produce the conventional bus
(Weights in kilograms)

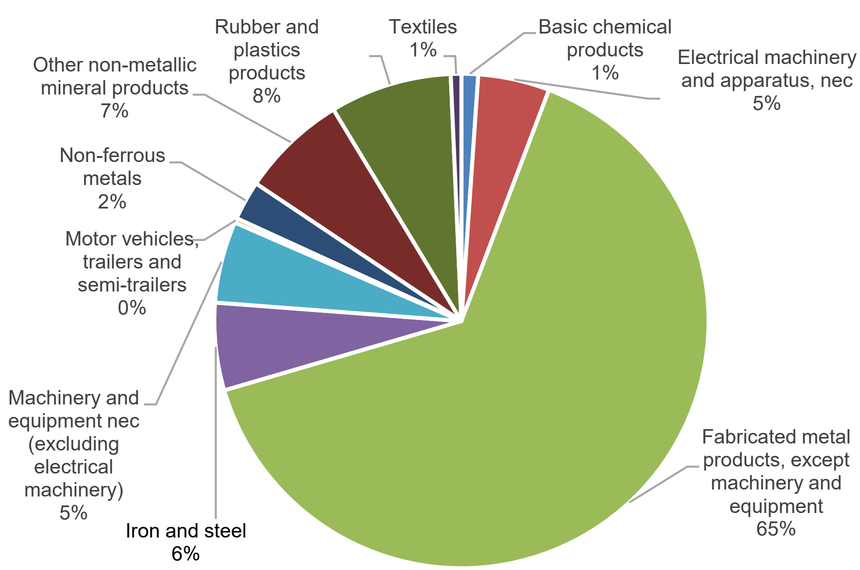
A. Cluster weights



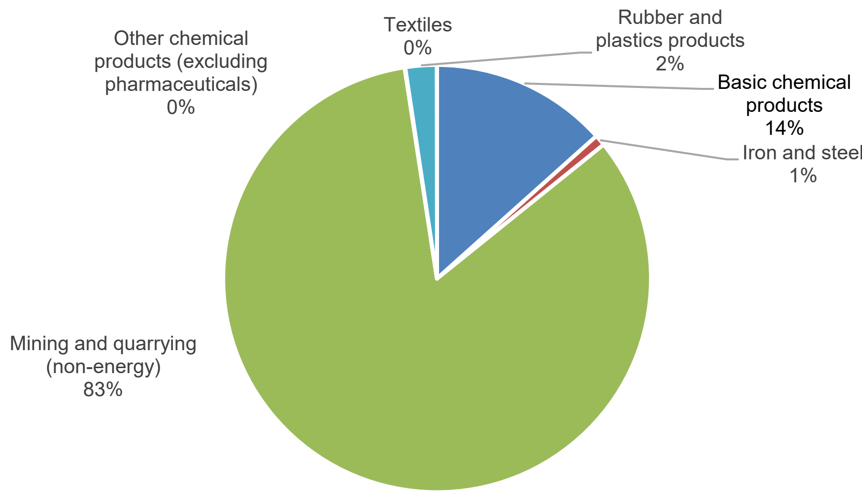
B. Elaborated parts vector with inputs aggregated by sector



C. Semi-elaborated parts vector with inputs aggregated by sector



D. Raw materials with inputs aggregated by sector



Source: Own elaboration.
Note. The sectors labelled "not defined" result from dummy codes introduced for products that have not been defined by the HS (for example Holding Bars in the Cabin cluster).

A. Key raw materials

The top four raw materials required for the production of both bus types are the same (see Table 24), even though with slightly varying weight requirements. This is mostly because the bus body, cabin and electronics clusters are the same for both types of bus. In the case of the electric bus, the top four raw material inputs represent 76% of total weight (82% for the conventional bus).

Table 24
Top four raw materials required to produce conventional and electric buses
(Weights in kilograms)

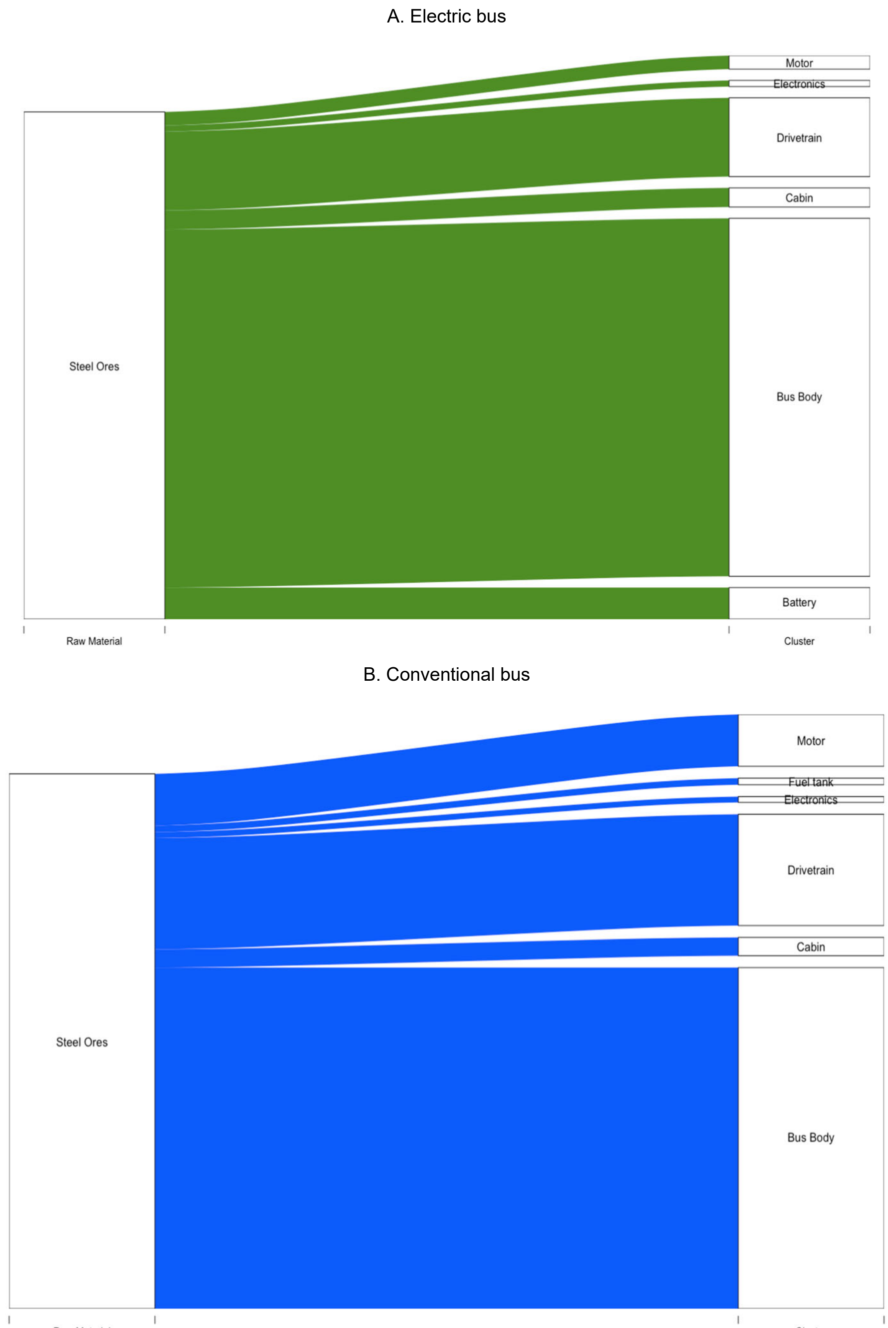
HS 2017	HS Description	Conventional bus	Electric bus	Difference
260111	Iron ores and concentrates; non-agglomerated	8 289.6	7 491.4	798.2
281122	Silicon dioxide	593.0	593.0	0.0
260600	Aluminum ores and concentrates	555.8	1 016.2	460.5
260300	Copper ores and concentrates	466.5	856.4	389.9

Source: Own elaboration.

Iron and concentrates

Iron is by far the most important raw material. It represents 55% of the weight of the electric bus and 66% of the conventional bus. Iron ores and concentrates are mainly required for the frame or bus body but also for the drivetrain and motor of both bus models (see Figure 21). It is important to have in mind the high energy intensity of the production and processing of iron ores and concentrates.

Figure 21
Requirements of iron ores and concentrates by cluster
(In kilograms)



Source: Own elaboration.

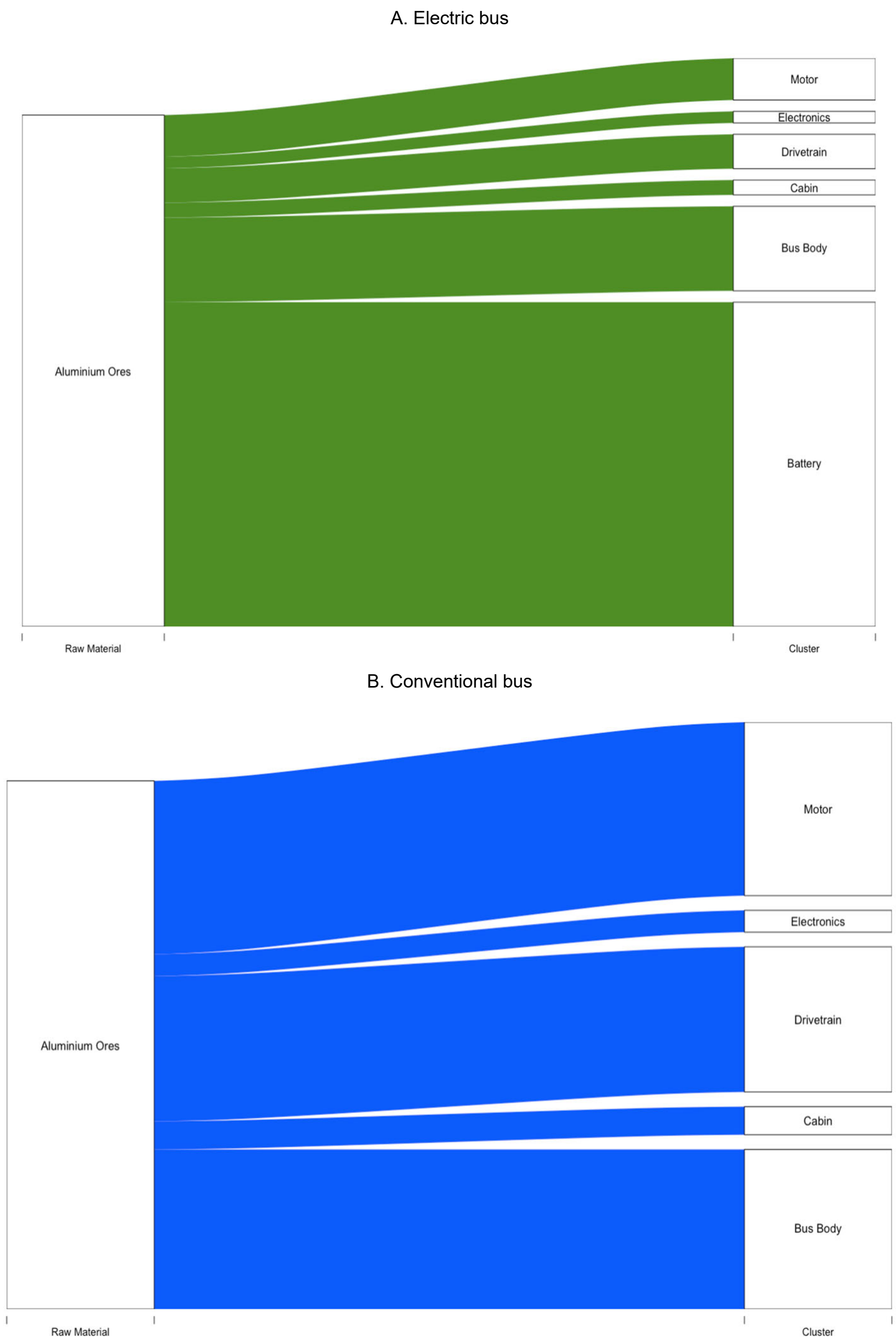
Silicon dioxide

Silicon Dioxide is required by both bus types in the same proportion. It is mainly required in the production of windows (91% of the total use of silicon dioxide) and of seats as it is an input material for glass fibers.

Aluminum ores and concentrates

Aluminum has various uses in both types of buses and can be found in different clusters (see Figure 22). In the case of the electric bus, it is mainly used as an input to produce the battery and bus body. In conventional buses, it is mostly incorporated into the bus body, motor, and drivetrain.

Figure 22
Requirements of aluminum ores and concentrates by cluster



Source: Own elaboration.

Copper ores and concentrates

Copper is another important raw material for electric and conventional buses and is required by different clusters. It is largely required by the electronics cluster because it is a key input for cables. The electric bus also requires large amounts of copper for the motor (30% of total copper required) and battery (16%).

B. Main differences between electric and conventional buses

The most obvious difference is the total weight of the buses: the electric bus is estimated to have a total weight of 13.7 tons, while the conventional bus was estimated to weigh only 12.4 tons (see Table 25). While some clusters are assumed to be identical for both buses, the drivetrain and motor clusters are specific to each type. In addition, the fuel tank is specific to the conventional bus while the battery is specific to the electric one. On the one hand, the conventional motor weighs almost twice as much as the electric motor. On the other hand, the batteries of the electric bus are not required by the conventional bus. However, it contains a standard vehicle battery, which is significantly lighter than a NMC electrical battery. Conventional bus, also requires a fuel tank, whereas the electrical bus does not.

Table 25
Differences in raw material requirements for electric and conventional buses
(Weights in kilograms)

Cluster	Conventional bus	Electric bus	Delta (abs. values)
Bus Body	5 600.0	5 600.0	0
Cabin	1 727.5	1 727.5	0
Electronics	1 656.6	1 656.6	0
Motor	1 113.0	584.1	528.9
Drivetrain	2 303.4	1 589.6	713.8
Fuel tank	135.0	0.0	135
Battery	59.7[a]	2 522.4	2 462.7
Grand Total	12 595.2	13 680.2	1 085.0

Source: Own elaboration.
[a] The battery contained in a conventional bus was not defined as a cluster, but we recognize its weight contributes to the total bus weight as a final elaborated product. However, the proportion of its weight with respect to the total weight is negligible.

When examining the absolute top 10 differences in raw material requirements (see Table 26), it must be borne in mind that not all the elaborated parts have been disaggregated. However, as both bus types have been disaggregated to a large and similar extent and three of their clusters are identical, a comparison seems appropriate.

The largest difference in raw material requirements stems from the larger requirement of iron by the conventional bus. This can largely be traced back to the relatively heavier motor and drivetrain of this type of bus. In contrast, the electric bus has a larger requirement of aluminum, which is mainly due to its use in batteries. Similarly, the larger requirements of copper, graphite, lithium, manganese, nickel and cobalt by the electric bus can be largely attributed to battery production. Finally, the rare earth metals scandium and yttrium are required in the motor production of electric buses. As the differences in the engines of the two bus types stack out, Box 5 details this analysis on the product level.

Table 26
Top differences in raw material requirements by electric and conventional buses
(Weights in kilograms)

HS 2017	HS Description	Conventional bus	Electric bus	Delta (abs. values)
260111	Iron ores and concentrates; non-agglomerated	8 289.6	7 491.4	798.2
260600	Aluminium ores and concentrates	555.8	1 016.2	460.5
260300	Copper ores and concentrates	466.5	856.4	389.9
250410	Graphite; natural in powder or in flakes	0.0	281.6	281.6
282520	Lithium oxide and hydroxide	0.0	246.4	246.4
260200	Manganese ores and concentrates including ferruginous manganese ores and concentrates with a manganese content of 20 or more calculated on the dry weight	0.0	222.9	222.9
260400	Nickel ores and concentrates	0.0	222.9	222.9
260500	Cobalt ores and concentrates	0.0	222.9	222.9
390410	Vinyl chloride other halogenated olefin polymers; poly (vinyl chloride) not mixed with any other substances in primary forms	337.0	407.4	70.4
280530	Earth-metals rare; scandium and yttrium whether or not intermixed or interalloyed	8.7	45.9	37.2

Source: Own elaboration.

Box 5
Comparison between diesel and electric engines

A comparison is made here of the level of elaborated and semi-elaborated products required to produce an engine for a conventional and an electric bus. This is shown in Table 34 for the electric bus, while for the conventional motor it is shown in Table 1. It is worth noting the significantly lower number of products used for the electric motor, which is mainly made of copper wires, although it contains magnets, which require rare metals. This translates into a much lower technological complexity involved in manufacturing the electric bus as well as a lower maintenance cost, both of which could be seen as an opportunity for production in LAC. However, there are other relevant issues that need to be considered when operating an electric bus, such as the services associated to its operation. For example, the electric bus requires a battery management system that acts as a communicator between the battery and the engine. This system relays the necessary data about the battery parameters to the motor controller, allowing resource optimization (EV Reporter, 2020).

Probably the main difference in the functioning of both types of buses is that the electric engine uses magnetism to propel the vehicle, compared to heat from combustion for the traditional engine. The engine of the electric vehicle draws power from the battery, creating a magnetic force that propels the car forward. Also, there are no moving parts in the electric motor that may be subject to wear or the need to be replaced on a regular basis. Consequently, the maintenance cost is much lower: studies have shown that maintenance costs for EVs are at least 23% lower compared to internal combustion engines (Laneva, n.d.). Yet, the most recurrent maintenance cost concerns the battery: due to the nature of lithium-ion technology, it loses capacity to hold power over time, resulting in decreasing autonomy (Suntec, 2018).

Table 1
Inputs for motors of electric buses on the elaborated- and semi-elaborated vector level
(Weights in kilograms)

Vector	HS 2012	HS Description	Weight
Elaborated parts	850133	Electric motors and generators; DC of an output exceeding 75kW but not exceeding 375kW	584.1
Semi-elaborated parts	730890	Iron or steel; structures and parts thereof n.e.c. in heading 7308	112.1
Semi-elaborated parts	740919	Copper; plates and sheets of a thickness exceeding 0.15mm of refined copper not in coils	5.9
Semi-elaborated parts	760611	Aluminium; plates sheets and strip thickness exceeding 0.2mm (not alloyed) rectangular (including square)	82.6
Semi-elaborated parts	848210	Ball bearings	11.8
Semi-elaborated parts	850511	Magnets; permanent magnets and articles intended to become permanent magnets after magnetisation of metal	118
Semi-elaborated parts	854411	Insulated electric conductors; winding wire of copper	253.7

Source: Own elaboration.

Table 2
Inputs for motors of conventional buses on the elaborated- and semi-elaborated vector level
(Weights in kilograms)

Vector	HS 2012	HS description	Weight
Elaborated parts	381512	Catalysts supported; reaction initiators reaction accelerators and catalytic preparations with precious metal or precious metal compounds as the active substance n.e.c. or included	171.3
Elaborated parts	840820	Engines; compression-ignition internal combustion piston engines (diesel or semi-diesel engines) of a kind used for the propulsion of vehicles of chapter 87	604.5
Elaborated parts	851130	Ignition or starting equipment; distributors and ignition coils of a kind used for spark-ignition or compression-ignition internal combustion engines	6.5
Elaborated parts	851140	Ignition or starting equipment; starter motors and dual purpose starter-generators of a kind used for spark or compression-ignition internal combustion engines	19.5
Elaborated parts	870891	Vehicle parts; radiators and parts thereof	150.0
Elaborated parts	870892	Vehicle parts; silencers (mufflers) and exhaust pipes; parts thereof	161.3
Semi-elaborated parts	401033	Rubber; vulcanised endless transmission belts of trapezoidal cross-section (V-belts) V-ribbed of an outside circumference exceeding 180cm but not exceeding 240 cm	6.5
Semi-elaborated parts	401699	Rubber; vulcanised (other than hard rubber) articles n.e.c. in heading no. 4016 of non-cellular rubber	13.0
Semi-elaborated parts	730300	Cast iron; tubes pipes and hollow profiles	212.7
Semi-elaborated parts	730890	Iron or steel; structures and parts thereof n.e.c. in heading 7308	512.8
Semi-elaborated parts	731520	Chain; skid articulated link chain and parts thereof of iron or steel	13.0
Semi-elaborated parts	761699	Aluminium; articles n.e.c. in heading 7616	182.5
Semi-elaborated parts	830710	Tubing; flexible with or without fittings of iron or steel	6.5
Semi-elaborated parts	840290	Boilers; parts of steam or other vapour generating boilers	19.5
Semi-elaborated parts	841330	Pumps; fuel lubricating or cooling medium pumps for internal combustion piston engines	13.0
Semi-elaborated parts	841459	Fans; n.e.c. in item no. 8414.51	19.5
Semi-elaborated parts	842139	Machinery; for filtering or purifying gases other than intake air filters for internal combustion engines	10.0
Semi-elaborated parts	842199	Machinery; parts for filtering or purifying liquids or gases	13.0
Semi-elaborated parts	848310	Transmission shafts (including cam shafts and crank shafts) and cranks	58.5
Semi-elaborated parts	854411	Insulated electric conductors; winding wire of copper	6.5

Source: Own elaboration.

V. Retrofitting and recycling opportunities

Another opportunity for fast and low-cost adoption of sustainable transport and to accelerate electromobility is the retrofitting of conventional diesel vehicles. Retrofitting has a range of advantages, especially because it represents a relatively cost-effective way to obtain an electrically driven bus (new electric buses are usually significantly more expensive than conventional buses). Furthermore, gaining experience in retrofitting and potentially producing some of the parts required for it locally might prepare countries to step into the production of entire electric buses (Samaniego, n.d.). Another crucial advantage of retrofitting is that owners can get their electric buses tailored to their specific needs in terms of autonomy (ibid.). Table 27 sums up the strength, weaknesses, opportunities, and threats of retrofitting in the context of buses.

Table 27
SWOT analysis of retrofitting

Strength	Weaknesses
• Motivated and informed entrepreneurs about the industry. • Product with excellent attributes (economic, social, environmental) and cost/benefit ratio, without competition at national and regional level. • Good previous working relationship of the entrepreneurs with local and international technological institutes and universities potentially interested in supporting the project.	• Lack of experienced personnel in vehicle retrofitting at the local level. • New industry, without references or previous local experience. • New technological product, which must overcome the corresponding "adoption curve" in a conservative target market (bus operators).
Opportunities	**Threats**
• Potential market at national and regional level. • Significant potential for knowledge generation and productive chaining. • Significant potential for employment generation. • Platform for the development of new knowledge-based industries.	• Accelerated reduction in the cost of imported electric buses. • Increase in the price of components required for retrofit. • Underperformance of components selected for retrofit.

Source: Taken from Samaniego (n.d.).

The core idea of retrofitting is to turn a conventional bus into an electric bus by replacing only the necessary vehicle parts. Even though electric buses employ more recent and complex technology, their setup is more modular. Therefore, it is easier to make adaptations to the capacity or size by varying the kind of motor or number of batteries, for example (Samaniego, n.d.). The methodology presented in this paper identifies the parts required for the retrofitting of conventional buses.

Retrofitting for electric buses

The parts to be removed from the conventional bus are basically the drivetrain, engine, gearbox, and the drive axle (pepper motion, n.d.). Electric axles and motors are to be installed instead, as well as the battery system (again, a NMC battery is assumed). In this respect, the battery modules are installed on the roof of the bus and in the section that had been occupied by the diesel engine before. Furthermore, auxiliary components such as air conditioning and air compressors must be replaced by electrically powered components. Additionally, the driver requires an additional display to be able to review the vehicle status and level of charge of the battery (pepper motion, n.d.).

Table 28 presents the products required for the retrofitting of a conventional bus at the elaborated parts vector level.

Table 28
Elaborated input changes for retrofitting

Cluster	HS 2017	HS Description	Weight in kg	Required Action
Motor	850133	Electric motors and generators; DC of an output exceeding 75kW but not exceeding 375kW	584.1	Install
Drivetrain	870850	Vehicle parts; drive-axles with differential whether or not provided with other transmission components and non-driving axles; parts thereof	630.0	Install
Electronics	853120	Signaling apparatus; electric sound or visual indicator panels incorporating liquid crystal devices (LCD) or light emitting diodes (LED) excluding those of heading no. 8512 or 8530	7.4	Install
Fuel tank	730900	Reservoirs tanks vats and similar containers; for any material (excluding compressed or liquefied gas) of iron or steel capacity exceeding 300l whether or not lined or heat insulated	62.1	Remove
Motor	870892	Vehicle parts; silencers (mufflers) and exhaust pipes; parts thereof	161	Remove
Motor	870891	Vehicle parts; radiators and parts thereof	150	Remove
Motor	851140	Ignition or starting equipment; starter motors and dual-purpose starter-generators of a kind used for spark or compression-ignition internal combustion engines	20	Remove
Motor	851130	Ignition or starting equipment; distributors and ignition coils of a kind used for spark-ignition or compression-ignition internal combustion engines	7	Remove
Motor	840820	Engines; compression-ignition internal combustion piston engines (diesel or semi-diesel engines) of a kind used for the propulsion of vehicles of chapter 87	605	Remove
Motor	381512	Catalysts supported; reaction initiators reaction accelerators and catalytic preparations with precious metal or precious metal compounds as the active substance n.e.c. or included	171	Remove
Drivetrain	870850	Vehicle parts; drive-axles with differential whether or not provided with other transmission components and non-driving axles; parts thereof	973	Remove
Drivetrain	870840	Vehicle parts; gear boxes and parts thereof	317	Remove
Electronics	841520	Air conditioning machines; comprising a motor driven fan and elements for changing the temperature and humidity of a kind used for persons in motor vehicles	177.3	Replace
Drivetrain	841490	Pumps and compressors; parts of air or vacuum pumps air or other gas compressors and fans ventilating or recycling hoods incorporating a fan	36	Replace
Battery	no code	Battery parts: case no description	630.0	Install
Battery	no code	Battery parts: Other parts of electronics no description	56.0	Install
Battery	no code	Battery cooling system no description	70.0	Install
Battery	850690	Cells and batteries; primary parts thereof	-	Install
Battery	850650	Cells and batteries; primary lithium	1 742.4	Install
Battery	850433	Transformers; n.e.c. in item no. 8504.2 having a power handling capacity exceeding 16kVA but not exceeding 500kVA	24.0	Install

Source: Own elaboration.

Trolley buses

Another retrofitting option is to install a pantograph on the roof of the bus so that it can be charged during operation. This is an option to reduce the number of battery modules without having to reduce the autonomy of the bus. Table 29 lists the required inputs for producing a pantograph. It is important to note that the operation of the pantograph requires the existence of appropriate infrastructure.

Table 29
Inputs to produce a pantograph
(Weights in kilograms)

HS 2017	HS Description	Weight
730890	Iron or steel; structures and parts thereof n.e.c. in heading 7308	29.75
732090	Iron or steel; springs n.e.c. in heading no. 7320	5.1
380190	Graphite or other carbon-based preparations; in the form of pastes blocks plates or other semi-manufactures	1.7
391739	Plastics; tubes pipes and hoses thereof n.e.c. in item no. 3917.30	11.9
401699	Rubber; vulcanized (other than hard rubber) articles n.e.c. in heading no. 4016 of non-cellular rubber	5.1
740811	Copper; wire of refined copper of which the maximum cross-sectional dimension exceeds 6mm	5.95
731210	Iron or steel; stranded wire ropes and cables not electrically insulated	3.4
850132	Electric motors and generators; DC of an output exceeding 750W but not exceeding 75kW	4.25
850433	Transformers; n.e.c. in item no. 8504.2 having a power handling capacity exceeding 16kVA but not exceeding 500kVA	17.85

Source: Own elaboration.

VI. Opportunities and limitations of the proposed methodology

The methodology presented in this paper has several advantages. First, it is reproducible. The vector can be used to analyze the trade flows of any country that registers them in the HS. Analyzing trade flows provides us with an idea of the productive capacity of a country. Moreover, it is very helpful in identifying the main global players in parts and pieces required by the industry.

The definition of different clusters gives the methodology some flexibility: it allows to change assumptions and therefore, some clusters or inputs may be interchanged. For example, the battery type might be changed to a lithium-iron-phosphate battery, which would require the definition of its inputs and the interchange of these clusters. Similarly, the strategy of retrofitting conventional buses can be included in this methodology by identifying the clusters of the conventional bus that must be substituted with parts and pieces of the electric bus.

The presented methodology can also be linked to, or serve as a basis for, other methodologies. Firstly, the HS codes can be grouped into economic sectors based on a methodology previously developed by ECLAC and applied in the context of input-output-tables. Therefore, the methodology proposed in this paper can be linked to the input-output methodology that analyzes the trade interlinkages between countries. Furthermore, based on the input-output methodology, the participation of women among the labor force in exports can be estimated on the level of economic sectors. For example, the share of women can be estimated among total export labor for the vehicle sector. Thirdly, the codes can be linked to tariff data, which allows to analyze the degree of protection in different countries at the product level. Finally, the cost structure of the two types of buses may be estimated based on current raw material prices and the estimated inputs weights.

The proposed methodology also has some limitations. First, the weights of some of the inputs had to be estimated due to lack of data. Estimates may be inaccurate even if made by experts. In this respect, the total weight of the electric bus was overestimated by about 300 kilograms. However, this represents only about 2 % of the total weight of the bus.

A second limitation is that there is no basis in the literature for the assignment of products to the distinct vector levels (elaborated and semi-elaborated parts, and raw materials). Therefore, the disaggregation of the different inputs in those three vectors required simplifications and especially the assignment of products based on the researchers' estimations. This means that a value chain of basically only three stages is represented for the different products: thus, many steps of processing are neglected. In case of the battery, the different steps of processing of the key raw materials have been identified (namely for lithium, cobalt, nickel, manganese, and graphite).

Another important point to be considered is that the HS code for the chassis is not directly included in the vectors as the way the chassis is presented in the HS (870600 "Chassis; fitted with engines for the motor vehicles of heading no. 8701 to 8705") was not compatible with the used cluster definitions. Even though all components of the cassis are included in different clusters, the code of the chassis has been included in the general necessary parts vector.

Another limitation relates to the simplifications involved in the disaggregation process. For example, the different HS codes for rubber have been disaggregated in the same way even though the rubber products distinguish themselves from one another slightly. Consequently, they contain the same raw materials even if the final products are different. This is a simplification that was necessary to cope with the complexity and the number of products that had to be disaggregated. Still, it remains an important limitation of this work.

Additionally, including only three vectors implying three levels of disaggregation entails some limitations. Some products might be assigned to more than one vector, so assigning it uniquely to one vector has been difficult in some cases. For example, vinyl chloride (code 390410) has been assigned to the raw materials sector even if it also be assigned to the semi-elaborated parts vector.

Furthermore, it must be borne in mind that not all trade of input parts eventually enters into the production of buses but only a share. For example, the share of traded clutches that enters the bus industry will be larger than in the case of traded steel, since the latter product has multiple uses in a range of industries. To overcome this limitation, a factor weight may be introduced that estimates the share of a traded product that goes into the production of electric or conventional buses.

VII. Cost structure of an electric versus a conventional diesel bus

The goal of the performed price estimation is to link the different inputs with their respective prices to estimate the cost structure of the electric bus. In doing so, we aim to identify firstly which are the most valuable inputs, and secondly, where to find high levels of value added at the product or cluster level.

The reference bus, a Mercedes-Benz eCitaro, has a total purchase cost of 740,000 dollars (Knote et al., 2017). Therefore, input costs should be significantly lower than this figure as other costs such as capital and labour are not accounted for in this analysis.

To obtain the weighted average import price (per kg and per unit), the relevant import data for 2019 were collected for the following countries: China, Japan, United States, Canada, Turkey, Czech Republic, United Arab Emirates, Spain, Poland, and Hungary. The focus was set on these countries as collectively they represent 79% of global electric bus exports in 2019. The weighted price per kg was calculated by dividing the total import value for each input by its respective total import weight. Following the same method, we calculated the weighted price per unit for all the inputs for which unit quantity information was available. Data from countries that do not report import weight or quantity was excluded.

Furthermore, in cases where there is no specific HS code assigned to an input, the aggregate cost for that input will be derived from the previous vector level (i.e., missing cost for an elaborated input will be derived from its aggregate cost in the semi-elaborated level). In cases where there is no specific weight assigned to an input, then its input cost cannot be computed.[12] Finally, the cluster price for each vector level is calculated by summing all the input costs for each cluster.

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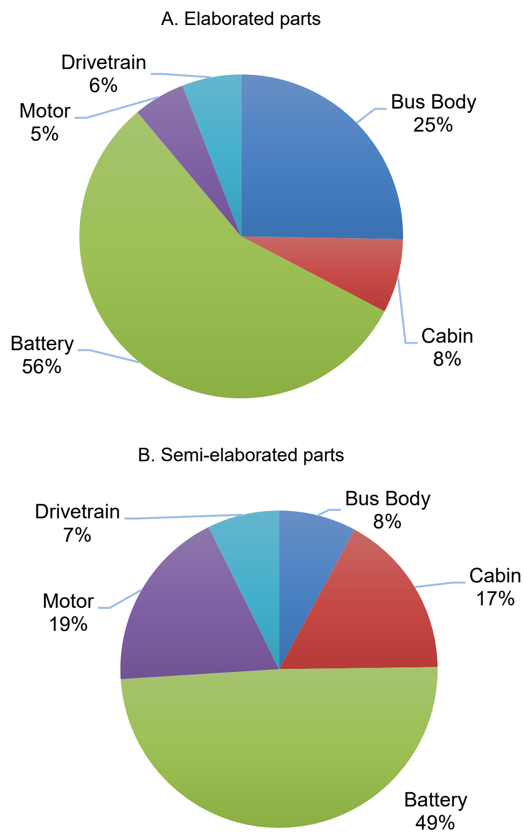
[12] Specific weights are not assigned for few inputs in the elaborated section due to their high complexity. These include cells and batteries (850690), loudspeakers (851829), microphones (851810), signalling apparatus (853180 and 853110), and suspension systems (870880).

Figure 23 shows the detailed cost proportion for each cluster per vector level. For simplicity, the electronics cluster was removed from the graph due to a higher share of inputs without disaggregation levels. As shown in the figure, battery cluster is consistently taking a major share of the cluster cost proportion with 56 %, 31 %, and 49 % for elaborated, semi-elaborated, and raw materials vector, respectively.[13] In addition to the battery, the bus body is also shown to share a significant portion of the total costs to manufacture an electric bus in the elaborated and semi-elaborated vector.

With the aim to trace the main cost components of raw materials vector for an electric bus, the top ten raw material inputs by the corresponding costs are exhibited in Figure 24. Lithium oxide and hydroxide, copper ores, and rare earth-metals (i.e., scandium, yttrium, etc.) are shown to be the most expensive raw materials components in the vector, with lithium equivalent to 32 % of the total raw materials costs. The price of lithium as of May of 2022 has been increasing to a staggering level to reach almost six times than what it was in 2019.[14] With such a large share, the upward price trend of lithium will induce significant extra costs to build an electric bus. This highlights how the current fluctuation of input prices, specifically lithium, can hamper the growth of the electric bus industry in the future.

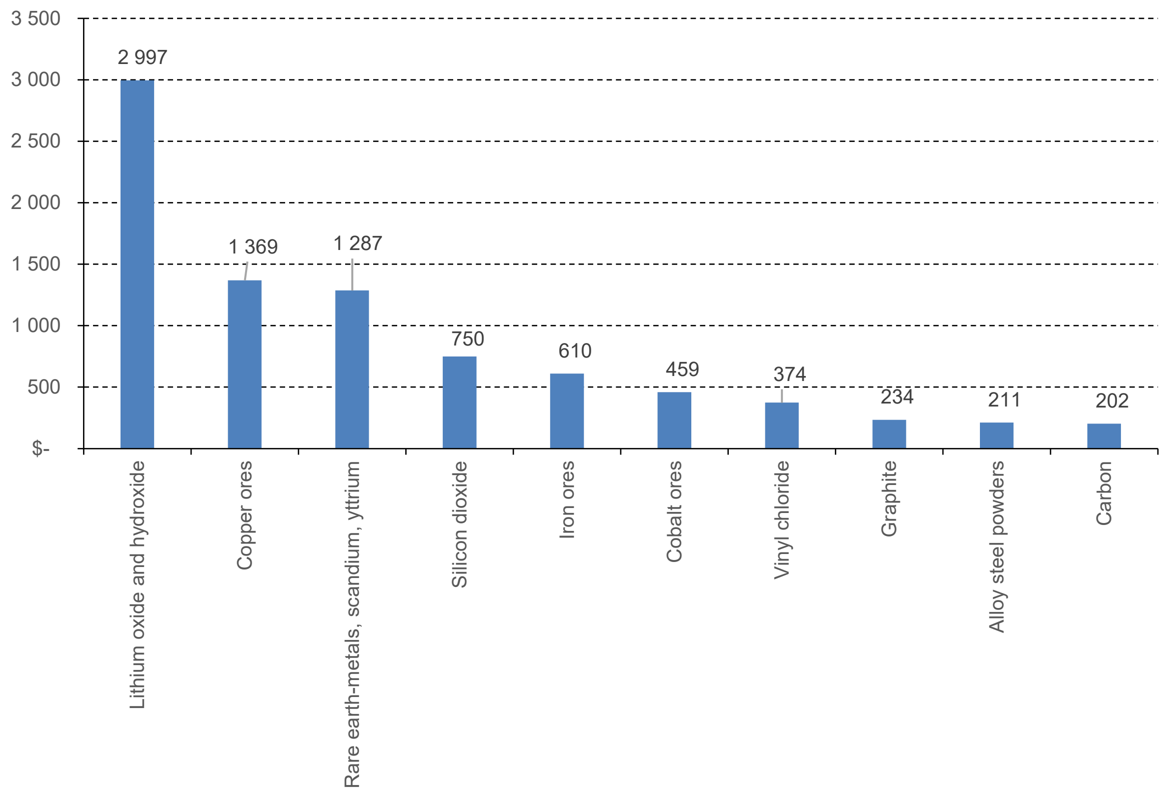
Figure 23
Cluster cost share by vector level
(In percentages)



Source: Own elaboration.
Note. The electronics cluster was excluded from this figure as it has not been fully disaggregated into its semi-elaborated parts and raw materials to be adequately represent its cost share.

[13] With the exclusion of electronics cluster.
[14] Considering the weighted average import price per Kg of $12.16 for Lithium in 2019 with the current lithium spot price of $70; Source: https://tradingeconomics.com/commodity/lithium.

Figure 24
Raw materials: top 10 inputs by costs
(In U.S. Dollars)



Source: Own elaboration.

VIII. Factor weight for estimating trade in inputs

Conversion factors were calculated for all inputs required to produce an electric bus. The goal of the conversion factor is to capture the share of global trade in a particular input that goes into the production of electric buses. For example, a conversion factor of 1.88 for vehicle bodies means that 1.88% of world exports of this input go into the production of electric buses. Conversion factors were calculated at the product level using the HS 2017 edition and are based on the methodology already presented. They were calculated for all inputs for which required weights were estimated.

Two measures to estimate the conversion factor are presented below: the intra-industry conversion factor (which includes products primarily from the vehicle sector, subsection 87 of the HS, 5th Revision) and the conversion factor for components that also belong to other industries. The reason for this distinction is that components within the vehicle sector (for example, engines and safety belts) are used only for the production of vehicles, whereas other components such as iron ores, which are required to produce vehicle bodies- are also used in a range of industries (construction, aircraft, etc.). As the methodology should adequately capture the amounts traded that go into the production of electric and conventional buses, two distinct approaches are suggested. For both approaches, the year 2019 was used as baseline.

The products that belong to the general necessary cluster parts were excluded from the analysis as no weights have been assigned to these products because they are indirectly accounted for by larger inputs (e.g., valves in an engine). However, exceptions were made for products with a considerable share in global trade flows. For these products, the conversion factor was estimated based on the one applied for products of the same category.

Conversion factor I: intra-industry

Firstly, all identified products that belong to HS Chapter 87 were identified and listed. In the second step, each product was reviewed to determine whether it is only used for the production of electric buses or it is also required for conventional buses. Then, in the third step, all required products from other HS chapters that are exclusively used in the production of motor vehicles were selected. As these products do not find applications in other industries, they are assigned the same conversion factor that is assigned to the products belonging to Chapter 87 (Tab. 40).

In the next step, the export share of electric buses over all vehicles was computed to estimate the intra-industry conversion factor, reflecting the share of the components that go into the production of electric buses.

$$foc_{intra-industry} = \frac{X_k^{ebus}}{\sum XT_k} \quad (1)$$

Equation 1 reflects this calculation, with XT_k representing the export value of all vehicles in chapter 87 (tractors, cars and buses) and X_k^{ebus} the value of exports of electric buses. The estimated intra-industry conversion factor was estimated to be 1.88. This means that for example, 1.88% of all seatbelts traded are used to produce electric buses globally.

Table 30
Products with an intra-industry conversion factor of 1.88

HS 2017	HS Description
830120	Locks; of a kind used for motor vehicles (key combination or electrically operated) of base metal
851240	Windscreen wipers defrosters and demisters; electrical of kinds used for cycles or motor vehicles
870790	Vehicles; bodies (including cabs) for the motor vehicles of heading no. 87018702 8704 or 8705
870821	Vehicles; parts of bodies safety seat belts
870830	Vehicle parts; brakes servo-brakes and parts thereof
870850	Vehicle parts; drive-axles with differential whether or not provided with other transmission components and non-driving axles; parts thereof
870870	Vehicle parts; road wheels and parts and accessories thereof
870894	Vehicle parts; steering wheels steering columns and steering boxes; parts thereof
870895	Vehicle parts; safety airbags with inflater system; parts thereof
940120	Seats; of a kind used for motor vehicles
870810	Vehicles; bumpers and parts thereof for the vehicles of heading no. 8701 to 8705
401120	Rubber; new pneumatic tyres of a kind used on buses or lorries
700910	Glass; rear-view mirrors for vehicles
830120	Locks; of a kind used for motor vehicles (key combination or electrically operated) of base metal
854370	Electrical machines and apparatus; having individual functions not specified or included elsewhere in this chapter n.e.c. in heading no. 8543
940190	Seat; parts

Source: Own elaboration based on HS 2017.

Conversion factor II: inter-industry

For inputs that are also required by other industries outside the vehicle industry, an inter-industry conversion factor was developed. In short, the extra-industry conversion factor is based on the global production of buses and its resource requirements at the product-level. Furthermore, it estimates the share of each product's trade that goes into the production of electric buses.

Calculating the inter-industry conversion factor required firstly the estimation of global bus production. Therefore, publicly available databases were collected and reviewed as well as other sources. The base year was 2019 and in case of missing information, the last available year was used. For some economies (Australia, the Chinese Province of Taiwan, and Vietnam) no information could be found. The sum of the buses produced by countries with available information was 829,296 buses (Table 31). It is important to mention that this number includes transit buses and coaches and does not discriminate between conventional, electric, or other types of buses. To estimate the share of electric buses, we used a procedure similar to the one mentioned above, consistent in collect information on the production of electric bus units for the group of countries that present such information. Following this procedure, we estimated a global production of 80,813 electric buses.

Table 31
Number of vehicles produced by type, 2019 or latest year available

Type	Units	Share
Vehicles	91 786 861	100%
Buses	829 296	0.9%
Electric buses	80 813	0.1%

Sources: OICA (n.d), ACEA (2022), Helgi Library (2021), INE (2022), Bureau of Transport Statistics (n.d), ADEFA (n.d), Placek (2022), Statista Research Department (2022), Textor (2022), Gorka (2021), Sun (2021), Seob Yoon (2020), Manakitsomboon (2022) & Portafolio (n.d).

To estimate the total input requirement for each product, the total number of electric buses was multiplied by the amount of weight (in kg) required per bus. This way, the global demand for inputs to produce electric buses could be estimated. In addition, all the trade data from UN Comtrade for the year 2019 was obtained. Once the total weight needed for the global electric bus production and also the global import value and weight for all the required inputs were at hand, three different methods were deployed to arrive at the final conversion factor for each input. The details are as follows:

(i) Value Conversion Factor (per kg): The first conversion factor is calculated using the proportion of total import value for each input that goes into the global production of electric buses out of the global import value for that specific input. Subsequently, to obtain the total import value that goes into the production of electric buses, the total accumulated weight for each input (required input weight per bus times the total number of electric buses) was multiplied by the weighted average import price per kg for that input.

(ii) Value Conversion Factor (per unit): The second conversion factor is very similar to the first one except that the weighted price per unit was used instead of weighted price per kg to arrive at the total import value that goes into the production of electric buses for each specific input. Like the first conversion, to obtain the total import value that goes into the production of electric buses, the total accumulated unit for each input (required input unit per bus times the total number of electric buses) was multiplied by the weighted average import price per unit for that input. The conversion method was utilized for specific inputs that we deemed appropriate.

(iii) Weight Conversion Factor: The third conversion factor is calculated using the share of total weight for each input that goes into the global production of electric buses out of the global import weight for that specific input. To obtain the total weight that goes into the production of electric buses, the required weight (per electric bus) for each input by the total number of electric buses produced.

In the world import data there was some missing information on the weight, unit or value of specific inputs. Thus, various adjustments were needed to arrive at the final extra-industry conversion factors. For consistency, starting point was the value conversion factor (per kg) and then the numbers were adjusted appropriately following internal and external research for each specific input. The adjustments included: i) using the weight conversion factor or value conversion factor (per unit) (or a combination of both) where deemed it appropriate, such as when the weighted import price (per kg) has high variability among countries; and ii) using consultants' and/or experts' suggestions when there is significantly high variability among the derived conversion factors. This gives the extra-industry conversion factor for each input product.

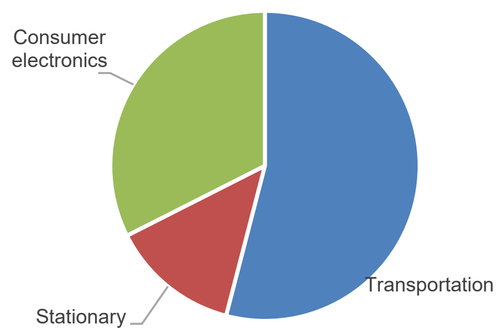
Selected inputs

For selected inputs, the conversion factor was directly taken from academic publications or derived manually. The derivation of the conversion factors for batteries, copper, iron, and semiconductors is briefly explained below.

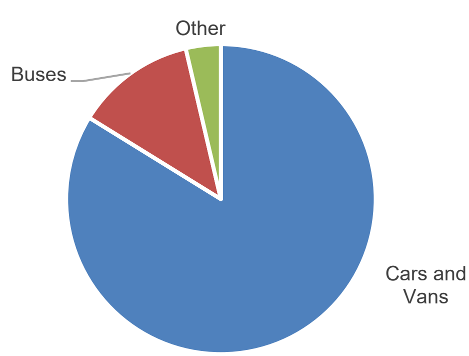
The conversion factor for the battery was derived manually because the HS product code includes a broad range of battery types. Figure 25A shows the applications for batteries across large industries, while Figure 25B presents the battery demand by vehicle type. The transport sector requires 54% of the global batteries and the bus sector consumes 13% of the batteries within the vehicle industry. Therefore, the estimated conversion factor is equal to 7% (0,54*0,13).

Figure 25
Battery demand, 2020
(In gigawatt hours)

A. Battery demand by industry



B. Battery demand by vehicle type



Source Placek (2021) & IEA (2021).

Table 32 exhibits the applications of copper, iron and steel, and semiconductors by industry. Based on the share of each good required by the transport equipment sector, the conversion factor is calculated by multiplying it by the share of electric buses among total vehicles (equal to 0.1, see Table 32). The conversion factor for each product is applied to other products containing these inputs (for example, the conversion factor of iron is used for iron ores and for structures made of iron, among others).

Table 32
Industry applications of copper, iron and steel and semiconductors
(In percentages)

Industry	Copper	Iron and steel	Semiconductors
Construction and infrastructure	43	50	23
Machinery and equipment[a]	7	27	12
Transport equipment	20	18	10
Electronics	20	3	46
Consumption goods	10	2	10
Total	100	100	100
Conversion factor calculated	1.76	1.58	0.86

Source: Based on Geology (n.d), Fernandez (2022), Statista Research Department (2022a), OECD (2010) & Wisconsin Metal Tech (2019),
[a]Includes metal products.

Limitations

The approach described above has some limitations. Firstly, it is difficult to estimate precisely global transit bus production. Secondly, the prices are based on estimations where there might be discrepancies on the reported import weight, unit and/or value. Thirdly, the approach assumes that all inputs used in bus production are traded and consequently, does not account for inputs produced locally. Therefore, the derived conversion factor might over-estimate the trade flows of some products (i.e. steel). On the other hand, it might also underestimate the trade flows for products that have a high concentration of production such as batteries (which are mainly produced in Asia). Another point to consider is material waste during production, which is not accounted for in the estimation. Therefore, larger amounts of raw materials likely go into the production of buses, which implies an under-estimation of the conversion factor for these inputs.

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Annexes

Annex 1
Disaggregation into raw materials of main imputs

Table A1.1
Density of some fillers in rubbers

HS-Code	Component	Density		HS-Code	Component	Density	
			Fillers, Minerals and Fibers				
281810	Aluminium oxide; artificial corundum	2.10	1.9	252020	Plasters; (consisting of calcined gypsum or calcium sulphate) whether or not coloured with or without small quantities of accelerators or retarders	2.21	2.0
282710	Chlorides; of ammonium	1.59	1.4	281610	Hydroxide and peroxide of magnesium	3.60	3.3
282580	Antimony oxides	3.30	3.0		NOT FOUND	2.95	2.7
261710	Antimony ores and concentrates	5.40	4.9	251310	Pumice stone whether or not heat treated	2.35	2.1
252490	Asbestos; other than crocidolite (blue asbestos)	2.70	2.4	250300	Sulphur of all kinds; other than sublimed precipitated and colloidal sulphur	1.95	1.8
283327	Sulphates; of barium	4.50	4.1	280200	Sulphur; sublimed or precipitated colloidal sulphur	2.05	1.9
810720	Cadmium; unwrought powders	4.40	4.0	282300	Titanium oxides	8.10	7.3
251010	Natural calcium phosphates natural aluminium calcium phosphates and phosphatic chalk; unground	2.20	2.0	320641	Colouring matter; ultramarine and preparations based thereon	2.35	2.1
251010	Natural calcium phosphates natural aluminium calcium phosphates and phosphatic chalk; unground	2.10	1.9	252020	Plasters; (consisting of calcined gypsum or calcium sulphate) whether or not coloured with or without small quantities of accelerators or retarders	5.53	5.0
NOT FOUND		1.81	1.6	281700	Zinc; oxide and peroxide	3.30	3.0
250700	Kaolin and other kaolinic clays; whether or not calcined	2.50	2.3	281700	Zinc; oxide and peroxide	5.57	5.0
281990	Chromium oxides and hydroxides; excluding chromium trioxide	5.21	4.7	260800	Zinc ores and concentrates	1.06	1.0
520512	Cotton yarn; (not sewing thread) single of uncombed fibres 85 or more by weight of cotton less than 714.29 but not less than 232.56 decitex (exceeding 14 but not exceeding 43 metric number) not for retail sale	1.05	1.0	293190	Organo-inorganic compounds; other than tetramethyl lead tetraethyl lead and tributyltin compounds	5.70	5.2
NOT FOUND		1.27	1.2	260700	Lead ores and concentrates		
250410	Graphite; natural in powder or in flakes	2.25	2.0				

HS-Code	Component	Density		HS-Code	Component	Density	
		Fillers, Minerals and Fibers					
282110	Iron oxides and hydroxides	5.14	4.7				
						Organic components	
680710	Asphalt or similar material; articles (e.g. petroleum bitumen or coal tar pitch) in rolls	1.04	0.9	400219	Rubber; synthetic styrene-butadiene rubber (SBR) and carboxylated styrene-butadiene rubber (XSBR) (other than latex) in primary forms or in plates sheets or strip	1.02	0.9
340420	Waxes; artificial and prepared of poly(oxyethylene) (polyethylene glycol)	0.92	0.8	271220	Paraffin wax; containing by weight less than 0.75 of oil obtained by synthesis or by other processes whether or not coloured	0.90	0.8
391110	Petroleum resins coumarone indene or coumarone-indene resins and polyterpenes; in primary forms	1.11	1.0	271210	Petroleum jelly	0.90	0.8
291739(10)	Plasticizer Dbp (Dibutyl Phthalate)	1.04	0.9	390940	Phenolic resins; in primary forms	1.27	1.2
291713(90)	Dibutyl Sebacate - 1 Ml - Pharmaceutical Reference Standard	0.94	0.9	380590(10)	Pine oil	0.93	0.8
291739(20)	Di-Octyl Phthalate (Dop) Flexi	0.98	0.9	380700(10)	Pine Tar	1.08	1.0
NOT FOUND		1.04	0.9	391110(90)	Petroleum Resin L-150	0.99	0.9
381190	Oxidation and gum inhibitors viscosity improvers anti-corrosive preparations other prepared additives for mineral oils or liquids used as mineral oils (including gasoline) n.e.c. in heading no. 3811	1.02	0.9				
381190	Oxidation and gum inhibitors viscosity improvers anti-corrosive preparations other prepared additives for mineral oils or liquids used as mineral oils (including gasoline) n.e.c. in heading no. 3811	0.93	0.8				
	Total	56.54	51.2		Total	53.81	48.8

Source: Own elaboration based on González Cantú (2003) and HS 2017.

Table A1.2
Disaggregation of other relevant inputs
(Density in grams/cm³ and share in)

HS 2017 6-digit code	HS 2017 2-digit code	Product description	Mass of input required	Of total mass required	HS 2012 code (6 to 10 digits)	Product description	Input percentage (range)		Weight in kg
700711	70	Glass; safety glass toughened [...]	700.82	5.1	281122	Silicon dioxide	71	73	511.6
					283620	Carbonates; disodium carbonate	13	14	98.1
					283650	Carbonates; calcium carbonate	7.70	9.20	61.0
					281610	Hydroxide and peroxide of magnesium	2.90	4.0	24.2
					281810	Aluminium oxide; artificial corundum	0.10	1.6	6.0
850511	85	Magnets; [...]	68.23	0.5	280530(0020)	Earth-metals rare; [...] (Neodymium)	29.0	32.0	20.8
					260111	Iron ores and concentrates; non-agglomerated	64.20	68.5	45.3
					280450	Boron; tellurium	1.0	1.2	0.8
					260600	Aluminium ores and concentrates	0.2	0.4	0.2
					261590	Niobium tantalum vanadium ores and concentrates	0.5	1.0	0.5
					280530(30)	Dysoprium	0.8	1.2	0.7
854590	85	Carbon; [...]	281.6	2.0	250490	Graphite; natural in other forms excluding powder or flakes		100	281.6
392010	39	Plastics; plates sheets film foil and strip [...]	70.4	0.5	390410	Vinyl chloride [...]	17	100	70.4
391729	39	Plastics; tubes pipes and hoses [...]	38.3	0.3	39021000 (3902)	Polypropylene (Polymers [...])	17	100	38.3
960621	96	Buttons; of plastics [...]	18.5	0.1	39021000 (3902)	Polypropylene (Polymers [...])	17	100	18.5
392590	39	Plastics; builders' ware n.e.c. or included in heading no. 3925	7.5	0.1	39021000 (3902)	Polypropylene (Polymers [...])	17	100	7.5
401699	40	Rubber; vulcanised [...]	442.2	3.2	400110	Rubber; natural rubber latex w[...]		27.0	181.5
401693	40		209.1	1.5	400219	Rubber; synthetic [...]		14.0	94.1
401033	40		14.8	0.1	270111 280300(00)	Carbon "carbon blacks [...]		28.0	188.3
401691	40		5.0	0.0	720521	Alloy steel powders		14.5	97.5
400942	40		1.3	0.0	Fibers, Softeners, Oxidant and Antioxidants etc.			16.5	110.9

Source: Own elaboration based on HS 2017.

Annex 2
Electric bus input vectors

Table A2.1
Elaborated parts vector (electric bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	HS 2017	Disaggregated	Weight
Elaborated parts	Battery	Battery parts: case	no code	Yes	630.0
Elaborated parts	Battery	Battery parts: electronics	850433	Yes	24.0
Elaborated parts	Battery	Battery parts: Other parts of electronics	no code	Yes	56.0
Elaborated parts	Battery	Battery cells	850650	Yes	1 742.4
Elaborated parts	Battery	Battery cooling system	no code	Yes	70.0
Elaborated parts	Battery	Battery parts	850690	No	0.0
Elaborated parts	Bus Body	Frame	870790	Yes	5 600.0
Elaborated parts	Cabin	Floor covers and isolation	no code	Yes	244.4
Elaborated parts	Cabin	Holding bars	no code	Yes	119.0
Elaborated parts	Cabin	Other cabin parts	700910	No	24.0
Elaborated parts	Cabin	Other cabin parts	842410	No	9.8
Elaborated parts	Cabin	Other cabin parts	851240	No	0.5
Elaborated parts	Cabin	Other cabin parts	870821	No	17.3
Elaborated parts	Cabin	Other cabin parts	870895	No	3.0
Elaborated parts	Cabin	Other cabin parts	940592	No	17.3
Elaborated parts	Cabin	Other cabin parts	960621	No	5.0
Elaborated parts	Cabin	Seats	940120	Yes	305.4
Elaborated parts	Cabin	Windows	no code	Yes	981.7
Elaborated parts	Drivetrain	Front Axle (ZF RL 75)	870850	Yes	482.0
Elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	870850	Yes	630.0
Elaborated parts	Drivetrain	Pressure air system	841490	Yes	36.0
Elaborated parts	Drivetrain	Steering system	870894	Yes	65.6
Elaborated parts	Drivetrain	Wheel parts	870830	Yes	25.0
Elaborated parts	Drivetrain	Wheel parts	870870	Yes	25.0
Elaborated parts	Drivetrain	Wheels	401120	Yes	326.0
Elaborated parts	Electronics	Human control devices	830120	No	3.7
Elaborated parts	Electronics	Human control devices	847050	No	19.8
Elaborated parts	Electronics	Human control devices	851762	No	7.4
Elaborated parts	Electronics	Human control devices	851810	No	0.0
Elaborated parts	Electronics	Human control devices	851829	No	0.0
Elaborated parts	Electronics	Human control devices	851840	No	12.4
Elaborated parts	Electronics	Human control devices	853110	No	0.0
Elaborated parts	Electronics	Human control devices	853120	No	7.4
Elaborated parts	Electronics	Human control devices	853180	No	0.0
Elaborated parts	Electronics	Human control devices	853190	No	7.4
Elaborated parts	Electronics	Human control devices	853650	No	2.5
Elaborated parts	Electronics	Human control devices	902910	No	9.9
Elaborated parts	Electronics	Human control devices	902920	No	7.4
Elaborated parts	Electronics	Human control devices	960622	No	2.5
Elaborated parts	Electronics	Human control devices: Other parts	no code	Yes	33.5
Elaborated parts	Electronics	Internal control devices	841950	No	15.1
Elaborated parts	Electronics	Internal control devices	850131	No	30.2
Elaborated parts	Electronics	Internal control devices	852190	No	41.5
Elaborated parts	Electronics	Internal control devices	853400	No	28.9

Vector	Cluster	Sub-cluster	HS 2017	Disaggregated	Weight
Elaborated parts	Electronics	Internal control devices	853630	No	22.6
Elaborated parts	Electronics	Internal control devices	853649	No	45.2
Elaborated parts	Electronics	Internal control devices	853650	No	30.2
Elaborated parts	Electronics	Internal control devices	854231	No	45.2
Elaborated parts	Electronics	Internal control devices	854233	No	7.5
Elaborated parts	Electronics	Internal control devices	902519	No	5.1
Elaborated parts	Electronics	Internal control devices	902610	No	4.6
Elaborated parts	Electronics	Internal control devices	902620	No	5.1
Elaborated parts	Electronics	Internal control devices	903039	No	9.7
Elaborated parts	Electronics	Internal control devices	903210	No	45.2
Elaborated parts	Electronics	Internal control devices	903281	No	15.1
Elaborated parts	Electronics	Internal control devices: Other parts	no code	Yes	30.2
Elaborated parts	Electronics	Other electronics: Air conditioning	841520	Yes	177.3
Elaborated parts	Electronics	Other electronics: cable harness	no code	Yes	479.8
Elaborated parts	Electronics	Other electronics: Display	852190	No	200.0
Elaborated parts	Electronics	Other electronics: lights	no code	Yes	46.2
Elaborated parts	Electronics	Transformers	850431	No	31.0
Elaborated parts	Electronics	Transformers	850433	No	98.0
Elaborated parts	Electronics	Transformers	850434	No	56.8
Elaborated parts	Electronics	Transformers	850440	No	28.4
Elaborated parts	Electronics	Transformers	851850	No	28.4
Elaborated parts	Electronics	Transformers: Other parts	no code	Yes	15.5
Elaborated parts	Motor	Motor	850133	Yes	584.1

Source: Own elaboration.

Table A2.2
Semi-elaborated parts vector (electric bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	HS 2017	Disaggregated	Weight
Semi-elaborated parts	Battery	Battery parts: case	730890	Yes	126.0
Semi-elaborated parts	Battery	Battery parts: case	761699	Yes	504.0
Semi-elaborated parts	Battery	Battery parts: electronics	no code	Yes	24.0
Semi-elaborated parts	Battery	Battery parts: Other parts of electronics	730890	Yes	24.0
Semi-elaborated parts	Battery	Battery parts: Other parts of electronics	741999	Yes	1.6
Semi-elaborated parts	Battery	Battery parts: Other parts of electronics	761699	Yes	23.2
Semi-elaborated parts	Battery	Battery parts: Other parts of electronics	854442	No	7.2
Semi-elaborated parts	Battery	Battery cells	392010	Yes	70.4
Semi-elaborated parts	Battery	Battery cells	730890	Yes	316.8
Semi-elaborated parts	Battery	Battery cells	741999	Yes	123.2
Semi-elaborated parts	Battery	Battery cells	761699	Yes	35.2
Semi-elaborated parts	Battery	Battery cells	854590	Yes	281.6
Semi-elaborated parts	Battery	Battery cells	no code	Yes	915.2
Semi-elaborated parts	Battery	Battery cooling system	840290	Yes	70.0
Semi-elaborated parts	Bus Body	Frame	401699	Yes	109.0
Semi-elaborated parts	Bus Body	Frame	730890	Yes	5 287.0
Semi-elaborated parts	Bus Body	Frame	760611	Yes	168.0
Semi-elaborated parts	Bus Body	Frame	870810	Yes	36.0
Semi-elaborated parts	Cabin	Floor covers and isolation	390469	No	19.8

Vector	Cluster	Sub-cluster	HS 2017	Disaggregated	Weight
Semi-elaborated parts	Cabin	Floor covers and isolation	391810	Yes	219.6
Semi-elaborated parts	Cabin	Floor covers and isolation	401691	Yes	5.0
Semi-elaborated parts	Cabin	Holding bars	730490	Yes	119.0
Semi-elaborated parts	Cabin	Seats	390720	Yes	106.1
Semi-elaborated parts	Cabin	Seats	521151	No	3.3
Semi-elaborated parts	Cabin	Seats	701912	Yes	76.5
Semi-elaborated parts	Cabin	Seats	732690	Yes	90.0
Semi-elaborated parts	Cabin	Seats	760611	Yes	29.6
Semi-elaborated parts	Cabin	Windows	391729	Yes	37.1
Semi-elaborated parts	Cabin	Windows	401033	Yes	14.8
Semi-elaborated parts	Cabin	Windows	401693	Yes	120.0
Semi-elaborated parts	Cabin	Windows	700711	Yes	700.8
Semi-elaborated parts	Cabin	Windows	700721	Yes	35.0
Semi-elaborated parts	Cabin	Windows	730830	Yes	74.0
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	401693	Yes	4.8
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	401699	Yes	53.0
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	681381	No	19.3
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	730490	Yes	101.2
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	730890	Yes	202.4
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	732690	Yes	72.3
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	848210	Yes	19.3
Semi-elaborated parts	Drivetrain	Front Axle (ZF RL 75)	848310	Yes	9.6
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	401693	Yes	6.3
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	401699	Yes	12.6
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	681381	No	12.6
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	730490	Yes	107.1
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	730890	Yes	245.7
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	732690	Yes	56.7
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	760611	Yes	63.0
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	848210	Yes	31.5
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	848310	Yes	37.8
Semi-elaborated parts	Drivetrain	Portal Axles (ZF AVE 130)	848390	Yes	56.7
Semi-elaborated parts	Drivetrain	Pressure air system	401699	Yes	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	730490	Yes	3.5
Semi-elaborated parts	Drivetrain	Pressure air system	731100	Yes	10.1
Semi-elaborated parts	Drivetrain	Pressure air system	732690	Yes	20.0
Semi-elaborated parts	Drivetrain	Pressure air system	848130	No	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	848140	No	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	848180	No	0.9
Semi-elaborated parts	Drivetrain	Pressure air system	848210	Yes	0.4
Semi-elaborated parts	Drivetrain	Steering system	391729	Yes	1.3
Semi-elaborated parts	Drivetrain	Steering system	400942	Yes	1.3
Semi-elaborated parts	Drivetrain	Steering system	401699	Yes	1.3
Semi-elaborated parts	Drivetrain	Steering system	730300	Yes	13.3
Semi-elaborated parts	Drivetrain	Steering system	730490	Yes	8.0
Semi-elaborated parts	Drivetrain	Steering system	730890	Yes	11.9
Semi-elaborated parts	Drivetrain	Steering system	732690	Yes	9.9

Vector	Cluster	Sub-cluster	HS 2017	Disaggregated	Weight
Semi-elaborated parts	Drivetrain	Steering system	761699	Yes	5.3
Semi-elaborated parts	Drivetrain	Steering system	848210	Yes	2.0
Semi-elaborated parts	Drivetrain	Steering system	848310	Yes	8.6
Semi-elaborated parts	Drivetrain	Steering system	848390	Yes	2.7
Semi-elaborated parts	Drivetrain	Wheel parts	730890	Yes	50.0
Semi-elaborated parts	Drivetrain	Wheels	401699	Yes	233.1
Semi-elaborated parts	Drivetrain	Wheels	730890	Yes	29.0
Semi-elaborated parts	Drivetrain	Wheels	732090	Yes	60.2
Semi-elaborated parts	Drivetrain	Wheels	848210	Yes	3.8
Semi-elaborated parts	Electronics	Human control devices: Other parts	391810	Yes	9.9
Semi-elaborated parts	Electronics	Human control devices: Other parts	392590	Yes	5.0
Semi-elaborated parts	Electronics	Human control devices: Other parts	730890	Yes	14.9
Semi-elaborated parts	Electronics	Human control devices: Other parts	848140	No	3.7
Semi-elaborated parts	Electronics	Internal control devices: Other parts	730890	Yes	18.9
Semi-elaborated parts	Electronics	Internal control devices: Other parts	841459	No	11.3
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	401699	Yes	18.5
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	730890	Yes	20.0
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	731100	Yes	18.5
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	840290	Yes	10.0
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	841430	No	55.0
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	841459	No	9.2
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	841460	No	18.5
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	850511	Yes	9.2
Semi-elaborated parts	Electronics	Other electronics: Air conditioning	850519	Yes	18.5
Semi-elaborated parts	Electronics	Other electronics: cable harness	400942	Yes	3.8
Semi-elaborated parts	Electronics	Other electronics: cable harness	401693	Yes	16.0
Semi-elaborated parts	Electronics	Other electronics: cable harness	854411	Yes	460.0
Semi-elaborated parts	Electronics	Other electronics: lights	853910	No	27.7
Semi-elaborated parts	Electronics	Other electronics: lights	940540	No	18.5
Semi-elaborated parts	Electronics	Transformers: Other parts	392590	Yes	2.6
Semi-elaborated parts	Electronics	Transformers: Other parts	761699	Yes	12.9
Semi-elaborated parts	Motor	Motor	730890	Yes	112.1
Semi-elaborated parts	Motor	Motor	740919	Yes	5.9
Semi-elaborated parts	Motor	Motor	760611	Yes	82.6
Semi-elaborated parts	Motor	Motor	848210	Yes	11.8
Semi-elaborated parts	Motor	Motor	850511	Yes	118.0
Semi-elaborated parts	Motor	Motor	854411	Yes	253.7

Source: Own elaboration.

Table A2.3
Raw materials vector (electric bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Battery	Battery parts: case	260111	126.0
Natural resources	Battery	Battery parts: case	260600	504.0
Natural resources	Battery	Battery parts: electronics	260300	12.0
Natural resources	Battery	Battery parts: electronics	260600	12.0
Natural resources	Battery	Battery parts: Other parts of electronics	260111	24.0
Natural resources	Battery	Battery parts: Other parts of electronics	260300	1.6
Natural resources	Battery	Battery parts: Other parts of electronics	260600	23.2
Natural resources	Battery	Battery cells	250410	281.6
Natural resources	Battery	Battery cells	260111	316.8
Natural resources	Battery	Battery cells	260200	222.9
Natural resources	Battery	Battery cells	260300	123.2
Natural resources	Battery	Battery cells	260400	222.9
Natural resources	Battery	Battery cells	260500	222.9
Natural resources	Battery	Battery cells	260600	35.2
Natural resources	Battery	Battery cells	282520	246.4
Natural resources	Battery	Battery cells	390410	70.4
Natural resources	Battery	Battery cooling system	260600	70.0
Natural resources	Bus Body	Frame	250300	0.6
Natural resources	Bus Body	Frame	251010	0.7
Natural resources	Bus Body	Frame	260111	5 287.0
Natural resources	Bus Body	Frame	260600	168.0
Natural resources	Bus Body	Frame	261710	1.8
Natural resources	Bus Body	Frame	280200	0.7
Natural resources	Bus Body	Frame	280300	30.5
Natural resources	Bus Body	Frame	281610	1.2
Natural resources	Bus Body	Frame	281700	1.8
Natural resources	Bus Body	Frame	281990	1.7
Natural resources	Bus Body	Frame	282110	1.7
Natural resources	Bus Body	Frame	282300	2.6
Natural resources	Bus Body	Frame	283090	1.4
Natural resources	Bus Body	Frame	283327	1.5
Natural resources	Bus Body	Frame	340420	0.3
Natural resources	Bus Body	Frame	381190	0.6
Natural resources	Bus Body	Frame	390210	36.0
Natural resources	Bus Body	Frame	390940	0.4
Natural resources	Bus Body	Frame	391110	0.7
Natural resources	Bus Body	Frame	400110	29.4
Natural resources	Bus Body	Frame	400219	15.3
Natural resources	Bus Body	Frame	520512	0.3
Natural resources	Bus Body	Frame	720521	15.8
Natural resources	Cabin	Floor covers and isolation	250300	0.0
Natural resources	Cabin	Floor covers and isolation	251010	0.0
Natural resources	Cabin	Floor covers and isolation	260111	119.0
Natural resources	Cabin	Floor covers and isolation	261710	0.1
Natural resources	Cabin	Floor covers and isolation	280200	0.0
Natural resources	Cabin	Floor covers and isolation	280300	1.4
Natural resources	Cabin	Floor covers and isolation	281610	0.1
Natural resources	Cabin	Floor covers and isolation	281700	0.1
Natural resources	Cabin	Floor covers and isolation	281990	0.1

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Cabin	Floor covers and isolation	282110	0.1
Natural resources	Cabin	Floor covers and isolation	282300	0.1
Natural resources	Cabin	Floor covers and isolation	283090	0.1
Natural resources	Cabin	Floor covers and isolation	283327	0.1
Natural resources	Cabin	Floor covers and isolation	340420	0.0
Natural resources	Cabin	Floor covers and isolation	381190	0.0
Natural resources	Cabin	Floor covers and isolation	390410	219.6
Natural resources	Cabin	Floor covers and isolation	390940	0.0
Natural resources	Cabin	Floor covers and isolation	391110	0.0
Natural resources	Cabin	Floor covers and isolation	400110	1.4
Natural resources	Cabin	Floor covers and isolation	400219	0.7
Natural resources	Cabin	Floor covers and isolation	520512	0.0
Natural resources	Cabin	Floor covers and isolation	720521	0.7
Natural resources	Cabin	Seats	260111	90.0
Natural resources	Cabin	Seats	260600	29.6
Natural resources	Cabin	Seats	281122	55.8
Natural resources	Cabin	Seats	281610	2.6
Natural resources	Cabin	Seats	281810	0.7
Natural resources	Cabin	Seats	283620	10.7
Natural resources	Cabin	Seats	283650	6.7
Natural resources	Cabin	Seats	390410	106.1
Natural resources	Cabin	Windows	250300	0.8
Natural resources	Cabin	Windows	251010	0.9
Natural resources	Cabin	Windows	260111	74.0
Natural resources	Cabin	Windows	261710	2.2
Natural resources	Cabin	Windows	280200	0.8
Natural resources	Cabin	Windows	280300	37.7
Natural resources	Cabin	Windows	281122	537.1
Natural resources	Cabin	Windows	281610	26.8
Natural resources	Cabin	Windows	281700	2.2
Natural resources	Cabin	Windows	281810	6.3
Natural resources	Cabin	Windows	281990	2.1
Natural resources	Cabin	Windows	282110	2.1
Natural resources	Cabin	Windows	282300	3.3
Natural resources	Cabin	Windows	283090	1.8
Natural resources	Cabin	Windows	283327	1.8
Natural resources	Cabin	Windows	283620	103.0
Natural resources	Cabin	Windows	283650	64.0
Natural resources	Cabin	Windows	340420	0.4
Natural resources	Cabin	Windows	381190	0.8
Natural resources	Cabin	Windows	390210	37.1
Natural resources	Cabin	Windows	390940	0.5
Natural resources	Cabin	Windows	391110	0.8
Natural resources	Cabin	Windows	400110	36.4
Natural resources	Cabin	Windows	400219	18.9
Natural resources	Cabin	Windows	520512	0.4
Natural resources	Cabin	Windows	720521	19.5
Natural resources	Drivetrain	Front Axle (ZF RL 75)	250300	0.3
Natural resources	Drivetrain	Front Axle (ZF RL 75)	251010	0.4
Natural resources	Drivetrain	Front Axle (ZF RL 75)	260111	401.6
Natural resources	Drivetrain	Front Axle (ZF RL 75)	261000	3.3
Natural resources	Drivetrain	Front Axle (ZF RL 75)	261710	0.9

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Drivetrain	Front Axle (ZF RL 75)	280200	0.4
Natural resources	Drivetrain	Front Axle (ZF RL 75)	280300	16.2
Natural resources	Drivetrain	Front Axle (ZF RL 75)	281610	0.6
Natural resources	Drivetrain	Front Axle (ZF RL 75)	281700	1.0
Natural resources	Drivetrain	Front Axle (ZF RL 75)	281990	0.9
Natural resources	Drivetrain	Front Axle (ZF RL 75)	282110	0.9
Natural resources	Drivetrain	Front Axle (ZF RL 75)	282300	1.4
Natural resources	Drivetrain	Front Axle (ZF RL 75)	283090	0.8
Natural resources	Drivetrain	Front Axle (ZF RL 75)	283327	0.8
Natural resources	Drivetrain	Front Axle (ZF RL 75)	340420	0.2
Natural resources	Drivetrain	Front Axle (ZF RL 75)	381190	0.3
Natural resources	Drivetrain	Front Axle (ZF RL 75)	390940	0.2
Natural resources	Drivetrain	Front Axle (ZF RL 75)	391110	0.4
Natural resources	Drivetrain	Front Axle (ZF RL 75)	400110	15.6
Natural resources	Drivetrain	Front Axle (ZF RL 75)	400219	8.1
Natural resources	Drivetrain	Front Axle (ZF RL 75)	520512	0.2
Natural resources	Drivetrain	Front Axle (ZF RL 75)	720521	8.4
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	250300	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	251010	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	260111	530.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	260600	63.0
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	261000	5.4
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	261710	0.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	280200	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	280300	5.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	281610	0.2
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	281700	0.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	281990	0.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	282110	0.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	282300	0.5
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	283090	0.2
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	283327	0.3
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	340420	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	381190	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	390940	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	391110	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	400110	5.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	400219	2.6
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	520512	0.1
Natural resources	Drivetrain	Portal Axles (ZF AVE 130)	720521	2.7
Natural resources	Drivetrain	Pressure air system	250300	0.0
Natural resources	Drivetrain	Pressure air system	251010	0.0
Natural resources	Drivetrain	Pressure air system	260111	33.9
Natural resources	Drivetrain	Pressure air system	261000	0.1
Natural resources	Drivetrain	Pressure air system	261710	0.0
Natural resources	Drivetrain	Pressure air system	280200	0.0
Natural resources	Drivetrain	Pressure air system	280300	0.1
Natural resources	Drivetrain	Pressure air system	281610	0.0
Natural resources	Drivetrain	Pressure air system	281700	0.0
Natural resources	Drivetrain	Pressure air system	281990	0.0
Natural resources	Drivetrain	Pressure air system	282110	0.0
Natural resources	Drivetrain	Pressure air system	282300	0.0

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Drivetrain	Pressure air system	283090	0.0
Natural resources	Drivetrain	Pressure air system	283327	0.0
Natural resources	Drivetrain	Pressure air system	340420	0.0
Natural resources	Drivetrain	Pressure air system	381190	0.0
Natural resources	Drivetrain	Pressure air system	390940	0.0
Natural resources	Drivetrain	Pressure air system	391110	0.0
Natural resources	Drivetrain	Pressure air system	400110	0.1
Natural resources	Drivetrain	Pressure air system	400219	0.1
Natural resources	Drivetrain	Pressure air system	520512	0.0
Natural resources	Drivetrain	Pressure air system	720521	0.1
Natural resources	Drivetrain	Steering system	250300	0.0
Natural resources	Drivetrain	Steering system	251010	0.0
Natural resources	Drivetrain	Steering system	260111	56.0
Natural resources	Drivetrain	Steering system	260600	5.3
Natural resources	Drivetrain	Steering system	261000	0.3
Natural resources	Drivetrain	Steering system	261710	0.0
Natural resources	Drivetrain	Steering system	280200	0.0
Natural resources	Drivetrain	Steering system	280300	0.7
Natural resources	Drivetrain	Steering system	281610	0.0
Natural resources	Drivetrain	Steering system	281700	0.0
Natural resources	Drivetrain	Steering system	281990	0.0
Natural resources	Drivetrain	Steering system	282110	0.0
Natural resources	Drivetrain	Steering system	282300	0.1
Natural resources	Drivetrain	Steering system	283090	0.0
Natural resources	Drivetrain	Steering system	283327	0.0
Natural resources	Drivetrain	Steering system	340420	0.0
Natural resources	Drivetrain	Steering system	381190	0.0
Natural resources	Drivetrain	Steering system	390410	1.3
Natural resources	Drivetrain	Steering system	390940	0.0
Natural resources	Drivetrain	Steering system	391110	0.0
Natural resources	Drivetrain	Steering system	400110	0.7
Natural resources	Drivetrain	Steering system	400219	0.4
Natural resources	Drivetrain	Steering system	520512	0.0
Natural resources	Drivetrain	Steering system	720521	0.4
Natural resources	Drivetrain	Wheel parts	260111	50.0
Natural resources	Drivetrain	Wheels	250300	1.4
Natural resources	Drivetrain	Wheels	251010	1.5
Natural resources	Drivetrain	Wheels	260111	92.2
Natural resources	Drivetrain	Wheels	261000	0.6
Natural resources	Drivetrain	Wheels	261710	3.7
Natural resources	Drivetrain	Wheels	280200	1.4
Natural resources	Drivetrain	Wheels	280300	65.3
Natural resources	Drivetrain	Wheels	281610	2.5
Natural resources	Drivetrain	Wheels	281700	3.9
Natural resources	Drivetrain	Wheels	281990	3.6
Natural resources	Drivetrain	Wheels	282110	3.6
Natural resources	Drivetrain	Wheels	282300	5.6
Natural resources	Drivetrain	Wheels	283090	3.1
Natural resources	Drivetrain	Wheels	283327	3.1
Natural resources	Drivetrain	Wheels	340420	0.6
Natural resources	Drivetrain	Wheels	381190	1.4
Natural resources	Drivetrain	Wheels	390940	0.9

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Drivetrain	Wheels	391110	1.5
Natural resources	Drivetrain	Wheels	400110	62.9
Natural resources	Drivetrain	Wheels	400219	32.6
Natural resources	Drivetrain	Wheels	520512	0.7
Natural resources	Drivetrain	Wheels	720521	33.8
Natural resources	Electronics	Human control devices: Other parts	260111	14.9
Natural resources	Electronics	Human control devices: Other parts	390210	5.0
Natural resources	Electronics	Human control devices: Other parts	390410	9.9
Natural resources	Electronics	Internal control devices: Other parts	260111	18.9
Natural resources	Electronics	Other electronics: Air conditioning	250300	0.1
Natural resources	Electronics	Other electronics: Air conditioning	251010	0.1
Natural resources	Electronics	Other electronics: Air conditioning	260111	56.8
Natural resources	Electronics	Other electronics: Air conditioning	260600	10.1
Natural resources	Electronics	Other electronics: Air conditioning	261590	0.2
Natural resources	Electronics	Other electronics: Air conditioning	261710	0.3
Natural resources	Electronics	Other electronics: Air conditioning	280200	0.1
Natural resources	Electronics	Other electronics: Air conditioning	280300	5.2
Natural resources	Electronics	Other electronics: Air conditioning	280450	0.3
Natural resources	Electronics	Other electronics: Air conditioning	280530	8.7
Natural resources	Electronics	Other electronics: Air conditioning	281610	0.2
Natural resources	Electronics	Other electronics: Air conditioning	281700	0.3
Natural resources	Electronics	Other electronics: Air conditioning	281990	0.3
Natural resources	Electronics	Other electronics: Air conditioning	282110	0.3
Natural resources	Electronics	Other electronics: Air conditioning	282300	0.4
Natural resources	Electronics	Other electronics: Air conditioning	283090	0.2
Natural resources	Electronics	Other electronics: Air conditioning	283327	0.2
Natural resources	Electronics	Other electronics: Air conditioning	340420	0.1
Natural resources	Electronics	Other electronics: Air conditioning	381190	0.1
Natural resources	Electronics	Other electronics: Air conditioning	390940	0.1
Natural resources	Electronics	Other electronics: Air conditioning	391110	0.1
Natural resources	Electronics	Other electronics: Air conditioning	400110	5.0
Natural resources	Electronics	Other electronics: Air conditioning	400219	2.6
Natural resources	Electronics	Other electronics: Air conditioning	520512	0.1
Natural resources	Electronics	Other electronics: Air conditioning	720521	2.7
Natural resources	Electronics	Other electronics: cable harness	250300	0.1
Natural resources	Electronics	Other electronics: cable harness	251010	0.1
Natural resources	Electronics	Other electronics: cable harness	260300	460.0
Natural resources	Electronics	Other electronics: cable harness	261710	0.3
Natural resources	Electronics	Other electronics: cable harness	280200	0.1
Natural resources	Electronics	Other electronics: cable harness	280300	5.5
Natural resources	Electronics	Other electronics: cable harness	281610	0.2
Natural resources	Electronics	Other electronics: cable harness	281700	0.3
Natural resources	Electronics	Other electronics: cable harness	281990	0.3
Natural resources	Electronics	Other electronics: cable harness	282110	0.3
Natural resources	Electronics	Other electronics: cable harness	282300	0.5
Natural resources	Electronics	Other electronics: cable harness	283090	0.3
Natural resources	Electronics	Other electronics: cable harness	283327	0.3
Natural resources	Electronics	Other electronics: cable harness	340420	0.1
Natural resources	Electronics	Other electronics: cable harness	381190	0.1
Natural resources	Electronics	Other electronics: cable harness	390940	0.1
Natural resources	Electronics	Other electronics: cable harness	391110	0.1
Natural resources	Electronics	Other electronics: cable harness	400110	5.3

Vector	Cluster	Sub-cluster	HS 2017	Weight
Natural resources	Electronics	Other electronics: cable harness	400219	2.8
Natural resources	Electronics	Other electronics: cable harness	520512	0.1
Natural resources	Electronics	Other electronics: cable harness	720521	2.9
Natural resources	Electronics	Transformers: Other parts	260600	12.9
Natural resources	Electronics	Transformers: Other parts	390210	2.6
Natural resources	Motor	Motor	260111	200.2
Natural resources	Motor	Motor	260300	259.6
Natural resources	Motor	Motor	260600	83.0
Natural resources	Motor	Motor	261000	2.0
Natural resources	Motor	Motor	261590	0.9
Natural resources	Motor	Motor	280450	1.3
Natural resources	Motor	Motor	280530	37.2

Source: Own elaboration.

Annex 3
Conventional bus input vector

Table A3.1
Elaborated parts vector (convencional bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	HS 2017	Weight
Elaborated parts	Bus Body	Frame	870790	5 600.0
Elaborated parts	Cabin	Floor covers and isolation	No code	244.4
Elaborated parts	Cabin	Holding bars	No code	119.0
Elaborated parts	Cabin	Other cabin parts	700910	24.0
Elaborated parts	Cabin	Other cabin parts	842410	9.8
Elaborated parts	Cabin	Other cabin parts	851240	0.5
Elaborated parts	Cabin	Other cabin parts	870821	17.3
Elaborated parts	Cabin	Other cabin parts	870895	3.0
Elaborated parts	Cabin	Other cabin parts	940592	17.3
Elaborated parts	Cabin	Other cabin parts	960621	5.0
Elaborated parts	Cabin	Seats	940120	305.4
Elaborated parts	Cabin	Windows	No code	981.7
Elaborated parts	Drivetrain	Automatic Gear VOITH DIWA 854.6	870840	317.3
Elaborated parts	Drivetrain	Clutch and parts	870893	8.5
Elaborated parts	Drivetrain	Frontal axle (ZF RL 75)	870850	527.0
Elaborated parts	Drivetrain	Middle Axle (ZF AV 133)	870850	973.0
Elaborated parts	Drivetrain	Pressure air system	841490	36.0
Elaborated parts	Drivetrain	Steering system	870894	65.6
Elaborated parts	Drivetrain	Wheel parts	870830	25.0
Elaborated parts	Drivetrain	Wheel parts	870870	25.0
Elaborated parts	Drivetrain	Wheels	401120	326.0
Elaborated parts	Electronics	Human control devices	830120	3.7
Elaborated parts	Electronics	Human control devices	847050	19.8
Elaborated parts	Electronics	Human control devices	851762	7.4
Elaborated parts	Electronics	Human control devices	851810	0.0
Elaborated parts	Electronics	Human control devices	851829	0.0
Elaborated parts	Electronics	Human control devices	851840	12.4
Elaborated parts	Electronics	Human control devices	853110	0.0
Elaborated parts	Electronics	Human control devices	853120	7.4
Elaborated parts	Electronics	Human control devices	853180	0.0
Elaborated parts	Electronics	Human control devices	853190	7.4
Elaborated parts	Electronics	Human control devices	853650	2.5
Elaborated parts	Electronics	Human control devices	902910	9.9
Elaborated parts	Electronics	Human control devices	902920	7.4
Elaborated parts	Electronics	Human control devices	960622	2.5
Elaborated parts	Electronics	Human control devices: Other parts	No code	33.5
Elaborated parts	Electronics	Internal control devices	841950	15.1
Elaborated parts	Electronics	Internal control devices	850131	30.2
Elaborated parts	Electronics	Internal control devices	852190	41.5
Elaborated parts	Electronics	Internal control devices	853400	28.9
Elaborated parts	Electronics	Internal control devices	853630	22.6
Elaborated parts	Electronics	Internal control devices	853649	45.2
Elaborated parts	Electronics	Internal control devices	853650	30.2
Elaborated parts	Electronics	Internal control devices	854231	45.2
Elaborated parts	Electronics	Internal control devices	854233	7.5
Elaborated parts	Electronics	Internal control devices	902519	5.1

Vector	Cluster	Sub-cluster	HS 2017	Weight
Elaborated parts	Electronics	Internal control devices	902610	4.6
Elaborated parts	Electronics	Internal control devices	902620	5.1
Elaborated parts	Electronics	Internal control devices	903039	9.7
Elaborated parts	Electronics	Internal control devices	903210	45.2
Elaborated parts	Electronics	Internal control devices	903281	15.1
Elaborated parts	Electronics	Internal control devices: Other parts	No code	30.2
Elaborated parts	Electronics	Other electronics: Air conditioning	841520	177.3
Elaborated parts	Electronics	Other electronics: cable harness	no code	479.8
Elaborated parts	Electronics	Other electronics: Display	852190	200.0
Elaborated parts	Electronics	Other electronics: lights	no code	46.2
Elaborated parts	Electronics	Transformers	850431	31.0
Elaborated parts	Electronics	Transformers	850433	98.0
Elaborated parts	Electronics	Transformers	850434	56.8
Elaborated parts	Electronics	Transformers	850440	28.4
Elaborated parts	Electronics	Transformers	851850	28.4
Elaborated parts	Electronics	Transformers: Other parts	No code	15.5
Elaborated parts	Engine	Engine Block OM 936	840820	604.5
Elaborated parts	Engine	Engine Starter	851130	6.5
Elaborated parts	Engine	Engine Starter	851140	19.5
Elaborated parts	Engine	Exhaust system	381512	171.3
Elaborated parts	Engine	Exhaust system	870892	161.3
Elaborated parts	Engine	Other engine parts	870891	150.0
Elaborated parts	Fuel tank	Diesel tank	730900	62.1
Elaborated parts	Fuel tank	Other parts	No code	72.9
Elaborated parts	Bus Body	Frame	870790	5600.0
Elaborated parts	Cabin	Floor covers and isolation	No code	244.4
Elaborated parts	Cabin	Holding bars	No code	119.0
Elaborated parts	Cabin	Other cabin parts	700910	24.0
Elaborated parts	Cabin	Other cabin parts	842410	9.8
Elaborated parts	Cabin	Other cabin parts	851240	0.5
Elaborated parts	Cabin	Other cabin parts	870821	17.3
Elaborated parts	Cabin	Other cabin parts	870895	3.0
Elaborated parts	Cabin	Other cabin parts	940592	17.3
Elaborated parts	Cabin	Other cabin parts	960621	5.0
Elaborated parts	Cabin	Seats	940120	305.4
Elaborated parts	Cabin	Windows	No code	981.7
Elaborated parts	Drivetrain	Automatic Gear VOITH DIWA 854.6	870840	317.3
Elaborated parts	Drivetrain	Clutch and parts	870893	8.5
Elaborated parts	Drivetrain	Frontal axle (ZF RL 75)	870850	527.0
Elaborated parts	Drivetrain	Middle Axle (ZF AV 133)	870850	973.0
Elaborated parts	Drivetrain	Pressure air system	841490	36.0
Elaborated parts	Drivetrain	Steering system	870894	65.6
Elaborated parts	Drivetrain	Wheel parts	870830	25.0
Elaborated parts	Drivetrain	Wheel parts	870870	25.0
Elaborated parts	Drivetrain	Wheels	401120	326.0
Elaborated parts	Electronics	Human control devices	830120	3.7
Elaborated parts	Electronics	Human control devices	847050	19.8
Elaborated parts	Electronics	Human control devices	851762	7.4
Elaborated parts	Electronics	Human control devices	851810	0.0
Elaborated parts	Electronics	Human control devices	851829	0.0
Elaborated parts	Electronics	Human control devices	851840	12.4
Elaborated parts	Electronics	Human control devices	853110	0.0
Elaborated parts	Electronics	Human control devices	853120	7.4
Elaborated parts	Electronics	Human control devices	853180	0.0

Vector	Cluster	Sub-cluster	HS 2017	Weight
Elaborated parts	Electronics	Human control devices	853190	7.4
Elaborated parts	Electronics	Human control devices	853650	2.5
Elaborated parts	Electronics	Human control devices	902910	9.9
Elaborated parts	Electronics	Human control devices	902920	7.4
Elaborated parts	Electronics	Human control devices	960622	2.5
Elaborated parts	Electronics	Human control devices: Other parts	No code	33.5
Elaborated parts	Electronics	Internal control devices	841950	15.1
Elaborated parts	Electronics	Internal control devices	850131	30.2
Elaborated parts	Electronics	Internal control devices	852190	41.5
Elaborated parts	Electronics	Internal control devices	853400	28.9
Elaborated parts	Electronics	Internal control devices	853630	22.6
Elaborated parts	Electronics	Internal control devices	853649	45.2
Elaborated parts	Electronics	Internal control devices	853650	30.2
Elaborated parts	Electronics	Internal control devices	854231	45.2
Elaborated parts	Electronics	Internal control devices	854233	7.5
Elaborated parts	Electronics	Internal control devices	902519	5.1
Elaborated parts	Electronics	Internal control devices	902610	4.6
Elaborated parts	Electronics	Internal control devices	902620	5.1
Elaborated parts	Electronics	Internal control devices	903039	9.7
Elaborated parts	Electronics	Internal control devices	903210	45.2
Elaborated parts	Electronics	Internal control devices	903281	15.1
Elaborated parts	Electronics	Internal control devices: Other parts	No code	30.2
Elaborated parts	Electronics	Other electronics: Air conditioning	841520	177.3
Elaborated parts	Electronics	Other electronics: cable harness	No code	479.8
Elaborated parts	Electronics	Other electronics: Display	852190	200.0
Elaborated parts	Electronics	Other electronics: lights	No code	46.2
Elaborated parts	Electronics	Transformers	850431	31.0
Elaborated parts	Electronics	Transformers	850433	98.0
Elaborated parts	Electronics	Transformers	850434	56.8
Elaborated parts	Electronics	Transformers	850440	28.4
Elaborated parts	Electronics	Transformers	851850	28.4
Elaborated parts	Electronics	Transformers: Other parts	No code	15.5
Elaborated parts	Engine	Engine Block OM 936	840820	604.5
Elaborated parts	Engine	Engine Starter	851130	6.5
Elaborated parts	Engine	Engine Starter	851140	19.5
Elaborated parts	Engine	Exhaust system	381512	171.3
Elaborated parts	Engine	Exhaust system	870892	161.3
Elaborated parts	Engine	Other engine parts	870891	150.0
Elaborated parts	Fuel tank	Diesel tank	730900	62.1
Elaborated parts	Fuel tank	Other parts	No code	72.9

Source: Own elaboration.

Table A3.2
Semi-elaborated parts vector (convencional bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Semi-elaborated parts	Bus body	Frame	401699	109.0
Semi-elaborated parts	Bus body	Frame	730890	5287.0
Semi-elaborated parts	Bus body	Frame	760611	168.0
Semi-elaborated parts	Bus body	Frame	870810	36.0
Semi-elaborated parts	Cabin	Floor covers and isolation	390469	19.8
Semi-elaborated parts	Cabin	Floor covers and isolation	391810	219.6
Semi-elaborated parts	Cabin	Floor covers and isolation	401691	5.0
Semi-elaborated parts	Cabin	Holding bars	730490	119.0
Semi-elaborated parts	Cabin	Seats	390720	106.1
Semi-elaborated parts	Cabin	Seats	521151	3.3
Semi-elaborated parts	Cabin	Seats	701912	76.5
Semi-elaborated parts	Cabin	Seats	732690	90.0
Semi-elaborated parts	Cabin	Seats	760611	29.6
Semi-elaborated parts	Cabin	Windows	391729	37.1
Semi-elaborated parts	Cabin	Windows	401033	14.8
Semi-elaborated parts	Cabin	Windows	401693	120.0
Semi-elaborated parts	Cabin	Windows	700711	700.8
Semi-elaborated parts	Cabin	Windows	700721	35.0
Semi-elaborated parts	Cabin	Windows	730830	74.0
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	401693	3.3
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	681389	26.7
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	730890	110.2
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	732090	6.7
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	761699	50.1
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	848210	16.7
Semi-elaborated parts	Drivetrain	Automatic gear voith diwa 854.6	848390	103.5
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	401693	5.3
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	401699	58.0
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	681381	21.1
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	730490	110.7
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	730890	221.3
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	732690	79.1
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	848210	21.1
Semi-elaborated parts	Drivetrain	Frontal axle (zf rl 75)	848310	10.5
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	401693	9.7
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	401699	19.5
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	681381	19.5
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	730490	165.4
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	730890	379.5
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	732690	87.6
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	760611	97.3
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	848210	48.7
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	848310	58.4
Semi-elaborated parts	Drivetrain	Middle axle (zf av 133)	848390	87.6
Semi-elaborated parts	Drivetrain	Pressure air system	401699	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	730490	3.5
Semi-elaborated parts	Drivetrain	Pressure air system	731100	10.1
Semi-elaborated parts	Drivetrain	Pressure air system	732690	20.0
Semi-elaborated parts	Drivetrain	Pressure air system	848130	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	848140	0.4
Semi-elaborated parts	Drivetrain	Pressure air system	848180	0.9
Semi-elaborated parts	Drivetrain	Pressure air system	848210	0.4
Semi-elaborated parts	Drivetrain	Steering system	391729	1.3
Semi-elaborated parts	Drivetrain	Steering system	400942	1.3
Semi-elaborated parts	Drivetrain	Steering system	401699	1.3
Semi-elaborated parts	Drivetrain	Steering system	730300	13.3
Semi-elaborated parts	Drivetrain	Steering system	730490	8.0

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Semi-elaborated parts	Drivetrain	Steering system	730890	11.9
Semi-elaborated parts	Drivetrain	Steering system	732690	9.9
Semi-elaborated parts	Drivetrain	Steering system	761699	5.3
Semi-elaborated parts	Drivetrain	Steering system	848210	2.0
Semi-elaborated parts	Drivetrain	Steering system	848310	8.6
Semi-elaborated parts	Drivetrain	Steering system	848390	2.7
Semi-elaborated parts	Drivetrain	Wheel parts	730890	50.0
Semi-elaborated parts	Drivetrain	Wheels	401699	233.1
Semi-elaborated parts	Drivetrain	Wheels	730890	29.0
Semi-elaborated parts	Drivetrain	Wheels	732090	60.2
Semi-elaborated parts	Drivetrain	Wheels	848210	3.8
Semi-elaborated parts	Electronics	Human control devices: other parts	391810	9.9
Semi-elaborated parts	Electronics	Human control devices: other parts	392590	5.0
Semi-elaborated parts	Electronics	Human control devices: other parts	730890	14.9
Semi-elaborated parts	Electronics	Human control devices: other parts	848140	3.7
Semi-elaborated parts	Electronics	Internal control devices: other parts	730890	18.9
Semi-elaborated parts	Electronics	Internal control devices: other parts	841459	11.3
Semi-elaborated parts	Electronics	Other electronics: air conditioning	401699	18.5
Semi-elaborated parts	Electronics	Other electronics: air conditioning	730890	20.0
Semi-elaborated parts	Electronics	Other electronics: air conditioning	731100	18.5
Semi-elaborated parts	Electronics	Other electronics: air conditioning	840290	10.0
Semi-elaborated parts	Electronics	Other electronics: air conditioning	841430	55.0
Semi-elaborated parts	Electronics	Other electronics: air conditioning	841459	9.2
Semi-elaborated parts	Electronics	Other electronics: air conditioning	841460	18.5
Semi-elaborated parts	Electronics	Other electronics: air conditioning	850511	9.2
Semi-elaborated parts	Electronics	Other electronics: air conditioning	850519	18.5
Semi-elaborated parts	Electronics	Other electronics: cable harness	400942	3.8
Semi-elaborated parts	Electronics	Other electronics: cable harness	401693	16.0
Semi-elaborated parts	Electronics	Other electronics: cable harness	854411	460.0
Semi-elaborated parts	Electronics	Other electronics: lights	853910	27.7
Semi-elaborated parts	Electronics	Other electronics: lights	940540	18.5
Semi-elaborated parts	Electronics	Transformers: other parts	392590	2.6
Semi-elaborated parts	Electronics	Transformers: other parts	761699	12.9
Semi-elaborated parts	Engine	Catalysts	730300	38.1
Semi-elaborated parts	Engine	Catalysts	730890	123.1
Semi-elaborated parts	Engine	Catalysts	842139	10.0
Semi-elaborated parts	Engine	Engine block om 936	401033	6.5
Semi-elaborated parts	Engine	Engine block om 936	401699	13.0
Semi-elaborated parts	Engine	Engine block om 936	730300	136.5
Semi-elaborated parts	Engine	Engine block om 936	730890	266.5
Semi-elaborated parts	Engine	Engine block om 936	731520	13.0
Semi-elaborated parts	Engine	Engine block om 936	761699	32.5
Semi-elaborated parts	Engine	Engine block om 936	830710	6.5
Semi-elaborated parts	Engine	Engine block om 936	840290	19.5
Semi-elaborated parts	Engine	Engine block om 936	841330	13.0
Semi-elaborated parts	Engine	Engine block om 936	841459	19.5
Semi-elaborated parts	Engine	Engine block om 936	842199	13.0
Semi-elaborated parts	Engine	Engine block om 936	848310	58.5
Semi-elaborated parts	Engine	Engine block om 936	854411	6.5
Semi-elaborated parts	Engine	Other engine parts	761699	150.0
Semi-elaborated parts	Engine	Silencers	730300	38.1
Semi-elaborated parts	Engine	Silencers	730890	123.1
Semi-elaborated parts	Fuel tank	Diesel tank	730890	62.1
Semi-elaborated parts	Fuel tank	Other parts	400942	5.4
Semi-elaborated parts	Fuel tank	Other parts	401699	1.4
Semi-elaborated parts	Fuel tank	Other parts	730300	28.4
Semi-elaborated parts	Fuel tank	Other parts	730890	10.8
Semi-elaborated parts	Fuel tank	Other parts	841330	17.6
Semi-elaborated parts	Fuel tank	Other parts	842123	9.5

Source: Own elaboration.

Table A3.3
Raw materials vector (convencional bus)
(Weight in kilograms)

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Bus body	Frame	250300	0.6
Natural resources	Bus body	Frame	251010	0.7
Natural resources	Bus body	Frame	260111	5287.0
Natural resources	Bus body	Frame	260600	168.0
Natural resources	Bus body	Frame	261710	1.8
Natural resources	Bus body	Frame	280200	0.7
Natural resources	Bus body	Frame	280300	30.5
Natural resources	Bus body	Frame	281610	1.2
Natural resources	Bus body	Frame	281700	1.8
Natural resources	Bus body	Frame	281990	1.7
Natural resources	Bus body	Frame	282110	1.7
Natural resources	Bus body	Frame	282300	2.6
Natural resources	Bus body	Frame	283090	1.4
Natural resources	Bus body	Frame	283327	1.5
Natural resources	Bus body	Frame	340420	0.3
Natural resources	Bus body	Frame	381190	0.6
Natural resources	Bus body	Frame	390210	36.0
Natural resources	Bus body	Frame	390940	0.4
Natural resources	Bus body	Frame	391110	0.7
Natural resources	Bus body	Frame	400110	29.4
Natural resources	Bus body	Frame	400219	15.3
Natural resources	Bus body	Frame	520512	0.3
Natural resources	Bus body	Frame	720521	15.8
Natural resources	Cabin	Floor covers and isolation	250300	0.0
Natural resources	Cabin	Floor covers and isolation	251010	0.0
Natural resources	Cabin	Floor covers and isolation	260111	119.0
Natural resources	Cabin	Floor covers and isolation	261710	0.1
Natural resources	Cabin	Floor covers and isolation	280200	0.0
Natural resources	Cabin	Floor covers and isolation	280300	1.4
Natural resources	Cabin	Floor covers and isolation	281610	0.1
Natural resources	Cabin	Floor covers and isolation	281700	0.1
Natural resources	Cabin	Floor covers and isolation	281990	0.1
Natural resources	Cabin	Floor covers and isolation	282110	0.1
Natural resources	Cabin	Floor covers and isolation	282300	0.1
Natural resources	Cabin	Floor covers and isolation	283090	0.1
Natural resources	Cabin	Floor covers and isolation	283327	0.1
Natural resources	Cabin	Floor covers and isolation	340420	0.0
Natural resources	Cabin	Floor covers and isolation	381190	0.0
Natural resources	Cabin	Floor covers and isolation	390410	219.6
Natural resources	Cabin	Floor covers and isolation	390940	0.0
Natural resources	Cabin	Floor covers and isolation	391110	0.0
Natural resources	Cabin	Floor covers and isolation	400110	1.4
Natural resources	Cabin	Floor covers and isolation	400219	0.7
Natural resources	Cabin	Floor covers and isolation	520512	0.0
Natural resources	Cabin	Floor covers and isolation	720521	0.7
Natural resources	Cabin	Seats	260111	90.0
Natural resources	Cabin	Seats	260600	29.6
Natural resources	Cabin	Seats	281122	55.8
Natural resources	Cabin	Seats	281610	2.6

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Cabin	Seats	281810	0.7
Natural resources	Cabin	Seats	283620	10.7
Natural resources	Cabin	Seats	283650	6.7
Natural resources	Cabin	Seats	390410	106.1
Natural resources	Cabin	Windows	250300	0.8
Natural resources	Cabin	Windows	251010	0.9
Natural resources	Cabin	Windows	260111	74.0
Natural resources	Cabin	Windows	261710	2.2
Natural resources	Cabin	Windows	280200	0.8
Natural resources	Cabin	Windows	280300	37.7
Natural resources	Cabin	Windows	281122	537.1
Natural resources	Cabin	Windows	281610	26.8
Natural resources	Cabin	Windows	281700	2.2
Natural resources	Cabin	Windows	281810	6.3
Natural resources	Cabin	Windows	281990	2.1
Natural resources	Cabin	Windows	282110	2.1
Natural resources	Cabin	Windows	282300	3.3
Natural resources	Cabin	Windows	283090	1.8
Natural resources	Cabin	Windows	283327	1.8
Natural resources	Cabin	Windows	283620	103.0
Natural resources	Cabin	Windows	283650	64.0
Natural resources	Cabin	Windows	340420	0.4
Natural resources	Cabin	Windows	381190	0.8
Natural resources	Cabin	Windows	390210	37.1
Natural resources	Cabin	Windows	390940	0.5
Natural resources	Cabin	Windows	391110	0.8
Natural resources	Cabin	Windows	400110	36.4
Natural resources	Cabin	Windows	400219	18.9
Natural resources	Cabin	Windows	520512	0.4
Natural resources	Cabin	Windows	720521	19.5
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	250300	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	251010	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	260111	234.3
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	260600	50.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	261000	2.8
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	261710	0.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	280200	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	280300	0.9
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	281610	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	281700	0.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	281990	0.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	282110	0.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	282300	0.1
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	283090	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	283327	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	340420	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	381190	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	390940	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	391110	0.0
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	400110	0.9
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	400219	0.5
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	520512	0.0

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Drivetrain	Automatic gear voith diwa 854.6	720521	0.5
Natural resources	Drivetrain	Frontal axle (zf rl 75)	250300	0.4
Natural resources	Drivetrain	Frontal axle (zf rl 75)	251010	0.4
Natural resources	Drivetrain	Frontal axle (zf rl 75)	260111	439.1
Natural resources	Drivetrain	Frontal axle (zf rl 75)	261000	3.6
Natural resources	Drivetrain	Frontal axle (zf rl 75)	261710	1.0
Natural resources	Drivetrain	Frontal axle (zf rl 75)	280200	0.4
Natural resources	Drivetrain	Frontal axle (zf rl 75)	280300	17.7
Natural resources	Drivetrain	Frontal axle (zf rl 75)	281610	0.7
Natural resources	Drivetrain	Frontal axle (zf rl 75)	281700	1.0
Natural resources	Drivetrain	Frontal axle (zf rl 75)	281990	1.0
Natural resources	Drivetrain	Frontal axle (zf rl 75)	282110	1.0
Natural resources	Drivetrain	Frontal axle (zf rl 75)	282300	1.5
Natural resources	Drivetrain	Frontal axle (zf rl 75)	283090	0.8
Natural resources	Drivetrain	Frontal axle (zf rl 75)	283327	0.8
Natural resources	Drivetrain	Frontal axle (zf rl 75)	340420	0.2
Natural resources	Drivetrain	Frontal axle (zf rl 75)	381190	0.4
Natural resources	Drivetrain	Frontal axle (zf rl 75)	390940	0.2
Natural resources	Drivetrain	Frontal axle (zf rl 75)	391110	0.4
Natural resources	Drivetrain	Frontal axle (zf rl 75)	400110	17.1
Natural resources	Drivetrain	Frontal axle (zf rl 75)	400219	8.9
Natural resources	Drivetrain	Frontal axle (zf rl 75)	520512	0.2
Natural resources	Drivetrain	Frontal axle (zf rl 75)	720521	9.2
Natural resources	Drivetrain	Middle axle (zf av 133)	250300	0.2
Natural resources	Drivetrain	Middle axle (zf av 133)	251010	0.2
Natural resources	Drivetrain	Middle axle (zf av 133)	260111	818.8
Natural resources	Drivetrain	Middle axle (zf av 133)	260600	97.3
Natural resources	Drivetrain	Middle axle (zf av 133)	261000	8.3
Natural resources	Drivetrain	Middle axle (zf av 133)	261710	0.5
Natural resources	Drivetrain	Middle axle (zf av 133)	280200	0.2
Natural resources	Drivetrain	Middle axle (zf av 133)	280300	8.2
Natural resources	Drivetrain	Middle axle (zf av 133)	281610	0.3
Natural resources	Drivetrain	Middle axle (zf av 133)	281700	0.5
Natural resources	Drivetrain	Middle axle (zf av 133)	281990	0.5
Natural resources	Drivetrain	Middle axle (zf av 133)	282110	0.4
Natural resources	Drivetrain	Middle axle (zf av 133)	282300	0.7
Natural resources	Drivetrain	Middle axle (zf av 133)	283090	0.4
Natural resources	Drivetrain	Middle axle (zf av 133)	283327	0.4
Natural resources	Drivetrain	Middle axle (zf av 133)	340420	0.1
Natural resources	Drivetrain	Middle axle (zf av 133)	381190	0.2
Natural resources	Drivetrain	Middle axle (zf av 133)	390940	0.1
Natural resources	Drivetrain	Middle axle (zf av 133)	391110	0.2
Natural resources	Drivetrain	Middle axle (zf av 133)	400110	7.9
Natural resources	Drivetrain	Middle axle (zf av 133)	400219	4.1
Natural resources	Drivetrain	Middle axle (zf av 133)	520512	0.1
Natural resources	Drivetrain	Middle axle (zf av 133)	720521	4.2
Natural resources	Drivetrain	Pressure air system	250300	0.0
Natural resources	Drivetrain	Pressure air system	251010	0.0
Natural resources	Drivetrain	Pressure air system	260111	33.9
Natural resources	Drivetrain	Pressure air system	261000	0.1
Natural resources	Drivetrain	Pressure air system	261710	0.0
Natural resources	Drivetrain	Pressure air system	280200	0.0

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Drivetrain	Pressure air system	280300	0.1
Natural resources	Drivetrain	Pressure air system	281610	0.0
Natural resources	Drivetrain	Pressure air system	281700	0.0
Natural resources	Drivetrain	Pressure air system	281990	0.0
Natural resources	Drivetrain	Pressure air system	282110	0.0
Natural resources	Drivetrain	Pressure air system	282300	0.0
Natural resources	Drivetrain	Pressure air system	283090	0.0
Natural resources	Drivetrain	Pressure air system	283327	0.0
Natural resources	Drivetrain	Pressure air system	340420	0.0
Natural resources	Drivetrain	Pressure air system	381190	0.0
Natural resources	Drivetrain	Pressure air system	390940	0.0
Natural resources	Drivetrain	Pressure air system	391110	0.0
Natural resources	Drivetrain	Pressure air system	400110	0.1
Natural resources	Drivetrain	Pressure air system	400219	0.1
Natural resources	Drivetrain	Pressure air system	520512	0.0
Natural resources	Drivetrain	Pressure air system	720521	0.1
Natural resources	Drivetrain	Steering system	250300	0.0
Natural resources	Drivetrain	Steering system	251010	0.0
Natural resources	Drivetrain	Steering system	260111	56.0
Natural resources	Drivetrain	Steering system	260600	5.3
Natural resources	Drivetrain	Steering system	261000	0.3
Natural resources	Drivetrain	Steering system	261710	0.0
Natural resources	Drivetrain	Steering system	280200	0.0
Natural resources	Drivetrain	Steering system	280300	0.7
Natural resources	Drivetrain	Steering system	281610	0.0
Natural resources	Drivetrain	Steering system	281700	0.0
Natural resources	Drivetrain	Steering system	281990	0.0
Natural resources	Drivetrain	Steering system	282110	0.0
Natural resources	Drivetrain	Steering system	282300	0.1
Natural resources	Drivetrain	Steering system	283090	0.0
Natural resources	Drivetrain	Steering system	283327	0.0
Natural resources	Drivetrain	Steering system	340420	0.0
Natural resources	Drivetrain	Steering system	381190	0.0
Natural resources	Drivetrain	Steering system	390410	1.3
Natural resources	Drivetrain	Steering system	390940	0.0
Natural resources	Drivetrain	Steering system	391110	0.0
Natural resources	Drivetrain	Steering system	400110	0.7
Natural resources	Drivetrain	Steering system	400219	0.4
Natural resources	Drivetrain	Steering system	520512	0.0
Natural resources	Drivetrain	Steering system	720521	0.4
Natural resources	Drivetrain	Wheel parts	260111	50.0
Natural resources	Drivetrain	Wheels	250300	1.4
Natural resources	Drivetrain	Wheels	251010	1.5
Natural resources	Drivetrain	Wheels	260111	92.2
Natural resources	Drivetrain	Wheels	261000	0.6
Natural resources	Drivetrain	Wheels	261710	3.7
Natural resources	Drivetrain	Wheels	280200	1.4
Natural resources	Drivetrain	Wheels	280300	65.3
Natural resources	Drivetrain	Wheels	281610	2.5
Natural resources	Drivetrain	Wheels	281700	3.9
Natural resources	Drivetrain	Wheels	281990	3.6
Natural resources	Drivetrain	Wheels	282110	3.6

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Drivetrain	Wheels	282300	5.6
Natural resources	Drivetrain	Wheels	283090	3.1
Natural resources	Drivetrain	Wheels	283327	3.1
Natural resources	Drivetrain	Wheels	340420	0.6
Natural resources	Drivetrain	Wheels	381190	1.4
Natural resources	Drivetrain	Wheels	390940	0.9
Natural resources	Drivetrain	Wheels	391110	1.5
Natural resources	Drivetrain	Wheels	400110	62.9
Natural resources	Drivetrain	Wheels	400219	32.6
Natural resources	Drivetrain	Wheels	520512	0.7
Natural resources	Drivetrain	Wheels	720521	33.8
Natural resources	Electronics	Human control devices: other parts	260111	14.9
Natural resources	Electronics	Human control devices: other parts	390210	5.0
Natural resources	Electronics	Human control devices: other parts	390410	9.9
Natural resources	Electronics	Internal control devices: other parts	260111	18.9
Natural resources	Electronics	Other electronics: air conditioning	250300	0.1
Natural resources	Electronics	Other electronics: air conditioning	251010	0.1
Natural resources	Electronics	Other electronics: air conditioning	260111	56.8
Natural resources	Electronics	Other electronics: air conditioning	260600	10.1
Natural resources	Electronics	Other electronics: air conditioning	261590	0.2
Natural resources	Electronics	Other electronics: air conditioning	261710	0.3
Natural resources	Electronics	Other electronics: air conditioning	280200	0.1
Natural resources	Electronics	Other electronics: air conditioning	280300	5.2
Natural resources	Electronics	Other electronics: air conditioning	280450	0.3
Natural resources	Electronics	Other electronics: air conditioning	280530	8.7
Natural resources	Electronics	Other electronics: air conditioning	281610	0.2
Natural resources	Electronics	Other electronics: air conditioning	281700	0.3
Natural resources	Electronics	Other electronics: air conditioning	281990	0.3
Natural resources	Electronics	Other electronics: air conditioning	282110	0.3
Natural resources	Electronics	Other electronics: air conditioning	282300	0.4
Natural resources	Electronics	Other electronics: air conditioning	283090	0.2
Natural resources	Electronics	Other electronics: air conditioning	283327	0.2
Natural resources	Electronics	Other electronics: air conditioning	340420	0.1
Natural resources	Electronics	Other electronics: air conditioning	381190	0.1
Natural resources	Electronics	Other electronics: air conditioning	390940	0.1
Natural resources	Electronics	Other electronics: air conditioning	391110	0.1
Natural resources	Electronics	Other electronics: air conditioning	400110	5.0
Natural resources	Electronics	Other electronics: air conditioning	400219	2.6
Natural resources	Electronics	Other electronics: air conditioning	520512	0.1
Natural resources	Electronics	Other electronics: air conditioning	720521	2.7
Natural resources	Electronics	Other electronics: cable harness	250300	0.1
Natural resources	Electronics	Other electronics: cable harness	251010	0.1
Natural resources	Electronics	Other electronics: cable harness	260300	460.0
Natural resources	Electronics	Other electronics: cable harness	261710	0.3
Natural resources	Electronics	Other electronics: cable harness	280200	0.1
Natural resources	Electronics	Other electronics: cable harness	280300	5.5
Natural resources	Electronics	Other electronics: cable harness	281610	0.2
Natural resources	Electronics	Other electronics: cable harness	281700	0.3
Natural resources	Electronics	Other electronics: cable harness	281990	0.3
Natural resources	Electronics	Other electronics: cable harness	282110	0.3
Natural resources	Electronics	Other electronics: cable harness	282300	0.5
Natural resources	Electronics	Other electronics: cable harness	283090	0.3

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Electronics	Other electronics: cable harness	283327	0.3
Natural resources	Electronics	Other electronics: cable harness	340420	0.1
Natural resources	Electronics	Other electronics: cable harness	381190	0.1
Natural resources	Electronics	Other electronics: cable harness	390940	0.1
Natural resources	Electronics	Other electronics: cable harness	391110	0.1
Natural resources	Electronics	Other electronics: cable harness	400110	5.3
Natural resources	Electronics	Other electronics: cable harness	400219	2.8
Natural resources	Electronics	Other electronics: cable harness	520512	0.1
Natural resources	Electronics	Other electronics: cable harness	720521	2.9
Natural resources	Electronics	Transformers: other parts	260600	12.9
Natural resources	Electronics	Transformers: other parts	390210	2.6
Natural resources	Engine	Catalysts	260111	161.3
Natural resources	Engine	Engine block om 936	260111	266.5
Natural resources	Engine	Engine block om 937	260111	136.5
Natural resources	Engine	Engine block om 938	260111	58.5
Natural resources	Engine	Engine block om 939	250300	0.1
Natural resources	Engine	Engine block om 939	251010	0.1
Natural resources	Engine	Engine block om 939	260111	19.5
Natural resources	Engine	Engine block om 939	260300	6.5
Natural resources	Engine	Engine block om 939	260600	32.5
Natural resources	Engine	Engine block om 939	261710	0.3
Natural resources	Engine	Engine block om 939	280200	0.1
Natural resources	Engine	Engine block om 939	280300	5.5
Natural resources	Engine	Engine block om 939	281610	0.2
Natural resources	Engine	Engine block om 939	281700	0.3
Natural resources	Engine	Engine block om 939	281990	0.3
Natural resources	Engine	Engine block om 939	282110	0.3
Natural resources	Engine	Engine block om 939	282300	0.5
Natural resources	Engine	Engine block om 939	283090	0.3
Natural resources	Engine	Engine block om 939	283327	0.3
Natural resources	Engine	Engine block om 939	340420	0.1
Natural resources	Engine	Engine block om 939	381190	0.1
Natural resources	Engine	Engine block om 939	390940	0.1
Natural resources	Engine	Engine block om 939	391110	0.1
Natural resources	Engine	Engine block om 939	400110	5.3
Natural resources	Engine	Engine block om 939	400219	2.7
Natural resources	Engine	Engine block om 939	520512	0.1
Natural resources	Engine	Engine block om 939	720521	2.8
Natural resources	Engine	Other engine parts	260600	150.0
Natural resources	Engine	Silencers	260111	161.3
Natural resources	Fuel tank	Diesel tank	260111	62.1
Natural resources	Fuel tank	Other parts	250300	0.0
Natural resources	Fuel tank	Other parts	251010	0.0
Natural resources	Fuel tank	Other parts	260111	39.2
Natural resources	Fuel tank	Other parts	261710	0.1
Natural resources	Fuel tank	Other parts	280200	0.0
Natural resources	Fuel tank	Other parts	280300	1.9
Natural resources	Fuel tank	Other parts	281610	0.1
Natural resources	Fuel tank	Other parts	281700	0.1
Natural resources	Fuel tank	Other parts	281990	0.1
Natural resources	Fuel tank	Other parts	282110	0.1
Natural resources	Fuel tank	Other parts	282300	0.2

Vector	Cluster	Sub-cluster	Hs 2017	Weight
Natural resources	Fuel tank	Other parts	283090	0.1
Natural resources	Fuel tank	Other parts	283327	0.1
Natural resources	Fuel tank	Other parts	340420	0.0
Natural resources	Fuel tank	Other parts	381190	0.0
Natural resources	Fuel tank	Other parts	390940	0.0
Natural resources	Fuel tank	Other parts	391110	0.0
Natural resources	Fuel tank	Other parts	400110	1.8
Natural resources	Fuel tank	Other parts	400219	0.9
Natural resources	Fuel tank	Other parts	520512	0.0
Natural resources	Fuel tank	Other parts	720521	1.0

Source: Own elaboration.

This document, which was prepared as part of a collaborative project between the Economic Commission for Latin America and the Caribbean (ECLAC) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), provides a methodology for disaggregating electric and conventional buses into their parts, in order to analyse international trade flows in electromobility components. The vectors developed are based on the 2017 version of the Harmonized Commodity Description and Coding System and include all parts needed to build electric or conventional (diesel) buses. The vectors capture global trade related to parts on three levels: raw materials, semi-manufactured parts and manufactured parts. Disaggregation into different parts also enables reconstruction of global value chains for electric buses and identification of the key suppliers of inputs at all three product levels. The methodology can also be employed to determine prospects for productive integration in the manufacturing of buses in Latin America and the Caribbean.

ECLAC

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