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ANALYSIS OF THE APPLICATION OF CIRCULAR ECONOMY PRINCIPLES IN THE SECTOR OF THE COMMERCIAL VEHICLES

APPENDIX

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Appendix

2 Circular Economy application: the automotive sector

2.2 CE measurement for the automotive sector

2.2.3 Environment performance indicators

The method

1. **CNH Industrial**

In the Sustainability Report 2020 is specified that the environmental performances are referred to 56 plants, that represent the 89% of all company's plants and the 99% of revenues from sales of products manufactured at CNH Industrial plants.

Table 1. CNH Industrial air emissions (CNH Industrial,2020)

	Air emissions	
VOC	Plants (number)	56
	Average VOC emissions (g/m^2)	42.5
	Total VOC emissions (Kg)	1311182
NOx, SOx and dust	Plants (number)	57
	NOx (tons)	306.4
	SOx (tons)	38.3
	Dust (tons)	3.2

Table 2. CNH Industrial water management (CNH Industrial,2020)

	Water management	
	Plants (number)	56
Quality of water discharge	BOD (mg/L)	29.5
	COD (mg/L)	130.1
	TSS (mg/L)	72.4
	Total water discharge	2871
Withdrawal	(thousand of m^3)	4152
Consumption	(thousand of m^3)	1281
Recycling	Total water requirement (thousand of m^3)	8256
	of which covered by recycling (thousand of m^3)	4104
	of which water withdrawal (thousand of m^3)	4152
	Recycling index (%)	50

Table 3. CNH Industrial water management (CNH Industrial,2020)

	Waste management	
	Plants (number)	56
Generated	Non hazardous (tons)	159260
	Hazardous (tons)	14580
	Total waste generated	173840
	of which packaging	54143
	Specigic waste generated (Kg/hours of production)	0.26
Disposed	Treatment (tons)	8340
	of which incineration (tons)	198
	Sent to landfill (tons)	2278
	Total waste disposed (tons)	10618
	of which non-hazardous (tons)	8817
Recovered	Waste recovered (excluding waste to energy) (tons)	154985
	Waste to energy conversion (tons)	8237
	Total waste recovered (tons)	163222
	of which hazardous (tons)	12149
	Waste recovered (%)	93.9
	Waste sent to landfill (%)	1.3

Table 4. CNH Industrial direct energy consumption (CNH Industrial,2020)

	Energy consumption	
	Direct energy consumption	
	Plants (number)	57
Non renewable sources	Natural gas (GJ)	2422117
	Coal (GJ)	0
	Diesel (GJ)	269168
	LPG (GJ)	34908
	fuel oil) (GJ)	42
	Total (GJ)	2726292
Renewable sources	Biomass (GJ)	2139
	Solar thermal (GJ)	62
	Total (GJ)	2201

Table 5. CNH Industrial indirect energy consumption (CNH Industrial,2020)

	Energy consumption	
	Indirect energy consumption	
Non renewable resources	Electricity (GJ)	575963
	Thermal energy (GJ)	589867
	Other energy sources (GJ)	16643
	Total (GJ)	1182473
Renewable resources	Electricity (GJ)	1477298
	Thermal energy (GJ)	21422
	Other energy sources (GJ)	181376
	Total (GJ)	1680096

Table 6. CNH Industrial total energy consumption (CNH Industrial,2020)

	Energy consumption	
Total	From non renewable sources (GJ)	3908765
	From renewable sources (GJ)	1682297
	Total energy consumption (GJ)	5591062
	Electricity consumption from renewable sources (%)	72
	Energy consumption per production unit (GJ/hours of production)	0.09415

Table 7. CNH Industrial CO_2 emissions (CNH Industrial,2020)

CO2 emissions	
Plants (number)	57
Direct emissions (scope 1) (tons)	151441
Indirect emissions (scope 2) – market-based (tons)	132527
Indirect emissions (scope 2) – location-based (tons)	235757
Total CO2 emissions (tons)	283968
Direct and indirect CO2 emissions per production unit (tons of CO2/hours of production)	0.00467

2. Daimler AG

Table 8. Daimler air emissions (Daimler, 2020b)

	Air emissions	
Total	VOC (tons)	6483
	SO_2 (tons)	40
	CO (tons)	1502
	NOx (tons)	1349
	Dust (tons)	270
Specific solvent emissions: VOC emissions (Kg/vehicle)	Cars	1.77
	Trucks	8.24
	Vans	3.37
	Buses	14.88

Table 9. Daimler water management (Daimler, 2020b)

	Water management	
Waste water	Direct discharge	1040
	Indirect discharge	7631
	Total (1000 m^3)	8671
Quality of direct water discharge	COD (Kg)	21327
	Zn (Kg)	57
	Ni (Kg)	37
	Total Chrome (Kg)	12
Consumption	Total (1000 m^3)	11778
Specific water consumption (m^3/vehicle)	Cars	4.65
	Trucks	10.44
	Vans	4.15
	Buses	22.65

Table 10. . Daimler waste management (Daimler, 2020b)

	Waste management	
Disposed	Non hazardous waste for disposal	13
	Hazardous waste for disposal (1000 tons)	11
Recycled	Non-hazardous waste for	251
	tons)	685
	Hazardous waste for recycling (1000 t)	65
	Total (1000 tons)	1025
	Recycled (%)	98

Table 11. Daimler waste management- specific waste (Daimler, 2020b)

	Waste management - Specific waste (Kg/vehicle)					
	Non hazardous waste for disposal	**Non-hazardous waste for recovery**	**Scrap metal for recycling**	**Hazardous waste for disposal**	**Hazardous waste for recovery**	**Total**
Cars	6	87.2	377.2	4.9	35	510.3
Trucks	7.3	313.3	468.1	3.6	36.1	828.4
Vans	5.3	33.6	33.8	10.7	12.2	95.6
Buses	29.1	433.8	606.5	10.9	166.7	1247

Table 12. Daimler energy consumption (Daimler, 2020b)

	Energy consumption	
Consumption	Electricity (GWh)	3587
	Natural gas (GWh)	4662
	Distict heating (GWh)	732
	Heating oil (GWh)	67
	LPG (GWh)	56
	Coke (GWh)	21
	Fuels (GWh)	587
	Total (GWh)	9712
Specific energy consumption (MWh/vehicle)	Cars	3.72
	Trucks	7.28
	Vans	2.77
	Buses	12.67

Table 13. Daimler CO_2 emissions (Daimler, 2020b)

	CO_2 emissions				
	CO2 direct (Scope 1)	CO2 indirect (Scope 2) - market-based (Scope 2)	CO2 indirect (Scope 2) - location-based	Total - market-based	Total - location-based
From energy consumption (1000 tons)	1027	1035	1492	2062	2519
Cars (Kg/vehicle)	326	426		752	
Trucks (Kg/vehicle)	742	954		1696	
Vans (Kg/vehicle)	333	147		480	
Buses (Kg/vehicle)	1471	1245		2716	

3. Volvo Group

Table 14. Volvo group air emissions (Volvo Group, 2020)

Air emissions	
NOx (tons)	204
SOx (tons)	5.6
Solvents (VOC) (tons)	1342

Table 15. Volvo group water management (Volvo Group, 2020)

Water management	
Total water consumption (Mega-liters)	5218
Relative water consumption (Cubic meters/SEK M net sales)	16

Table 16. Volvo group water management (Volvo Group, 2020)

	Waste management	
Recycled	Recycling,metal scrap from operations (metric tons)	84880
	Recycling, other metal scrap (metric tons)	13322
	Recycling, non-metal (metric tons)	141620
	% recycling of total	86
Recovered	Composting (metric tons)	1865
	Incineration with energy recovery (metric tons)	18387
	% recycled, composted or energy recovery	93
Disposed	Incineration without energy recovery (metric tons)	1644
	Treatment by professional waste contractor (tons)	9945
	Landfill (metric tons)	6076
	Landfill, only inert material (metric tons)	694
Total	Total residuals (metric tons)	278433
	whereof hazardous wastes (metric tons)	51806

Table 17. Volvo group energy consumption within and outside the organization (Volvo Group, 2020)

Energy consumption	
Energy within and outside the organization	
Natural gas (GWh)	459
Diesel (GWh)	168
Other (GWh)	144
Electricity (GWh)	873
District heating (GWh)	172
Total (GWh)	1816

Table 18. Volvo group energy consumption. Energy intensity and share from renewable resources (Volvo Group, 2020)

Energy consumption	
Energy intensity and share from renewable resources	
Net sales, SEK M	326
Energy / net sales (MWh /SEK M)	5.6
Share of energy from renewable sources, %	52

Table 19. Volvo group CO_2 emissions (Volvo Group, 2020)

CO_2 emissions	
CO2eq emissions scope 1 (metric tons*1000)	173
CO2eq emissions scope 2- market based (metric tons*1000)	97
Total CO2eq emissions, market based (metric tons*1000)	270

Results

Table 20. Environmental performances KPIs -results

Aspects	Sub-aspects	CNH Industrial	Daimler	Volvo group
Air emissions	VOC (Kg/T&B sold in 2020)	9.242	17.133	7.755
	Nox (Kg/T&B sold in 2020)	2.160	3.565	1.179
	Sox (Kg/T&B sold in 2020)	0.270	0.106	0.032
Water management	Total water consumption (m^3/T&B sold in 2020)	9.029	31.126	30.152
Waste management	Total waste generated (Kg/T&B sold in 2020)	1225.313	2708.774	1608.919
	Hazardous waste (Kg/T&B sold in 2020)	102.767	200.846	299.360
	Waste disposed (Kg/T&B sold in 2020)	74.841	63.425	106.087
	Waste recovered/recycled (Kg/T&B sold in 2020)	1139.541	1333.997	1496.294
Energy management	Energy consumption (MWh/T&B sold in 2020)	10.947	25.666	10.494
CO2 emissions	Direct emissions-scope 1 (tons/ T&B sold in 2020)	1.067	2.714	1.000
	Indirect emissions-scope 2 market based (tons/T&B sold in 2020)	0.934	2.735	0.561

2.2.4 Actions

1.Actions (company level)

Table 21. Actions implemented by the three companies to reach resource conservation (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Resource conservation		
Company	**Actions**	**Example of application**
CNH Industrial	Optimization of waste management	Replacement of wooden and/or cardboard shipping pallets and disposable packaging with reusable materials and adoption of reusable metal containers.
	Optimization of water withdrawal and discharge management system	Water recirculation within individual manufacturing processes and its reuse in multiple processes
	Promotion of renewable energy generation and use	Installation of high-efficiency and intelligent lighting systems (LED) inside and outside plants
	Monitoring of raw materials consumption	Monitoring of paper, cardboard, and wood consumption at its offices and in packaging at its plants, so as to assess impact and devise improvement measures, if needed.
Daimler	Waste recycling and waste optimization	Replacement of wooden packaging of engines and transmissions with multiple-use steel load carriers
	Reduction of water consumption by closing water cycles	Treatment of process water and using closed-loop cooling systems instead of open ones
	Reduction of energy consumption	Optimization of the switching times of lighting and ventilation systems at locations and replacement of conventional light sources with LEDs.
	Use less volumes of raw materials	Use of secondary materials and renewable resources for vehicles
Volvo group	Waste recycling and reduction of waste to landifll	Reclassification of the foundry sand from the operation Skövde, Sweden. This is from 2020 classified as non-metal recycling.
	Water consumption	Water consumption has also been reduced in absolute terms, although not to the same extent as other environmental indicators in relation to net sales.
	Reduction of energy consumption	In 2020, the Volvo Bus plant in Borås achieved its 100% renewable energy status in the production phase.
	Use less volumes of raw materials	A significant share of iron and aluminum are already from recycled material and they collaborate with suppliers to increase the use of recycled plastics.

Table 22. Actions implemented by the three companies to reduce the air emissions (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Air emissions reduction			
Actions	**CNH Industrial**	**Daimler**	**Volvo**
Reduction of GHG and CO2 emissions	Application of best available techniques for the reduction of volatile organic compounds (VOCs) in paint processes	Reduction of GHG emissions generated by the plant vehicle production and energy supply (e.g. purchasing green electricity)	Reduction of GHG emissions through the control of the production and operation phases
	Identification of measures and technologies to reduce energy consumption and CO2 emissions per production unit	Numerous energy efficiency and CO2 reduction projects have helped to reduce CO2 emissions	Logistic area: increasing of the use of CO2 efficient transport modes and reduction e unnecessary transports by e.g. increasing fill rates and more efficient routing
	Implementation of initiatives to reduce CO2 emissions and minimize the overall impact of logistics (e.g. intermodal solutions for transport)		
Reduction of ozone depleting substances	Removal of ozone depleting substances from all of its plants from 2016	Emission of very small amounts of ozone-depleting substances	

Table 23. Actions implemented by the three companies to protect biodiversity(CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Protecting biodiversity			
Actions	**CNH Industrial**	**Daimler**	**Volvo**
Index to evaluate biodiversity	Biodiversity Value Index (BVI) methodology to identify some of manufacturing sites adjacent to protected areas of particular environmental interests, assessing the level of biodiversity in such areas and identifying possible improvement measures for existing ecosystems.	Many of the plants in Germany use the biodiversity index (BIX) that the Company have developed in-house to assess their plant grounds and evaluate their biodiversity enhancement	No information provided
	Biodiversity Risk Evaluation (BRE) methodology that focuses only on the activities and impact of plants, and on the risks they might pose to biodiversity and natural resources, regardless of the plants' contribution to the overall activities and impacts reported in the surrounding areas.		
Initiatives	Approximately 20 employees at the Burlington plant (USA) participated in the Citizen Science program organized by the non-profit Monarch Watch at a local wildlife reserve, during which volunteers assisted scientists in tagging 15 individual monarch butterflies to study their numbers and migration patterns. In addition, to create a habitat for the Indiana bat (an endangered species), the facility performed soil analysis, treated invasive teasel weeds, mowed the grass areas, and then planted 25 shagbark hickory trees in its vicinity.	Creation of semi-natural habitats at plants (e.g. insect hotels and nesting aids for local birds,creation of greening for roofs, facades, and dry stream beds)	No information provided
		Redesigning semi-natural green areas at many of locations in Germany (e.g. marginal strips of land and previously little-used plots of ground have also been renatured and provided with species-appropriate nesting aids and birdhouses)	

Table 24. Actions implemented by the three companies to improve and integrate digitalization (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Digitalization		
Company	**Actions**	**Example of application**
CNH Industrial	Creation of tools that enable CNH Industrial's brands to offer customers ever-more efficient, sustainable, and smart products to support their businesses.	CNH Industrial Service Delivery Platform – the Company's own 'cloud' – that provides access to specific services and stores operational data for all connected machines: for example, for commercial vehicles, IVECO customers have access to innovative algorithms that cut fuel consumption by up to 15%, and that also reduce carbon footprints and total cost of ownership
Daimler	Setting of new benchmarks for sustainable production through 360-degree connectivity of worldwide production network	At Factory 56 alone the Company is saving about ten tons of paper annually compared to a factory that is not fully digitalized.
		In production, greater connectivity makes processes more efficient while digital product planning helps conserve resources
Volvo Group	Technologies to Increase productivity	Launching of new digital service, called "Efficient Load Out" that enables the connection of trucks and excavators, which increase efficiency and reduces transport emissions. When utilizing the system, the excavator operators and truck drivers start by logging in, and then the system gives the excavator operator a notification when there is a truck available for loading nearby

2. Actions (products level)

Table 25. Sustainable design criteria implemented on products by CNH Industrial (CNH industrial, 2020)

Sustainable design criteria	
Criteria	**CNH Industrial**
Environmental compatibility	LCA evaluation on products (e.g. LCA on FPT Industrial's Cursor 13 diesel engine)
Recyclability/recoverability	Primarily use of recoverable metals (aluminium, cast iron), thermoplastics, paints with low solvent content. For example, the recoverability rate is currently 95% of the total weight for the F1 engine and over 95% for the IVECO New Daily.
Elimination of critical substances	CNH Industrial is working to provide engineering standards for its design engineers and suppliers to ensure real-time information on prohibited substances and regulations that address hazardous substances potentially harmful to human health and the environment. Regarding critical materials as defined by the US National Research Council, CNH Industrial has started to analyze where cobalt, tungsten, and tantalum are found in its products and in its supply chain.
Environmental impact reduction and improved efficiency during use phase	Implementation of alternative systems (electric/hybrid) for Commercial & Specialty Vehicles (e.g. electric buses), Agriculture and Construction (e.g. CASE 580 EV) segments.
	Implementation of alternative fuels (e.g. biofuels and hydrogen). CNH Industrial offers a wide range of vehicles that use biomethane (natural gas) among its brands, such as the complete light-to-heavy range offered by NG market leader IVECO (e.g. the Crossway Natural Power, Urbanway city bus, Crealis rapid transit bus and Daily minibus).

Table 26. Sustainable design criteria implemented on products by Daimler AG (Daimler, 2020b)

Sustainable design criteria	
Criteria	**Daimler**
Environmental compatibility	LCA evaluation on products (e.g. LCA of A 250 plug-in hybrid)
Recyclability/recoverability	Use of secondary and renewable raw materials (e.g. seat cover textiles of e all-electric Mercedes-Benz EQC are made of 100 percent recycled PET bottles).For exmpale, in total, 95% of the A 250 e can be recovered. Many Mercedes-Benz cars are already almost completely recyclable today
Elimination of critical substances	Several types of raw materials that are needed for the production of electric vehicles are associated with certain risks. In order to better assess how critical the use of a raw material is or can become, Daimler's car division teamed up with partners from industry and science in 2015 to conduct the ESSENZ research project. The use of the ESSENZ method is based on the LCA methodology, which makes it possible to and not only examines the geological availability of a raw material but also takes socioeconomic factors and social and societal risks into account.
Environmental impact reduction and improved efficiency during use phase	Implementation of alternative systems (electric/hybrid) for Passenger Vehicles and Commercia Vehicles. In 2020 more than tripled the sales of plug-in hybrids and all-electric vehicles in thecar and van segments.
	Implementation of alternative fuels (e.g. biofuels and hydrogen) for Passenger and Commercial vehicles. Daimler produces cars, trucks, bus and vans powered by natural gas

Table 27. Sustainable design criteria implemented on products by Volvo group (Volvo Group, 2020)

Sustainable design criteria	
Criteria	**Volvo group**
Environmental compatibility	LCA evaluation on products (e.g. LCA on Volvo FE Electric, Volvo FE diesel, Volvo FH LNG, Volvo FH diesel)
Recyclability/recoverability	Use of materials that can increase the recycling rates of components and complete vehciles. For example, a typical truck from Volvo can be recycled at around 85% and an excavator to around 95–99% by weight.
Elimination of critical substances	In collaboration with partners, the Volvo Group proactively evaluates alternatives in the design and supply processes to minimize and eliminate use of scarce materials and substances of concern. Scarce materials may lead to a variety of difficulties such as high prices and increased risk for corrupt behavior or adverse human rights impacts when sourced from high risk areas. Volvo Group is implementing a dedicated supplier Sustainable Minerals Program, currently focusing on tin, tungsten, tantalum, gold and cobalt, to support sourcing of materials in a responsible way.
Environmental impact reduction and improved efficiency during use phase	Implementation of alternative systems (electric/hybrid) for Commercial vehicles (e.g. heavy-duty trucks, buses). In 2020, Volvo Buses sold 306 electrified buses.
	Implementation of alternative fuels (e.g. biofuels and hydrogen) for Commercial vehicles.Volvo group produces trucks and buses powered by natural gas (e.g. Volvo FH LNG)

Table 28. Technologies adopted to improve environmental performance of vehicles (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Improved environmental performances: technologies (vehicles)		
Company	**Emissions reduction**	**Fuel consumption reduction**
CNH Industrial	Selective cathalytic reduction (SCR) through HI-eSCR system	Implementation of hybrid systems (e.g. bus IVECO Urbanway full hybrid with a reduction of fuel by 33% than a conventional diesel)
	Diesel particulate filter (DPF)	FPT Tector 7 engine
	Biofuels: biodiesels (hydrogenated vegetable oils), biomethane (natural gas), dimethyl ether	
	Implementation of electric drive systems (zero emissions during use phase) and hybrid systems (e.g. Urbanway full hyrbrid reaches a CO2 reduction by 33 % perKm and Nox by 40% per Km than a conventional diesel)	
	Diesel Euro VI engine	
Daimler	Selective cathalytic reduction (SCR)	Implementation of hybrid systems (e.g. Citaro hybrid bus with a fuel saving by 8.5%)
	Diesel particulate filter (DPF)	
	Biofuels: biodiesels (hydrogenated vegetable oils), biomethane (natural gas)	
	Diesel Euro VI engine	
	Heat pump that uses the natural and environmentally friendly refrigerant R744 (CO2) for electric buses insted of using synthetic refrigerant	
	Implementation of electric drive systems (zero emissions during use phase) and hybrid systems	
Volvo group	Selective cathalytic reduction (SCR)	By combining the highly efficient Volvo 13-liter Turbo Compound engine and fuel-saving features, such as the map-based I-See, Volvo FH with I-Save cuts fuel costs by up to 10% in long haul operations compared with the older model without I-Save
	Diesel particulate filter (DPF)	Implementation of hybrid systems (e.g. Volvo trucks s with a fuel reduction by 30%)
	Biofuels: liquified natural gas (LNG), liquified biogas, hydrogenated	
	Diesel Euro VI engine	
	Implementation of electric drive systems (zero emissions during use phase) and hybrid systems	

Table 29. Sustainable end of life management adopted by the three companies (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Sustainable end of life management		
Company	**Remanufacturing**	**Recovery and recycling**
CNH Industrial	Remanufacturing of the cores (worn components) that will have the same performances of the respective new product, ensuring also reliability and a competitive price. Products, such as engines (blocks or components), transmissions, cylinder heads, turbines, starter motors, alternators, fuel injection systems, control units, flywheels, clutches, compressors, and hydraulic components, are remanufactured for Case IH, CASE Construction Equipment, New Holland Agriculture, New Holland Construction, and IVECO brands. Remanufcturing allows to avoid the extraction of raw material for the Company by 1200 tons per year.	The commitment to reduce the environmental impact of end-of-life vehicles (ELVs) starts in the concept and design phase, through the selection of easily recyclable components and continues every step of the way, from the remanufacturing of worn components (cores), to providing customer assistance in the scrapping of products that are no longer serviceable, but whose parts are suitable for remanufacturing. The recoverability rate is currently 95% of the total weight for the F1 engine and over 95% for the IVECO New Daily.
	Spare parts' net sales from remanufactured components (2020): 8.2 %	Thanks to an agreement with Fiat Chrysler Automobiles (FCA), the end-of-life of IVECO products in Italy is handled through a network of authorized agents, duly trained to recycle metals and separate polymers into different categories.
Daimler	In remanufacturing, Mercedes-Benz reconditions used vehicle parts for subsequent reuse them. In the process, the used Mercedes-Benz genuine parts for cars, vans, and trucks are reconditioned in such a way that their functionality, safety, and quality correspond to those of a new component (e.g. remanufacturing a Type OM 906 diesel engine saves about 527 kilograms of carbon dioxide and7,248 megajoules (2,013 kWh) of energy compared to a new part).	All Mercedes-Benz car models are 85 percent recyclable in accordance with ISO 22 628. In 2020, a total of 29,923 tons of old parts and materials (such as tires, catalytic converters, rubber parts) were collected in Germany and recycled. Around 1,475 tons of coolant and 694 tons of brake fluid, as well as 9,619 tons of old tires and 2,463 tons of car glass, were recycled
		Reutilization and recycling of lithium ion batteries
Volvo group	Volvo Group's products are made to be durable, and components are made to be remanufactured. One example is gearboxes. A remanufactured gearbox can save 50%, and sometimes up to 80%, of resources used compared to a new one. The saving comes from avoiding processing and refining new materials and the associated energy, water and emissions footprint	At the end of the useful service life of components or vehicles, Volvo grupo can recover certain materials which directly become new raw material. One example is the recovery of palladium and platinum from scrapped diesel particulate filters. For trucks, they also buy back complete vehicles to dismantle and use parts in their network of service workshops. Parts that can be refurbished or remanufactured are kept and used and the rest is sent for materials recycling. A typical truck from Volvo can be recycled at around 85% and an excavator to around 95–99% by weight

2.2.5 Strategy

Table 30. Supplier strategies adopted by the three companies (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Suppliers		
CNH Industrial	**Daimler**	**Volvo group**
Supplier selection : Potential Suppliers Assessment (PSA) evaluates a company's potential to become a CNH Industrial supplier and it involves key sustainability aspects, with explicit reference to both environmental and occupational health and safety management	Environmental responsibility: when addressing environmental issues, suppliers must follow precautionary principles and take initiatives to promote greater environmental responsibility as well as the development and spread of environmentally friendly technologies.They also expect that suppliers of production materials to operate with an environmental management system that is certified according to ISO 14001, EMAS or other comparable standards	The Supplier Code of Conduct outlines the minimum requirements, which suppliers shall comply with also in the areas of responsible sourcing of raw materials and environmental performance.
Suppliers assessment. It is articulated in: sustainability self-assessment questionnaire; the questionnaires are then analyzed and used to perform a sustainability risk assessment, which allows identifying critical suppliers whose compliance with sustainability criteria needs to be addressed; sustainability audits are performed at suppliers' plants by either CNH Industrial Supplier Quality Engineers (SQEs) or independent third-party auditors.	Environmentally Friendly Production: optimum environmental protection must be guaranteed during every phase of production.Especially significant in this context are the utilization and continued development of technologies for conserving energy and water, characterized by the use of strategies for reduction of emissions, reuse and recycling of materials.They require the raw material suppliers we cooperate with to meet high environmental and social standards — in the area of cobalt mining, for example, all the way back to the mine.	The supplier screening and auditing is centrally coordinated by Volvo Group Purchasing and it is made through a risk-based approach. All Volvo Group Purchasing employees receive regular mandatory trainings on the concept of Sustainability and on the content of our Supplier Code of Conduct.
Spreading an internal culture of sustainability: initiatives targeting the employees responsible for supplier relationships have been consolidated over the years, aiming at ensuring the satisfactory awareness of sustainability and good governance among suppliers through open and ongoing dialogue.	Environmentally Friendly Products: all products manufactured along the supply chain must meet the environmental standards of their market segments. This applies to the complete product life cycle as well as to all materials used.	A supplier sustainability assessment program requires a basic evaluation of all supply chain partners through the Sustainability Self-Assessment Questionnaire. In 2020, 95% of the total Volvo Group spend was to suppliers who were self-assessed on environmental and social criteria, 92% with a recorded approved score.
The Company joined in 2015 to the Responsible Mineral Initiative (RMI) that operates a smelter validation program to certify those smelters and refiners that are conflict-free, helping companies verify the origins of minerals in their supply chains.	Daimler has been a member of the Responsible Minerals Initiative (RMI) since 2018, to prevent human rights violations and improve transparency along the entire 3TG (tin, tantalum, tungsten and gold) supply chain.	Volvo Group is a member of RMI (Responsible Minerals Initiative, a collaborative platform addressing responsible mineral sourcing issues in global supply chains).

Table 31. Partnerships (CNH industrial, 2020; Daimler, 2020b; Volvo Group 2020)

Partnerships		
CNH Industrial	**Daimler**	**Volvo group**
In New Holland Agriculture's manufacturing facility in Saskatoon (Canada) are installed more than 1,000 solar panels, thanks to a partnership between CNH Industrial and the SESa Solar Co-op. The installation is the largest solar energy project in the province of Saskatchewan. It will yield 331 kilowatts of power, about 8% of the facility's annual electricity demand, and reduce its carbon footprint by 289 tons per year.	The network of hydrogen refueling stations is also growing. In the joint venture H2 MOBILITY Deutschland, the Company has been working together with Air Liquide, Linde, OMV, Shell, and Total since 2015 to expand the hydrogen refueling station infrastructure throughout Germany. At the end of 2020 there were 88 publicly accessible hydrogen refueling stations dispensing at a pressure of 700 bar in Germany.	Volvo Buses collaborates with Stena Recycling's Battery Loop to reuse batteries for a second life storing renewable energy. After the batteries are removed from Volvo's buses, they are reused as energy storage units in buildings and charging stations for a number of years.
With the objective to increase the fuel storage capacity of tractors equipped with natural gas engines, CNH Industrial started a co-development project with Bennamann, a technology company focused on biomethane and on delivering clean energy. This partnership has led to the development of a low pressure and low temperature liquid methane (LNG) tank, with the same shape and fit as a diesel tank. The total energy capacity of the tank is nearly double that of a compressed natural gas (CNG) storage system.	The Company is cooperating with the Chinese company Contemporary Amperex Technology Co. Limited (CATL) to drive the development of current and future battery technologies. CATL is currently working to develop pioneering battery generations that should be utilized in many vehicles in the years ahead.	Volvo Group and Samsung SDI have entered into a strategic alliance to develop battery packs for Volvo Group's electric trucks. Working together with Samsung SDI, Volvo Group aims to accelerate the speed of development and strengthen the long-term capabilities and assets within electromobility, to the benefit of customers in different truck segments and markets.
CNH Industrial took a minority investment in the Monarch Tractor, the first fully electric autonomous tractor on the market, which will contribute to accelerating agriculture's transition towards autonomy and electrification.	In 2020 Daimler entered into a partnership with the bioplastics manufacturer UBQ Materials . This startup from Israel recycles household waste and uses it to produce a new material that is 100 percent recycled and 100 percent recyclable.	Volvo Group and Ovako are collaborating on fossil-free hydrogen. Sweden's largest fossil-free hydrogen facility is being built in Hofors. The technical solution will enable large-scale and cost-effective production of hydrogen for applications like fossil-free freight using fuel-cell trucks.
IVECO, FPT Industrial, and Nikola Motor Company are currently collaborating on developing the Nikola TRE semi-truck, the first battery electric vehicle (BEV) of its kind for European markets.	Re-utilization of lithium-ion batteries: a partnership agreement for the use of stationary energy storage systems for hydroelectric power plants was signed in December 2020 by Mercedes-Benz Energy GmbH, which is a subsidiary of Mercedes-Benz AG, and ANDRITZ Hydro GmbH, a subsidiary of the international technology group ANDRITZ AG.	Volvo Group and SSAB have signed a collaboration agreement on research, development, serial production and commercialization of the world's first vehicles to be made of fossil-free steel. Volvo plans already this year to start the production of concept vehicles and components from steel made by SSAB using hydrogen
Through a collaboration with Microvast, a US-based company specialized in battery power systems for electric vehicles, the brand will design and assemble high-voltage battery packs in-house for CNH Industrial vehicles and third-party customers.	Daimler signed The Climate Pledge in October 2020. By joining this initiative they reaffirmed the ambition to continue moving systematically toward emission-free mobility and sustainable vehicle production. Together with Amazon, Global Optimism, and other participating companies, they are pursuing the goal of being CO2 -neutral by 2040	
The Company collaborates with academic institutions to promote the development of new innovations. In Europe CNH Industrial collaborates with the Catholic University of Leuven, the University of Ghent, and the Flanders Make research center (Belgium), Politecnico di Torino, Università degli Studi di Bologna, Università degli Studi di Modena e Reggio Emilia, and Università degli Studi di Torino (Italy).	The Volvo Group and Daimler Truck AG have signed a binding agreement for a joint venture to develop, produce and commercialize fuel-cell systems for use in heavy-duty trucks as the primary focus, as well as other applications. The ambition of both partners is to make the new company a leading global manufacturer of fuel cells, and thus help the world take a major step towards climate-neutral and sustainable transportation by 2050.	
In December, the Volvo Group, Daimler Truck AG, IVECO, OMV and Shell committed to work together to help create the conditions for the mass-market roll-out of hydrogen trucks in Europe. As a growing number of governments and businesses align on a common vision of a net-zero emissions energy system, the H2Accelerate participants believe that hydrogen is an essential fuel for the complete decarbonization of the truck sector.		

Table 32. CNH Industrial environmental expenditure and investments (CNH Industrial, 2020)

	Expenditure and investments	
Environment expenditure and investments	Plants (number)	56
	Expenditure ($ million)	41
	emissions treatment ($ million)	29
	of which on prevention and	12
	Investments ($ million)	3.4
	Cost savings ($ million)	2.9
Improvement in energy performance	Expenditure ($ million)	149
	Investments ($million)	8.3
	Cost savings ($million)	4.8
	Energy savings (GJ)	248529
	CO2 emissions reduction (tons)	19800

Table 33. CNH Industrial Research and Developments investments (CNH Industrial, 2020)

	R&D ($ million)	Capital expenditure ($ million)
Efficient diesel engines	116.2	27.8
Decarbonization strategy (electrification & natural gas)	105.4	11.1
Digitalization	88.6	76.4
Automation and connectivity	76.5	45.5
Total	386.7	160.8

Table 34. Daimler environmental expenditure and investments (Daimler, 2020b)

Environment related costs	
Investments (€ M)-mainly Germany	109
Expenditures (€ M)-mainly Germany	466
R&D expenditures (€ M)	4158

2.2.6 Targets

Table 35. CNH Industrial. Carbon neutrality targets-products level (CNH Industrial, 2020)

Carbon neutrality-products	
Targets	**Target horizon**
Extension of Life Cycle Assessment (LCA) methodology: completion and ISO 14067 certification of LCA on Cursor 13 engine	2021
Reduction of CO2 emissions through fuel consumption optimization: up to an additional -4% in fuel consumption and CO2 emissions on STRALIS and S-WAY diesel models, depending on mission and product configuration	2021
Expansion of natural gas-powered vehicle offering, featuring biomethane, compressed natural gas (CNG), and liquefied natural gas (LNG):development of next-generation alternative fuel engines running on CNG and LNG, and compatible with biomethane, to further reduce CO2 emissions and total cost of ownership (TCO)	2022
Expansion of natural gas-powered vehicle offering, featuring biomethane, compressed natural gas (CNG), and liquefied natural gas (LNG): focus on natural gas (NG) engine technologies to achieve ultra low NOX emissions in urban applications	2022
Expansion of natural gas-powered vehicle offering, featuring biomethane, compressed natural gas (CNG), and liquefied natural gas (LNG):distribution of new alternative-fuel tractors (methane and propane) generating approx. -80% in polluting emissions and -10% in CO2 emissions compared to diesel models	2022
Development of solutions that minimize environmental impact: up to +25% vs. 2015 in field productivity by expanding data management and control systems for harvesting, tractors, and crop production: up to +25% vs. 2015 in field productivity by expanding data management and control systems for harvesting, tractors, and crop production	2022
Introduction of alternative (electric/hybrid) drivelines to reduce environmental impact and improve efficiency: implementation of electric/hybrid drivelines on tractors	2023
Introduction of alternative (electric/hybrid) drivelines to reduce environmental impact and improve efficiency: development of full electric bus range and implementation of mild hybrid solutions on diesel and compressed natural gas (CNG) vehicles	2023
Introduction of alternative (electric/hybrid) drivelines to reduce environmental impact and improve efficiency: development of next generation Electric Daily (including in-house production of e-drivelines and battery packs)	2023
Reduction of CO2 emissions through fuel consumption optimization: implementation of state-of-the-art technologies to improve efficiency of next-generation combine harvesters and tractors, significantly reducing total cost of ownership (TCO)	2024
Expansion of natural gas-powered vehicle offering, featuring biomethane, compressed natural gas (CNG), and liquefied natural gas (LNG): 25% of product portfolio available with natural gas powertrains	2024
Expansion of natural gas-powered vehicle offering, featuring biomethane, compressed natural gas (CNG), and liquefied natural gas (LNG): distribution of new alternative-fuel wheel loaders (methane) generating approx. -80% in polluting emissions and -10% in CO2 emissions compared to diesel models	2024
Introduction of alternative (electric/hybrid) drivelines to reduce environmental impact and improve efficiency: development of new full electric and fuel cell heavy range (including in-house production of e-axles)	2024
Development of automated/autonomous vehicle technologies: increase in automation level for all agricultural products, to improve machine efficiency and productivity (+20% in fuel efficiency vs. 2020)	2024
Integration of sustainability criteria into the design of new products: 100% of new products developed using sustainability/recyclability design criteria	2024
Introduction of alternative (electric/hybrid) drivelines to reduce environmental impact and improve efficiency: implementation of alternative (electric/hybrid) driveline technologies on all vehicles, to achieve -50% in CO2 emissions	2030

Table 36. . CNH Industrial. Carbon neutrality targets- company level (CNH Industrial, 2020)

Carbon neutrality-Company	
Targets	**Target horizon**
Application of best available techniques for the reduction of volatile organic compounds (VOCs) in paint processes: -27% vs. 2014 in VOC emissions per square meter painted at Company plants worldwide	2022
Increase in number and distribution of remanufactured components: 10% of Aftermarket Solutions' net sales from remanufactured components	2022
Identification of measures and technologies to reduce energy consumption and CO2 emissions per production unit: reduction by 50% vs. 2014 in CO2 emissions per production unit at Company plants worldwide: reduction by 50% vs. 2014 in CO2 emissions per production unit at Company plants worldwide	2024
Implementation of initiatives to reduce CO2 emissions and minimize the overall impact of logistics: -20% vs. 2014 in kg of CO2 emissions per ton of goods transported (including spare parts)	2024
Promotion of renewable energy generation and use: 80% of total electricity consumption derived from renewable sources	2024
Promotion of renewable energy generation and use: 90% of total electricity consumption derived from renewable sources	2030
Identification of measures and technologies to reduce energy consumption and CO2 emissions per production unit: reduction by 50% vs. 2014 in CO2 emissions per production unit at Company plants worldwide: reduction by 60% vs. 2014 in CO2 emissions per production unit at Company plants worldwide	2030

Table 37. CNH Industrial. Resource conservation targets-company level (CNH Industrial, 2020)

Resource conservation-Company	
Targets	**Target horizon**
Formulation of guidelines for the identification and safeguard of protected species and biodiversity: implementation of improvement measures identified through BVI or BRE assessments, if needed	2021
Optimization of waste management based on country-specific characteristics: reduction of 25% vs. 2014 in waste generated per production unit at Company plants worldwide	2022
Optimization of waste management based on country-specific characteristics: reduction by 36% vs. 2014 in hazardous waste generated per production unit at Company plants worldwide	2022
Optimization of water withdrawal and discharge management system based on country-specific characteristics: -24% vs. 2014 in water withdrawal per production unit at Company plants worldwide	2022
Optimization of water withdrawal in water-stressed areas: reduction by 47% vs. 2014 in water withdrawal per production unit at the plant in Greater Noida (India)	2022
Optimization of water withdrawal in water-stressed areas: -19% vs. 2014 in water withdrawal per production unit at the plant in Pithampur (India)	2022
Optimization of water withdrawal in water-stressed areas: -4% vs. 2014 in water withdrawal per production unit at the plant in Queretaro (Mexico)	2022
Optimization of waste management based on country-specific characteristics:95% of waste recovered at Company plants worldwided	2024

Table 38. CNH Industrial. Sustainable policy-company level (CNH Industrial, 2020)

Sustainable policy-Company	
Targets	**Target horizon**
Execution of sustainability audits at suppliers worldwide: execution of 95 audits (incl. reassessments, action plan follow-ups, and new assessments)	2021
Enhancement of sustainability awareness among suppliers: implementation of sustainability awareness activities for suppliers	2021
Promotion of supplier involvement in the World Class Manufacturing (WCM) program: execution of more than 120 audits and follow-ups	2021
CO2 emissions monitoring of key suppliers: monitoring of CO2 emissions of 100% of key suppliers	2022
Distribution of self-assessment questionnaires on environmental and social performance to select suppliers: 100% of Tier 1 suppliers	2024

Table 39. Daimler. Carbon neutrality targets-products level (Daimler, 2020b)

Carbon neutrality-products	
Targets	**Target horizon**
Offering series-produced vehicles with battery-electric drive systems in the main sales regions Europe, the United States, and Japan	2022
The new fleet of cars no longer has any relevant impact on nitrogen dioxide (NO2) pollution in urban areas.	2025
At Mercedes-Benz Cars plan to have all-electric vehicles account for up to 25 percent of unit sales	2025
Market launch of new xEV models (> 10 battery-electric vehicles, > 25 plug-in hybrid electric vehicles) for cars only	2025
Reduction of the CO2 emissions of the Mercedes-Benz AG new vehicle fleet > 40% (compared to 2018, regarding the use phase)	2030
Daimler's goal is to have plug-in hybrids or all-electric vehicles account for more than 50 percent of car and van sales	2030
Have plug-in hybrids or all-electric vehicles account for more than 50 percent of car and van sales sales	2030
Achieve CO2 neutrality for our new car and van fleet	2039
CO2 -neutral vehicle: the Company aims to change our product range by offering only new vehicles that are locally CO2 -neutral in driving operation in the triad markets Europe, Japan, and North America.	2039
Trucks and buses:enable the use of CO2 -neutral transportation on all streets and roads	2050

Table 40. Daimler. Carbon neutrality targets-company level (Daimler, 2020b)

Carbon neutrality-Company	
Targets	**Target horizon**
CO_2 -neutral production at our Mercedes-Benz Cars and Vans production plants worldwide and at the Daimler Trucks & Buses production plants in Europe	Starting in 2022
CO_2-neutral production at all Daimler Trucks North America (DTNA) production plants.	2025
At Mercedes-Benz Cars & Vans, they want to reduce the CO_2 emissions at plants (Scope 1 and 2) by 50 percent relative to the reference year 2018	2030
CO_2-neutral production at all of our plants and in all of business units worldwide	2039

Table 41. Daimler. Resource conservation targets-company level (Daimler, 2020b)

Resource conservation-Company	
Targets	**Target horizon**
Energy consumption reduction per vehicle (compared to 2013/14): cars - 43% vans -25 %	2030
Water consumption reduction per vehicle (compared to 2013/14) : cars - 33% vans -28 %	2030
Water disposal reduction per vehicle (compared to 2013/14): cars - 43% vans -33 %	2030
Proportion of secondary raw materials per vehicle (On average for the Mercedes-Benz car fleet without smart and vans): cars 40%	2030
Increase of the share of secondary raw materials in car fleet by an average of 40 percent	2030

Table 42. Daimler. Sustainable policy targets-company level (Daimler, 2020b)

Sustainable policy-Company	
Targets	**Target horizon**
Assessment of the effectiveness of the Data Compliance Management System	2022
Review 70% of all the production raw materials we use that pose a high risk of human rights violations and to define any necessary remediation measures	2025

Table 43. Volvo group. Carbon neutrality targets-products level (Volvo Group,2020)

Carbon neutrality-products	
Targets	**Target horizon**
35% electric vehicle sales	2030
Volvo Group has developed its own pathway towards the 1.5ºC target for trucks and buses, with a targeted emissions reduction of 40% per vehicle km	2030

Table 44. Volvo group. Carbon neutrality/resource conservation targets-company level (Volvo Group,2020)

Carbon neutrality /resource conservation-Company	
Targets	**Target horizon**
Implement energy savings of 150 GWh	2021-2025
Reduce CO2 emissions from freight transports per produced unit by 30% , with 2018 as base year	2025
Reach the ambition of net zero value chain emissions	2050
Increase share of renewable energy to 65%	2025

3 The electric mobility

3.1 The automotive manufacturing market

3.1.1 The world automotive industry

Table 45. 2020 Motor vehicles production statistics by Country (OICA,2020)

Country/Region	Cars	Commercial Vehicles	Total	% change than 2019
Argentina	93001	164186	257187	-18%
Austria	104544		104544	-42%
Belgium	237057	30403	267460	-6%
Brazil	1608870	405185	2014055	-6%
Canada	327681	1048942	1376623	-28%
China	19994081	5231161	25225242	-2%
Czech Republic	1152901	6250	1159151	-19%
Egypt	23754		23754	28%
Finland	86270		86270	-25%
France	927718	388653	1316371	-39%
Germany	3515372	227082	3742454	-24%
Hungary	406497		406497	-18%
India	2851268	543178	3394446	-25%
Indonesia	551400	139886	691286	-46%
Iran	826210	54787	880997	7%
Italy	451826	325339	777165	-15%
Japan	6960025	1107532	8067557	-17%
Kazakhstan	64790	10041	74831	51%
Malasya	457755	27431	485186	-15%
Morocco	221299	27131	248430	-38%
Mexico	967479	2209121	3176600	-21%
Poland	278900	172482	451382	-31%
Portugal	211281	52955	264236	-24%
Romania	438107		438107	-11%
Russia	1260517	174818	1435335	-17%
Serbia	23272	103	23375	-33%
Slovakia	985000		985000	-11%
Slovenia	141714		141714	-29%
South Africa	238216	209002	447218	-29%
South Korea	3211706	295068	3506774	-11%
Spain	1800664	467521	2268185	-20%
Taiwan	180967	64648	245615	-2%
Thailand	537633	889441	1427074	-29%
Turkey	855043	442835	1297878	-11%
Ukraine	4202	750	4952	-32%
United Kingdom	920928	66116	987044	-29%
USA	1926795	6895604	8822399	-19%
Uzbekistan	280080		280080	3%
Others	709633	109475	819108	
Total	55834456	21787126	77621582	-16%

5.Hybrid and electric buses: emissions assessment

5.2 Buses emissions assessment: the city of Turin

5.2.2 Annual emissions assessment for the Turin urban bus fleet

Diesel Buses: EFs evaluation

Table 46. EFs for urban midi buses < 15 t

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	4.267	1.283	0.986	0.231
VOC	0.218	0.065	0.051	0.226
NOx	20.302	6.103	4.692	0.231
NMVOC	0.184	0.055	0.043	0.227
CH4	0.021	0.006	0.005	0.268
N2O	0.051	0.015	0.012	0.254
NH3	0.013	0.004	0.003	0.247
PM2.5	0.393	0.118	0.091	0.230
PM10	0.628	0.189	0.145	0.231
SO2	0.013	0.004	0.003	0.117
Pb	0.001	0.000	0.000	0.230
Black carbon	0.120	0.036	0.028	0.232
CO2	3198.083	961.344	739.130	0.231

Table 47. EFs for Urban midi buses < 15 t – Diesel Euro 6

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	0.9013	0.2423	0.2060	0.1499
VOC	0.1495	0.0402	0.0341	0.1517
NOx	1.8452	0.4961	0.4210	0.1514
NMVOC	0.1196	0.0322	0.0275	0.1448
CH4	0.0214	0.0057	0.0047	0.1815
N2O	0.1623	0.0436	0.0374	0.1430
NH3	0.0384	0.0103	0.0090	0.1293
PM2.5	0.2563	0.0689	0.0586	0.1496
PM10	0.4955	0.1332	0.1129	0.1525
SO2	0.0128	0.0034	0.0034	0.0132
Pb	0.0006	0.0002	0.0001	0.1519
Black carbon	0.0043	0.0011	0.0007	0.3905
CO2	3187.5664	857.0410	727.1071	0.1516

Table 48. EFs for Urban standard buses 15-18 t – Diesel Euro 1

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	7.9491	4.1816	2.6352	0.3698
VOC	2.5201	1.3257	0.8362	0.3692
NOx	31.8476	16.7534	10.5601	0.3697
NMVOC	1.9307	1.0156	0.6406	0.3693
CH4	0.4741	0.2494	0.1575	0.3685
N2O	0.0342	0.0180	0.0108	0.3992
NH3	0.0085	0.0045	0.0029	0.3547
PM2.5	1.4437	0.7595	0.4872	0.3585
PM10	1.6060	0.8449	0.5325	0.3697
SO2	0.0128	0.0067	0.0049	0.2731
Pb	0.3844	0.0002	0.0001	0.3690
Black carbon	0.8329	0.4382	0.2757	0.3708
CO2	3180.3349	1673.0152	1054.5800	0.3697

Table 49. EFs for Urban standard buses 15-18 t – Diesel Euro 2

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	7.5518	3.7835	2.4098	0.3631
VOC	1.8111	0.9073	0.5774	0.3636
NOx	36.0720	18.0721	11.5094	0.3631
NMVOC	1.4053	0.7041	0.4484	0.3631
CH4	0.3204	0.1605	0.1024	0.3620
N2O	0.0342	0.0171	0.0108	0.3692
NH3	0.0085	0.0043	0.0029	0.3224
PM2.5	0.7988	0.4002	0.2552	0.3623
PM10	0.9696	0.4858	0.3095	0.3629
SO2	0.0128	0.0064	0.0047	0.2679
Pb	0.4015	0.0002	0.0001	0.3657
Black carbon	0.4101	0.2054	0.1307	0.3638
CO2	3180.6468	1593.5040	1014.9000	0.3631

Table 50. EFs for Urban standard buses 15-18 t – Diesel Euro 3

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	8.0302	3.6879	2.6900	0.2706
VOC	1.6060	0.7376	0.5378	0.2709
NOx	30.4337	13.9767	10.1900	0.2709
NMVOC	1.2558	0.5767	0.4204	0.2711
CH4	0.2776	0.1275	0.0929	0.2714
N2O	0.0171	0.0078	0.0054	0.3118
NH3	0.0085	0.0039	0.0029	0.2608
PM2.5	0.7774	0.3570	0.2602	0.2712
PM10	0.9397	0.4316	0.3144	0.2715
SO2	0.0128	0.0059	0.0049	0.1674
Pb	0.3802	0.0002	0.0001	0.2691
Black carbon	0.4314	0.1981	0.1443	0.2717
CO2	3180.2538	1460.5316	1065.1000	0.2707

Table 51. EFs for Urban standard buses 15-18 t – Diesel Euro 4

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	4.1433	1.7644	1.2857	0.2713
VOC	0.2307	0.0982	0.0720	0.2670
NOx	20.1482	8.5801	6.5255	0.2395
NMVOC	0.2050	0.0873	0.0631	0.2773
CH4	0.0171	0.0073	0.0047	0.3540
N2O	0.0384	0.0164	0.0115	0.2975
NH3	0.0085	0.0036	0.0029	0.2028
PM2.5	0.3374	0.1437	0.1048	0.2707
PM10	0.5126	0.2183	0.1591	0.2711
SO2	0.0128	0.0055	0.0046	0.1570
Pb	0.4101	0.0002	0.0001	0.2693
Black carbon	0.1239	0.0528	0.0381	0.2777
CO2	3195.1225	1360.6429	991.8000	0.2711

Table 52. EFs for Urban standard buses 15-18 t – Diesel Euro 5

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	7.4664	3.1172	2.2363	0.2826
VOC	0.2008	0.0838	0.0599	0.2853
NOx	23.3816	9.7618	7.0014	0.2828
NMVOC	0.1751	0.0731	0.0521	0.2874
CH4	0.0171	0.0071	0.0047	0.3411
N2O	0.0982	0.0410	0.0299	0.2710
NH3	0.0384	0.0160	0.0110	0.3146
PM2.5	0.3759	0.1569	0.1122	0.2850
PM10	0.5553	0.2318	0.1664	0.2822
SO2	0.0128	0.0053	0.0044	0.1776
Pb	0.3374	0.1409	0.0001	0.9991
Black carbon	0.1452	0.0606	0.0436	0.2809
CO2	3193.8966	1333.4518	956.3900	0.2828

Table 53. EFs for Urban standard buses 15-18 t – Diesel Euro 6

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	0.8714	0.3121	0.2664	0.1465
VOC	0.1452	0.0520	0.0439	0.1561
NOx	1.5847	0.5677	0.4849	0.1458
NMVOC	0.1196	0.0428	0.0369	0.1387
CH4	0.0171	0.0061	0.0047	0.2321
N2O	0.1239	0.0444	0.0374	0.1571
NH3	0.0299	0.0107	0.0090	0.1597
PM2.5	0.1965	0.0704	0.0600	0.1475
PM10	0.3716	0.1331	0.1143	0.1414
SO2	0.0128	0.0046	0.0045	0.0197
Pb	0.3289	0.0001	0.0001	0.0830
Black carbon	0.0043	0.0015	0.0009	0.4118
CO2	3186.4644	1141.4393	974.7900	0.1460

Table 54. EFs for articulated urban buses > 18 t – Diesel Euro 1

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	8.5172	4.9783	3.5582	0.2853
VOC	2.1784	1.2733	0.9045	0.2896
NOx	31.9778	18.6910	13.3614	0.2851
NMVOC	1.6872	0.9862	0.7049	0.2852
CH4	0.3759	0.2197	0.1575	0.2831
N2O	0.0256	0.0150	0.0108	0.2790
NH3	0.0085	0.0050	0.0029	0.4192
PM2.5	1.4172	0.8283	0.5904	0.2872
PM10	1.5505	0.9063	0.6475	0.2855
SO2	0.0128	0.0075	0.0061	0.1856
Pb	0.3075	0.0002	0.0001	0.2835
Black carbon	0.8244	0.4819	0.3444	0.2853
CO2	3178.7759	1857.9945	1328.1400	0.2852

Table 55. EFs for articulated urban buses > 18 t – Diesel Euro 2

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	8.1199	5.0173	3.2964	0.3430
VOC	1.5035	0.9290	0.6112	0.3421
NOx	31.9778	19.7591	14.1994	0.2814
NMVOC	1.1832	0.7311	0.4797	0.3439
CH4	0.2520	0.1557	0.1024	0.3424
N2O	0.0256	0.0158	0.0108	0.3180
NH3	0.0085	0.0053	0.0029	0.4506
PM2.5	0.8158	0.5041	0.3239	0.3575
PM10	0.9525	0.5886	0.3864	0.3435
SO2	0.0128	0.0079	0.0061	0.2296
Pb	0.3161	0.0002	0.0001	0.3405
Black carbon	0.4314	0.2666	0.1747	0.3446
CO2	3178.7759	1964.1656	1328.1400	0.3238

Table 56. EFs for articulated urban buses > 18 t – Diesel Euro 3

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	8.4147	5.1994	3.5400	0.3192
VOC	1.3498	0.8340	0.5675	0.3196
NOx	29.9938	18.5332	12.6200	0.3191
NMVOC	1.0679	0.6598	0.4486	0.3201
CH4	0.2221	0.1372	0.0929	0.3231
N2O	0.0128	0.0079	0.0054	0.3180
NH3	0.0085	0.0053	0.0029	0.4506
PM2.5	0.7518	0.4645	0.3155	0.3208
PM10	0.8842	0.5463	0.3726	0.3180
SO2	0.0128	0.0079	0.0062	0.2170
Pb	0.3075	0.0002	0.0001	0.3222
Black carbon	0.4229	0.2613	0.1785	0.3169
CO2	3178.6392	1964.0812	1337.6200	0.3190

Table 57. EFs for articulated urban buses > 18 t – Diesel Euro 4

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	3.9596	2.4466	1.5646	0.3605
VOC	0.2221	0.1372	0.0872	0.3646
NOx	20.6736	12.7742	8.1694	0.3605
NMVOC	0.1965	0.1214	0.0774	0.3625
CH4	0.0128	0.0079	0.0047	0.4064
N2O	0.0299	0.0185	0.0115	0.3775
NH3	0.0085	0.0053	0.0029	0.4506
PM2.5	0.3118	0.1927	0.1238	0.3574
PM10	0.4570	0.2824	0.1808	0.3598
SO2	0.0128	0.0079	0.0058	0.2675
Pb	0.3246	0.0002	0.0001	0.3579
Black carbon	0.1196	0.0739	0.0474	0.3586
CO2	3192.8715	1972.8753	1261.9000	0.3604

Table 58. EFs for articulated urban buses > 18 t – Diesel Euro 5

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	7.3810	3.9506	2.8300	0.2836
VOC	0.1794	0.0960	0.0686	0.2856
NOx	18.5977	9.9541	7.1237	0.2843
NMVOC	0.1580	0.0846	0.0603	0.2871
CH4	0.0128	0.0069	0.0047	0.3147
N2O	0.0769	0.0412	0.0299	0.2734
NH3	0.0299	0.0160	0.0290	-0.8121
PM2.5	0.3417	0.1829	0.1238	0.3231
PM10	0.4912	0.2629	0.1875	0.2868
SO2	0.0128	0.0069	0.0056	0.1835
Pb	0.3374	0.0002	0.0001	0.2869
Black carbon	0.1367	0.0732	0.0524	0.2837
CO2	3192.0172	1708.4793	1222.7400	0.2843

Table 59. EFs for articulated urban buses > 18 t – Diesel Euro 6

Pollutant	EF (g/Kg fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	0.7261	0.3602	0.2824	0.2159
VOC	0.1239	0.0614	0.0490	0.2025
NOx	1.0977	0.5445	0.4277	0.2145
NMVOC	0.1068	0.0530	0.0418	0.2108
CH4	0.0128	0.0064	0.0047	0.2605
N2O	0.0940	0.0466	0.0374	0.1976
NH3	0.0214	0.0106	0.0090	0.1504
PM2.5	0.3204	0.1589	0.0674	0.5758
PM10	0.3204	0.1589	0.1244	0.2171
SO2	0.0128	0.0064	0.0057	0.1032
Pb	0.3289	0.0002	0.0001	0.2111
Black carbon	0.0043	0.0021	0.0010	0.5280
CO2	3185.7852	1580.1176	1242.4000	0.2137

CNG buses: EFs evaluation

Table 60.EFs for IVECO CNG EEV Cityclass 12 m

Pollutant	EF (g/m^3 fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	1.8440	1.6596	0.8924	0.4623
VOC	1.9166	1.7249	0.9278	0.4621
NOx	7.7770	6.9993	3.7641	0.4622
NMVOC	0.0305	0.0275	0.0150	0.4543
CH4	2.0235	1.8211	0.9800	0.4619
N2O	0.0000	0.0000	0.0000	0.0000
NH3	0.0000	0.0000	0.0000	0.0000
PM2.5	0.1336	0.1203	0.0645	0.4637
PM10	0.2443	0.2199	0.1188	0.4598
SO2	0.0000	0.0000	0.0000	0.0000
Pb	0.2634	0.0002	0.0001	0.4618
Black carbon	0.0000	0.0000	0.0000	0.0000
CO2	2200.2311	1980.2080	1065.0000	0.4622

Table 61. EFs for Irisbus CNG EEV Cityclass 12 m

Pollutant	EF (g/m^3 fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	1.8440	1.5490	0.8924	0.4239
VOC	1.9166	1.6099	0.9278	0.4237
NOx	7.7770	6.5327	3.7641	0.4238
NMVOC	0.0305	0.0257	0.0150	0.4153
CH4	2.0235	1.6997	0.9800	0.4234
N2O	0.0000	0.0000	0.0000	0.0000
NH3	0.0000	0.0000	0.0000	0.0000
PM2.5	0.1336	0.1122	0.0645	0.4254
PM10	0.2443	0.2052	0.1188	0.4212
SO2	0.0000	0.0000	0.0000	0.0000
Pb	0.2634	0.0002	0.0001	0.4234
Black carbon	0.0000	0.0000	0.0000	0.0000
CO2	2200.2311	1848.1941	1065.0000	0.4238

Table 62. EFs for Mercedes Connecto CNG EEV 12 m

Pollutant	EF (g/m^3 fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	1.8440	1.2281	0.8924	0.2734
VOC	1.9166	1.2764	0.9278	0.2731
NOx	7.7770	5.1795	3.7641	0.2733
NMVOC	0.0305	0.0203	0.0150	0.2626
CH4	2.0235	1.3476	0.9800	0.2728
N2O	0.0000	0.0000	0.0000	0.0000
NH3	0.0000	0.0000	0.0000	0.0000
PM2.5	0.1336	0.0890	0.0645	0.2752
PM10	0.2443	0.1627	0.1188	0.2700
SO2	0.0000	0.0000	0.0000	0.0000
Pb	0.2634	0.0002	0.0001	0.2727
Black carbon	0.0000	0.0000	0.0000	0.0000
CO2	2200.2311	1465.3539	1065.0000	0.2732

Table 63. EFs for Irisbus Citelis CNG 18 m

Pollutant	EF (g/m³ fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	1.8440	1.8228	0.8924	0.5104
VOC	1.9166	1.8945	0.9278	0.5103
NOx	7.7770	7.6875	3.7641	0.5104
NMVOC	0.0305	0.0302	0.0150	0.5032
CH4	2.0235	2.0002	0.9800	0.5100
N2O	0.0000	0.0000	0.0000	0.0000
NH3	0.0000	0.0000	0.0000	0.0000
PM2.5	0.1336	0.1321	0.0645	0.5117
PM10	0.2443	0.2415	0.1188	0.5081
SO2	0.0000	0.0000	0.0000	0.0000
Pb	0.2634	0.0003	0.0001	0.5100
Black carbon	0.0000	0.0000	0.0000	0.0000
CO2	2200.2311	2174.9284	1065.0000	0.5103

Table 64. EFs for Irisbus CNG Cityclass 18 m

Pollutant	EF (g/m³ fuel)	EF (g/km)	EF (g/Km) ISPRA	Difference
CO	1.8440	1.8532	0.8924	0.5185
VOC	1.9166	1.9261	0.9278	0.5183
NOx	7.7770	7.8159	3.7641	0.5184
NMVOC	0.0305	0.0307	0.0150	0.5113
CH4	2.0235	2.0336	0.9800	0.5181
N2O	0.0000	0.0000	0.0000	0.0000
NH3	0.0000	0.0000	0.0000	0.0000
PM2.5	0.1336	0.1343	0.0645	0.5197
PM10	0.2443	0.2456	0.1188	0.5162
SO2	0.0000	0.0000	0.0000	0.0000
Pb	0.2634	0.0003	0.0001	0.5180
Black carbon	0.0000	0.0000	0.0000	0.0000
CO2	2200.2311	2211.2322	1065.0000	0.5184

Annual emissions asessment: the actual scenario

Table 65. Annual emissions assessment for pollutants emitted by Turin urban buses 8-10 m (< 15 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg)	CH4 (kg)	N2O (Kg)
EPT-CACCIAMALI "ELFO" ELECTRIC	23	9875	Electric	0.0	0.0	0.0	0.0	0.0	0.0
BYD K7 ELETTRICO	8	11050	Electric	0.0	0.0	0.0	0.0	0.0	0.0
BMC NEOCITY	6	11472.5	Diesel Euro 6	72.7	12.1	148.8	9.6	1.7	13.1
MAN A47 LION'S CITY NL283 E4	5	13750	Diesel Euro 4	320.7	16.4	1525.7	13.8	1.6	3.9
Total				**393.4**	**28.4**	**1674.5**	**23.4**	**3.3**	**16.9**

Table 66. Annual emissions assessment for pollutants emitted by Turin urban buses 8-10 m (< 15 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	NH3 (Kg)	PM2.5 (Kg)	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon (Kg)	CO2 (Kg)
EPT-CACCIAMALI "ELFO" ELECTRIC	23	9875	Electric	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BYD K7 ELETTRICO	8	11050	Electric	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BMC NEOCITY	6	11472.5	Diesel Euro 6	3.1	20.7	40.0	1.0	0.0	0.3	257112.3
MAN A47 LION'S CITY NL283 E4	5	13750	Diesel Euro 4	1.0	29.5	47.2	1.0	0.0	9.0	240335.9
Total				**4.1**	**50.2**	**87.2**	**2.0**	**0.1**	**9.3**	**497448.2**

Table 67. Annual emissions assessment for pollutants emitted by Turin urban buses 12 m (15-18 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg)	CH4 (kg)	N2O (Kg)	NH3 (Kg)
IVECO 491E.12.24 CNG CITYCLASS	CNG (EEV)	100	15547.5	8298.113	8624.5393	34996.388	137.44286	9105.5893	0	0
IRISBUS 491E.12.29 - CITYCLASS E3	Diesel Euro 3	35	15220	6453.797	1290.7594	24459.204	1009.264	223.1366	13.731483	6.865742
IRISBUS 491E.12.29 - CITYCLASS E4	Diesel Euro 4	15	15220	1323.305	73.668515	6435.0812	65.483125	5.4569271	12.278086	2.728464
IRISBUS 491E.12.27 CNG - CITYCLASS	CNG (EEV)	88	15796	6815.516	7083.6216	28743.7	112.8864	7478.724	0	0
IRISBUS CITELIS 12.29 DIESEL EEV	Diesel EEV	100	15537	15586.13	419.07773	48809.181	365.57845	35.66619	205.08059	80.24893
IVECO CITELIS 12.29 DIESEL EEV	Diesel EEV	81	15423.5	12624.76	339.45296	39535.437	296.11854	28.889614	166.11528	65.00163
BYD K9UB ELECTRIC	Electric	20	16207.5	0	0	0	0	0	0	0
MERCEDES CONECTO E6	Diesel Euro 6	41	14722	639.8793	106.64654	1163.702	87.826566	12.546652	90.963229	21.95664
MERCEDES CONECTO CNG	CNG Euro 6	48	15455	2947.49	3063.4364	12430.717	48.819703	3234.3053	0	0
BYD K9UB ELECTRIC	Electric	50	16884	0	0	0	0	0	0	0
Total				**54688.99**	**21001.202**	**196573.41**	**2123.4197**	**20124.315**	**488.16867**	**176.8014**

Table 68. Annual emissions assessment for pollutants emitted by Turin urban buses 12 m (15-18 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	NH3 (Kg)	PM2.5 (Kg)	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon (Kg)	CO2 (Kg)
IVECO 491E.12.24 CNG CITYCLASS	CNG (EEV)	100	15547.5	0.0	601.3	1099.5	0.0	1.2	0.0	9901039.8
IRISBUS 491E.12.29 - CITYCLASS E3	Diesel Euro 3	35	15220.0	6.9	624.8	755.2	10.3	0.3	346.7	2555930.2
IRISBUS 491E.12.29 - CITYCLASS E4	Diesel Euro 4	15	15220.0	2.7	107.8	163.7	4.1	0.1	39.6	1020482.2
IRISBUS 491E.12.27 CNG - CITYCLASS	CNG (EEV)	88	15796.0	0.0	493.9	903.1	0.0	1.0	0.0	8132054.0
IRISBUS CITELIS 12.29 DIESEL EEV	Diesel EEV	100	15537.0	80.2	784.7	1159.2	26.7	0.7	303.2	6667259.2
IVECO CITELIS 12.29 DIESEL EEV	Diesel EEV	81	15423.5	65.0	635.6	938.9	21.7	0.6	245.6	5400480.0
BYD K9UB ELECTRIC	Electric	20	16207.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERCEDES CONECTO E6	Diesel Euro 6	41	14722.0	22.0	144.3	272.9	9.4	0.2	3.1	2339950.7
MERCEDES CONECTO CNG	CNG Euro 6	48	15455.0	0.0	213.6	390.6	0.0	0.4	0.0	3516849.3
BYD K9UB ELECTRIC	Electric	50	16884.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total				**176.8**	**3605.8**	**5683.1**	**72.2**	**4.5**	**938.1**	**39534045.5**

Table 69. Annual emissions assessment for pollutants emitted by Turin articulated urban buses 18 m (> 18 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg)	CH4 (kg)	N2O (Kg)
VAN HOOL AG 300 - DE SIMON URS 33.01	60.00	21770.00	Diesel Euro 2	15051.92	2787.10	59277.31	2193.26	467.16	47.51
VAN HOOL AG 300 - DE SIMON URS 33.01	25.00	22460.00	Diesel Euro 3	6499.27	1042.52	23166.44	824.78	171.55	9.90
IRISBUS 491E.18.31 CNG CITYCLASS	70.00	23120.00	CNG (EEV)	5421.43	5634.70	22864.31	89.80	5948.99	0.00
IRISBUS 491E.18.31 CNGCITYCLASS	27.00	23120.00	CNG (EEV)	2091.12	2173.38	8819.09	34.64	2294.61	0.00
IRISBUS CITELIS 18m DIESEL EEV	8.00	23937.50	Diesel EEV	1580.22	38.41	3981.65	33.84	2.74	16.46
IRISBUS CITELIS 18m CNG	4.00	24097.50	CNG (EEV)	364.56	378.90	1537.51	6.04	400.04	0.00
IRISBUS CITELIS 18m CNG	4.00	24097.50	CNG (EEV)	364.56	378.90	1537.51	6.04	400.04	0.00
IRISBUS CITELIS 18m DIESEL EEV	70.00	22893.00	Diesel (EEV)	13826.95	336.07	34839.44	296.06	24.01	144.03
IRISBUS CITELIS 18m DIESEL EEV	5.00	22893.00	Diesel (EEV)	987.64	24.01	2488.53	21.15	1.71	10.29
Merceds Connecto G E6	47.00	22019.00	Diesel Euro 6	846.37	144.38	1279.51	124.47	14.94	109.53
Total				**47034.06**	**12938.38**	**159791.30**	**3630.06**	**9725.78**	**337.71**

Table 70. Annual emissions assessment for pollutants emitted by Turin articulated urban buses 18 m (> 18 t)

Model	Number of vehicles	Mass at medium load (Kg)	Fuel	NH3 (Kg)	PM2.5 (Kg)	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon (Kg)	CO2 (Kg)
VAN HOOL AG 300 - DE SIMON URS 33.01	60.00	21770.00	Diesel Euro 2	15.8	1512.3	1765.7	23.8	0.6	799.7	5892496.8
VAN HOOL AG 300 - DE SIMON URS 33.01	25.00	22460.00	Diesel Euro 3	6.6	580.6	682.9	9.9	0.2	326.6	2455101.4
IRISBUS 491E.18.31 CNG CITYCLASS	70.00	23120.00	CNG (EEV)	0.0	392.9	718.4	0.0	0.8	0.0	6468679.4
IRISBUS 491E.18.31 CNGCITYCLASS	27.00	23120.00	CNG (EEV)	0.0	151.5	277.1	0.0	0.3	0.0	2495062.0
IRISBUS CITELIS 18m DIESEL EEV	8.00	23937.50	Diesel EEV	6.4	73.2	105.2	2.7	0.1	29.3	683391.7
IRISBUS CITELIS 18m CNG	4.00	24097.50	CNG (EEV)	0.0	26.4	48.3	0.0	0.1	0.0	434985.7
IRISBUS CITELIS 18m CNG	4.00	24097.50	CNG (EEV)	0.0	26.4	48.3	0.0	0.1	0.0	434985.7
IRISBUS CITELIS 18m DIESEL EEV	70.00	22893.00	Diesel (EEV)	56.0	640.1	920.2	24.0	0.6	256.1	5979677.7
IRISBUS CITELIS 18m DIESEL EEV	5.00	22893.00	Diesel (EEV)	4.0	45.7	65.7	1.7	0.0	18.3	427119.8
Merceds Connecto G E6	47.00	22019.00	Diesel Euro 6	24.9	373.4	373.4	14.9	0.4	5.0	3713276.4
Total				**113.7**	**3822.6**	**5005.2**	**77.1**	**3.1**	**1434.9**	**28984776.7**

5.2.3 Evaluation of alternative scenarios

Table 71. EFs calclauted for Iveco Urbanway Hybrid High value 12 m

Pollutant	EF (g/Kg fuel)	EF (g/km)
CO	0.7261	0.2029
VOC	0.1239	0.0346
NOx	1.0977	0.3067
NMVOC	0.1068	0.0298
CH4	0.0128	0.0036
N2O	0.0940	0.0263
NH3	0.0214	0.0060
PM2.5	0.3204	0.0895
PM10	0.3204	0.0895
SO2	0.0128	0.0036
Pb	0.3289	0.0001
Black carbon	0.0043	0.0012
CO2	3185.7852	890.1329

Table 72. EFs calclauted for Iveco Urbanway Hybrid High value 18 m

Pollutant	EF (g/Kg fuel)	EF (g/km)
CO	0.7261	0.2521
VOC	0.1239	0.0430
NOx	1.0977	0.3811
NMVOC	0.1068	0.0371
CH4	0.0128	0.0044
N2O	0.0940	0.0326
NH3	0.0214	0.0074
PM2.5	0.3204	0.1112
PM10	0.3204	0.1112
SO2	0.0128	0.0044
Pb	0.3289	0.0001
Black carbon	0.0043	0.0015
CO2	3185.7852	1106.0823

Table 73. Annual emissions assessment for pollutants emitted for the Scenario 1HYB

Model	Number of vehicles	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg)	CH4 (kg)	N2O (Kg)
Iveco full hybrid 18 m	85	Hybrid	1071.47	182.78	1619.81	157.57	18.91	138.66
Iveco full hybrid 12 m	55	Hybrid	557.94	95.18	843.48	82.05	9.85	72.20

Table 74. Annual emissions assessment for pollutants emitted for the Scenario 1HYB

Model	Number of vehicles	Fuel	NH3 (Kg)	PM2.5	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon (Kg)	CO2 (Kg)
Iveco full hybrid 18 m	85	Hybrid	31.51	472.71	472.71	18.91	0.49	6.30	4700849.93
Iveco full hybrid 12 m	55	Hybrid	16.41	246.15	246.15	9.85	0.25	3.28	2447865.55

Table 75. Annual emissions assessment for pollutants emitted for the Scenario 2HYB

Model	Number of vehicles	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg)	CH4 (kg)	N2O (Kg)
Iveco full hybrid 18 m	168	Hybrid	2117.72	361.26	3201.50	311.43	37.37	274.06
Iveco full hybrid 12 m	236	Hybrid	2394.08	408.40	3619.29	352.07	42.25	309.82

Table 76. Annual emissions assessment for pollutants emitted for the Scenario 2HYB

Model	Number of vehicles	Fuel	NH3 (Kg)	PM2.5	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon	CO2 (Kg)
Iveco full hybrid 18 m	168	Hybrid	62.286008	934.29	934.29	37.37	0.96	12.46	9291091.63
Iveco full hybrid 12 m	236	Hybrid	70.414261	1056.21	1056.21	42.25	1.08	14.08	10503568.56

Table 77. Annual emissions assessment for pollutants emitted for the Scenario 3HYB

Model	Number of vehicles	Fuel	CO (Kg)	VOC (Kg)	NOX (Kg)	NMVOC (Kg	CH4 (kg)	N2O (Kg)
Iveco full hybrid 18 m	215	Hybrid	2710.18	462.33	4097.16	398.56	47.83	350.73
Iveco full hybrid 12 m	283	Hybrid	2870.87	489.74	4340.08	422.19	50.66	371.52

Table 78. Annual emissions assessment for pollutants emitted for the Scenario 3HYB

Model	Number of vehicles	Fuel	NH3 (Kg)	PM2.5	PM10 (Kg)	SO2 (Kg)	Pb (Kg)	Black Carbon	CO2 (Kg)
Iveco full hybrid 18 m	168	Hybrid	79.71126	1195.67	1195.67	47.83	1.23	15.94	11890385.13
Iveco full hybrid 12 m	236	Hybrid	84.43744	1266.56	1266.56	50.66	1.30	16.89	12595380.94

6. Li-ion batteries impact assessment

6.1 Li-ion batteries production

Table 79. Cell composition for NMC111, NMC 622 and LFP

	cell composition (mass %)		
	NMC 111	NMC 622	LFP
Li	2.68	2.49	1.42
Co	6.89	3.84	0.00
Ni	6.86	11.47	0.00
Mn	6.42	3.58	0.00
Al	0.00	0.00	0.00
Fe	0.00	0.00	11.40
P	0.00	0.00	6.32
Graphite	19.00	20.70	16.60
Copper (electrode)	16.40	16.80	14.50
Aluminium (electrode)	8.20	8.40	7.50
Other material	33.54	32.72	42.26

Table 80. Kg of extracted materials for NMC111,NMC 622 and LFP

	Kg of extracted materials		
	NMC111	NMC622	LFP
Li	26.80	24.87	14.17
Co	68.92	38.38	0.00
Ni	68.64	114.70	0.00
Mn	64.24	35.81	0.00
Al	0.00	0.00	0.00
Fe	0.00	0.00	113.99
P	0.00	0.00	63.21
Graphite	190.00	207.00	166.00
Copper (electrode)	164.00	168.00	145.00
Aluminium (electrode)	82.00	84.00	75.00

Table 81. The cradle to gate GWP impacts associated with different elements (Nuss et al., 2014; Manjong et al.,2021)

Element	Global warming potential (Kg of CO2e/Kg)
Li	7.1
Co	8.3
Ni	6.5
Mn	1
Al	8.2
Fe	1.5
P	0
O	0
Graphite	4.2
Copper	2.8
Aluminium	8.2