Environmental Product Declaration

According to ISO 14025 for:

Solaris Urbino 18 electric bus

Programme	The International EPD® System EPD International AB | Box 210 60 | SE-100 31 Stockholm | Sweden www.environdec.com | info@environdec.com
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An EPD should provide current information, and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at www.environdec.com.

Product category rules (PCR): *PCR 2016:04 – UN CPC 49112 & 49113, Public and private buses and coaches. Version 2.0*
PCR review was conducted by: *Leo Breedveld, 2B Srl* *Contact via: breedveld@to-be.it*
Independent third-party verification of the declaration and data, according to ISO 14025:2006: ☐ EPD process certification ☒ EPD verification
Third party verifier: *Leo Breedveld, 2B Srl* Approved by: The International EPD® System
Procedure for follow-up of data during EPD validity involves third party verifier: ☒ Yes ☐ No

The EPD owner has the sole ownership, liability, and responsibility for the EPD. EPDs within the same product category but from different programmes may not be comparable.

1. SOLARIS INTRODUCTION

Solaris Bus & Coach sp. z o.o., being part of Group CAF, is one of the leading European bus and trolleybus manufacturers. Benefiting from 25 years of experience and having manufactured over 21 000 vehicles, Solaris affects the quality of city transport in hundreds of cities across Europe every day.

FIGURE 1 SOLARIS BUS & COACH HEADQUARTERS

Thinking of the future, the firm is setting new standards by dynamically developing its products, in particular in the electromobility sector. In 2001, the company introduced its first trolleybuses to the market, whereas in 2006 it premiered hybrid buses, in 2011 – its first battery-powered bus, and in 2014 – hydrogen-fuelled buses.

Solaris actively participates in the global transition to emission-free public transport and wants to be a strong partner for public transport operators by providing towns and cities with complex support in the transition to green solutions. In 2020, vehicles with alternative drives (electric buses, hybrid buses and trolleybuses) made up as much as 44% of the company's production. The manufacturer gradually strengthens its position as an electromobility leader, never ceasing in efforts to develop its e-mobility product range.

All Solaris vehicles, from the idea through design to execution, are created in the sites located near Poznań, Poland, which makes the company one of the largest employers in the region:

- Head Office and Bus Production in Bolechowo,
- Production of Steel Body Frames in Środa Wielkopolska/ Kijewo,
- Central Workshop, Customer Service Centre in Murowana Goślina,
- Production Support in Poznań,
- Solaris Logistics Center in Jasin.

Working toward the safety of the users of Solaris products and the highest quality of the vehicles produced, all buses and trolleybuses of the Solaris brand are manufactured in accordance with the Integrated Management System implemented in the company and certified according to the following international standards:

- ISO 9001:2015 Quality Management System,
- ISO 14001:2015 Environmental Management System,
- EN ISO 3834-2 Quality requirements for fusion welding of metallic materials.

While Solaris contributes to many of the UN Sustainable Development Goals (SDGs) and to building a better future, the company highlights taking a proactive role in achieving the following 4 Goals, associated directly with its business activity:

- Goal 7: Affordable and clean energy,
- Goal 9: Industry, innovation and infrastructure,
- Goal 11: Sustainable cities and communities,
- Goal 13: Climate action.

Solaris sustainability efforts are detailed in the Solaris Sustainability Report, available on Solaris website.

FIGURE 2 SOLARIS SUSTAINABILITY REPORT IS AVAILABLE ON SOLARISBUS.COM

2. SOLARIS URBINO 18 ELECTRIC BUS

Solaris offers transport operators interested in transition to electromobility buses fully customized to their needs. The customers receives a comprehensive battery-powered bus portfolio that helps to customize an ideal product, depending on factors such as climate, speed profile and load and even landform features. Solaris Urbino electric buses are exceptionally quiet, have no exhaust emissions and are distinguished by its modern design. What is more they guarantee low operation costs.

The portfolio includes different vehicle options in terms of vehicle length, motor, battery as well as charging methods. Urbino electric buses are available in 9, 12, 15, 18, and 24 meter versions. The vehicle is available in both a low-floor and low-entry variants. There is a wide range of internal equipment configurations and batteries to best suit the customer's needs. The urban environment offers ideal conditions for an appropriate charging infrastructure. Solaris electric buses are adapted to both fast charging methods, thanks to a pantograph installed on the roof of every vehicle, and night charging in a bus depot using a conventional plug-in system. The driving conditions in the city, e. g. with frequent acceleration and braking, allow, in particular, to effectively use energy recovery systems.

Thanks to innovative technical solutions electric buses can operate for an unlimited time, up to 24 hours a day. Moreover, their low noise emission and vibration level makes battery buses particularly suited for use in city centers.

Furthermore, electric buses do not require as many maintenance operations during their service life as the vehicles with conventional drives do, such us oil change or other advanced maintenance processes.

The product analysed is the Urbino 18 electric bus

FIGURE 3 URBINO 18 ELECTRIC BUS

18 000 mm
Length

3300-3480 mm
Height

2 550 mm
Width

320 mm
Entrance height

3 to 4
No. of doors

Up to 178
Passengers

Over 200 km
Range
(depending on battery capacity and driving conditions)

Li-ion
Battery technology

Nominal power / Maximum traction motor power:
240 kW asynchronous motor (standard)
2 x 125 kW, 2 motors located in the axle (option)

Solaris is constantly working on the design of Urbino buses, providing not only a more modern appearance but also better comfort for the driver and passengers. Giving drivers the sense of work comfort and safety is extremely important to the company, therefore the engineers develop assistance and support functionalities as well as ADAS (Advanced Driver Assistance Systems) solutions in the vehicles. Advanced Driver Assistance Systems help drivers by performing certain actions before them or in their stead. This provides the drivers with invaluable seconds for a proper response.

Through the continuous development of technical solutions, Solaris aims to ensure even better performance of its products. New solutions possible in Solaris Urbino electric offer a heating and air-conditioning system where CO2 is used as the working fluid. The use of a heat pump allows to procure heat from auxiliary devices and thus limit the consumption of energy derived from batteries, which, in turn, results in extending the vehicle driving range and ensures efficient operation at low temperatures. All of these operations occur in zero-exhaust emission mode.

Another novelty is the originally developed by Solaris remote diagnostic system for electric buses named eSConnect. It enhances and supports diagnostic and maintenance possibilities and also facilitates the analysis of specialist data derived from a vehicle. Buses equipped with a remote diagnostic system will allow the producer to establish a database of real performance data that can be later used to further perfect solutions applied by the manufacturer.

21. VEHICLE INFORMATION

In the next table, further technical details of the vehicle are presented (service life is assumed 800 000 km).

TABLE 1 TECHNICAL DESCRIPTION OF THE VEHICLE

GROUP	CONCEPT	VALUE
CHASIS	DENOMINATION	Solaris Urbino 18 electric
	LENGHT	18 000 mm
	WIDTH	2 550 mm
	PASSENGER CAPACITY	125
	DRIVER CABIN POSITION	Left
ELECTRIC ENGINE	DENOMINATION	TSA-TMF 35-44-4
	NOMINAL POWER	240 kW
	NOMINAL TORQUE	1470 Nm
	ENGINE POSITION	central left
AXLES	AXLES	3
	WHEELS	6 wheels (10 tyres)
	FIRST AXLE LOAD (MAX)	7 245 kg
	SECOND AXLE LOAD (MAX)	11 000 kg
	THIRD AXLE LOAD (MAX)	12 600 kg
	DISTANCE BETWEEN AXLES	1-2 = 5 900 mm; 2-3 = 6 000 mm
	FRONT OVERHANG	2 700 mm
	REAR OVERHANG	3 400 mm
STEERING CONTROL	DENOMINATION	ZF 8098 956 235
	WHEEL LOCK	45,5°
	TURN DIAMETER	22 250 mm
BATTERY	TECHNOLOGY	Lithium-Ion
BRAKE SYSTEM	DENOMINATION	FRONT: KNORR SN7; MIDDLE: KNORR SB7000; DRIVE: KNORR SB7187/SB7197
SUSPENSION	DENOMINATION	ZF Sachs shock absorbers Firestone bellows
	TYPE	oil-filled dampers air bellows
SECURITY	SYSTEMS	EBS, ABS, ASR + brake pad wear indication
AIR CONDITIONER	DENOMINATION	2x Konvekta UL700EM G2
ECE REGULATION №51	MOVING SOUND LEVEL	77,6 dB(A)
	STATIONARY SOUND LEVEL	n/a

2.2 CONTENT DECLARATION

The percentage of materials included in the LCA is 99.26 % of the total theoretical weight of the product (see TABLE 2). The remaining portion has not been considered in the study because the material was unknown.

FIGURE 4 and FIGURE 5 depict the material composition of the whole bus and material breakdown of the bus by vehicle group, respectively. The unknown fraction (0.74%) is reported in the category “others”.

TABLE 2 ANALYZED WEIGHT (BASED ON THE BOM – BILL OF MATERIALS) OF THE BUS FOR LCA

Group	Analysed weight (kg)	Theoretical weight (kg)
Frame	4740.0	19608.6
Running gear system	4181.6	
Powertrain	1324.5	
Battery	3360.0	
Electric harnesses and systems	957.1	
Exterior components	2249.2	
Interior components	1112.1	
Driver Cabin	243.3	
Seats and railings	583.2	
Heating system, air conditioning	556.4	
Fluids	150.0	
Total	19457.4	% analysed -> 99.26

Material composition

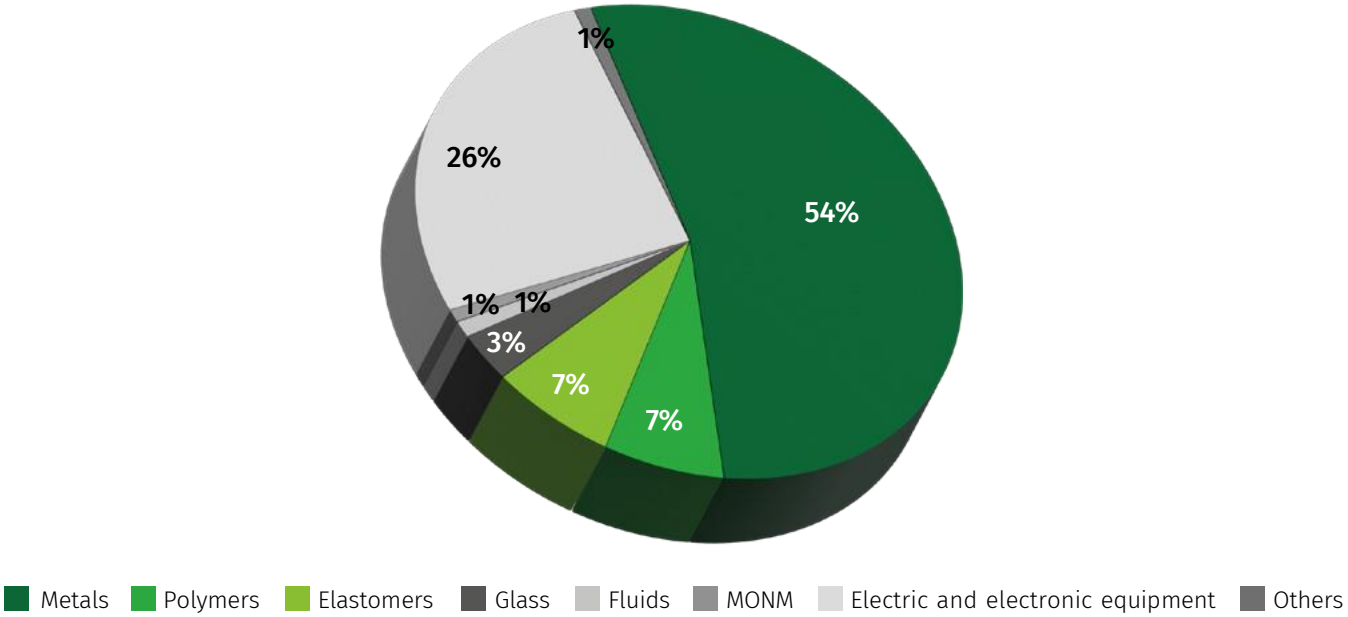


FIGURE 4 MATERIAL COMPOSITION OF THE WHOLE BUS (MONM; MODIFIED ORGANIC NATURAL MATERIAL)

Material breakdown by vehicle group

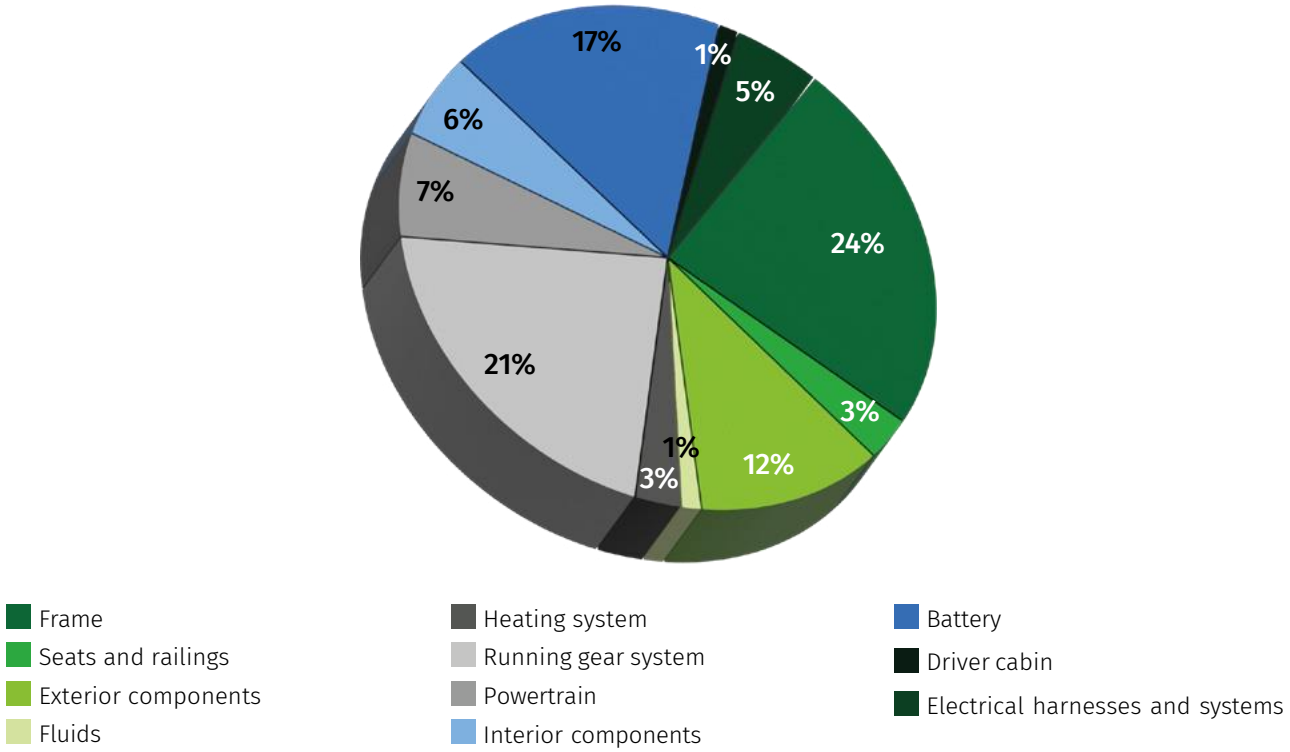


FIGURE 5 MATERIAL BREAKDOWN OF THE BUS BY VEHICLE GROUP*

*Vehicle group is a compartment of a bus

Detailed information about SVHC (substances of very high concern) in Solaris buses is listed in REACH declaration which is available on request.

3. ANALYSED SYSTEM SCOPE

3.1. FUNCTIONAL UNIT

The functional unit used in this study is “transport of one passenger along 1 km in the Solaris Urbino 18 electric bus”. According to the PCR guidelines, a travelled distance of 800000 km may be assumed as stated in Directive 2009/33/EC. Therefore, the functional unit calculation presented in TABLE 3 includes the following parameters.

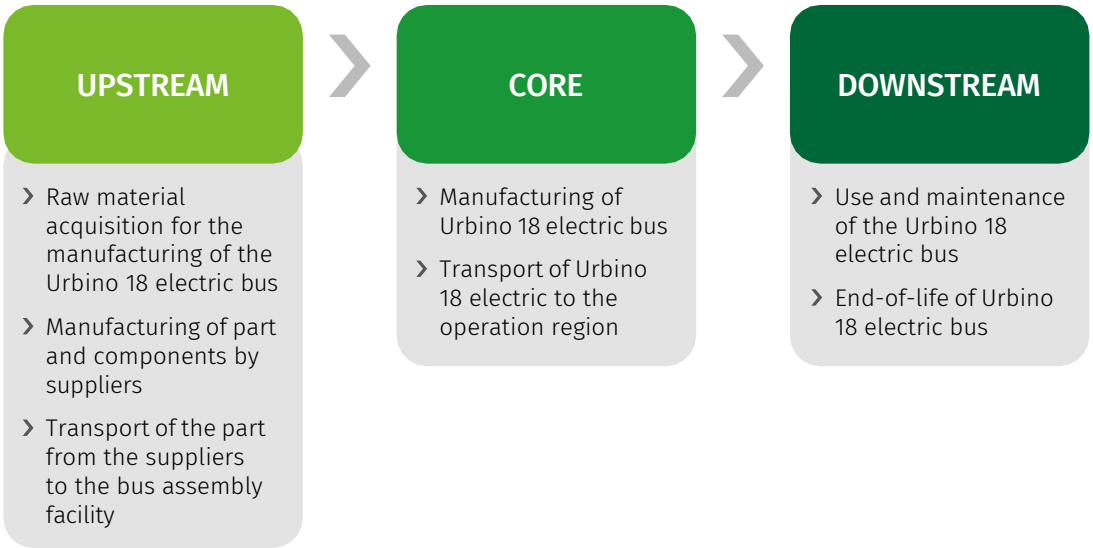
TABLE 3 FUNCTIONAL UNIT OF ELECTRIC BUS

Passenger capacity	Km/year	Service life (year)	Passenger*km
125	80 000	10	100 000 000

3.2. SYSTEM BOUNDARIES

This EPD is declared a Cradle-to-grave study, divided into three sections (upstream, core, downstream), as presented in FIGURE 6. The presented flowchart strictly follows the PCR 2016:04 – UN CPC 49112 and 49113 – Public and private buses and coaches. Version 2.0 requirements. The manufacturing of production equipment, buildings and other capital goods, business travel of personnel, travel to and from work by personnel are all excluded.

FIGURE 6 SYSTEM DIAGRAM ILLUSTRATING THE LIFE CYCLE OF BUSES AND COACHES COVERED BY THE PCR REFERRED IN THE TEXT



3.3. DETAILS ABOUT THE LIFE CYCLE ASSESSMENT

The specific data on the material composition of the Solaris Urbino 18 electric bus was collected by Solaris Technical and ESG departments in 2021. Technical datasheets on certain components were also acquired from their suppliers during this project. Where it was not possible to get actual data, proxies and literature sources were used to fill in the data gaps.

The bus manufacturing stage accounts for all processes performed at Solaris assembly facilities; welding, bonding, painting and main assembly. All these process stages take place in facilities over three production locations in Poland. Data collection includes all energy use and extra materials and chemicals for welding, bonding, painting, and the main assembly of the bus. Disposal of waste generated in this stage is also accounted for.

In the Solaris Sustainability Report (Solaris_Sustainability_Report_2020.pdf (solarisbus.com)) it was reported that the company's 71% suppliers are based in Poland. Higher participation of partners from Poland means the optimization of costs and delivery times, and thus enables Solaris to mitigate environmental impact. Solaris continuously works together with suppliers and partners to advance eco-awareness and build a circular green economy. Solaris and its suppliers apply the sustainable development approach to the whole process of selection, production and use of lithium-ion batteries that are installed in city transport vehicles and pay great attention to eco-friendly and ethical business practices.

Due to lack of data on transported masses, a conservative scenario was chosen for modelling transport from the suppliers to the assembly site and from there to the clients in Europe. The maximum distance has been chosen in both cases.

Solaris energy consumption methodology is based on in-house developed mathematical model for buses with electric powertrain. The model parameters are also corrected using data collected for eSConnect (therefore using feedback loop for machine learning estimations). The value stated in report are based on tenders for Urbino 18 electric articulated buses (statistical average energy consumption of the Urbino 18 electric bus: 1.88 kWh/km). The energy consumption stated by Solaris is on electric bus level. It is important to keep in mind that the energy consumption on power grid level will be little bit higher due to power losses on charging infrastructure. The chargers efficiency depends on individual selection of the customer. Based on Solaris Bus & Coach experience the E-SORT test results are not the most precise value to indicate real-life vehicle consumption.

The maintenance stage accounts for all the spare parts that need periodic replacement in the whole buses lifetime. This can include, fluids, air and oil filters, batteries etc.

To illustrate the end-of-life stage of the bus, the vehicle's recyclability and recoverability capacity has been calculated, based on the ISO 22628:2002 standard – "Road vehicles – Recyclability and recoverability – Calculation method". Recyclability rates of the bus is shown in FIGURE 7 and recoverability rates of the bus is shown in FIGURE 8.

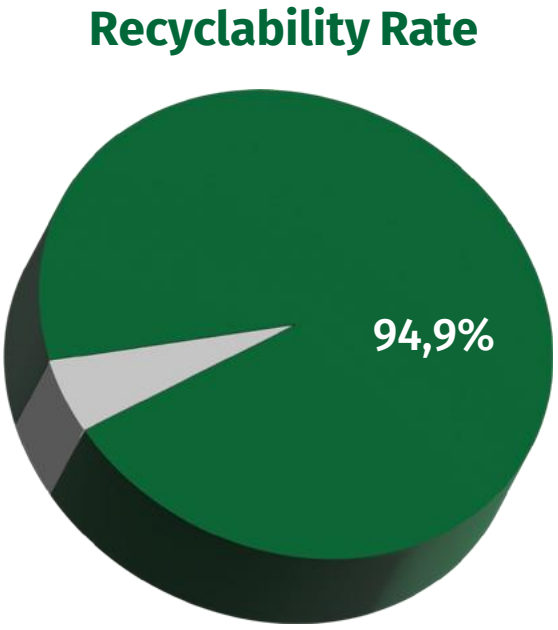


FIGURE 7 RECYCLABILITY RATES OF THE BUS

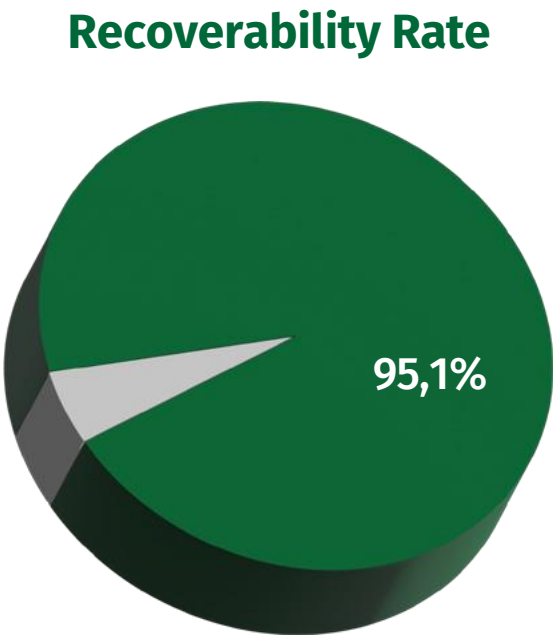


FIGURE 8 RECOVERABILITY RATES OF THE BUS

An LCA model has been made using the Simapro 9.2.0.1 software tool and the Ecoinvent 3.7 life cycle inventories database. The results of the environmental impacts throughout the life cycle of the vehicle have been calculated, as well as the consumption of natural resources and waste management, according to the requirements set out in the PCR 2016: 04 – UN CPC 49112 and 49113 – Public and private buses and coaches. Version 2.0.

The characterization factors used for environmental impact categories calculations, have been derived from the CML-IA environmental impact calculation methodology (version 4.8 – August 2016), from the Intergovernmental Panel on Climate Change (IPCC 2013 – AR5), from the LOTOS-EUROS methodology as applied in the ReCiPe LCIA 2008 method and from the AWARE method on water scarcity (WULCA recommendations on characterization model for water scarcity 2015, 2017). These factors are in line with the recommended databases used in the PCR ("Env. Perf. Indicators | EPD International," n.d.).

4. ENVIRONMENTAL PERFORMANCE

Environmental impacts

TABLE 4 POTENTIAL ENVIRONMENTAL IMPACTS

PARAMETER		UNIT	UPSTREAM	CORE	DOWNSTREAM	TOTAL
Global warming potential (GWP)	Fossil	kg CO2 eq.	2.0E-03	2.3E-04	8.0E-03	1.0E-02
	Biogenic	kg CO2 eq.	2.1E-04	1.5E-06	3.8E-04	5.9E-04
	Land use and land transformation	kg CO2 eq.	4.1E-06	1.2E-06	2.7E-06	8.1E-06
	TOTAL	kg CO2 eq.	2.2E-03	2.3E-04	8.4E-03	1.1E-02
Depletion potential of the stratospheric ozone layer (ODP)		kg CFC 11 eq.	3.1E-10	1.7E-11	2.8E-10	6.1E-10
Acidification potential (AP)		kg SO2 eq.	6.9E-05	1.5E-06	3.7E-05	1.1E-04
Eutrophication potential (EP)		kg $PO4^{3-}$ eq.	2.1E-06	1.4E-07	3.6E-06	5.8E-06
Photochemical oxidant formation potential (POFP)		kg NMVOC eq.	1.7E-05	9.1E-07	2.0E-05	3.8E-05
Abiotic depletion potential – Elements		kg Sb eq.	3.1E-07	5.2E-10	1.6E-07	4.8E-07
Abiotic depletion potential – Fossil resources		MJ. net calorific value	2.3E-02	2.8E-03	9.7E-02	1.2E-01
Water scarcity potential		m3 eq.	2.9E-03	3.0E-05	3.1E-03	6.0E-03

Use of resources

TABLE 5 INDICATORS DESCRIBING USE OF PRIMARY AND SECONDARY RESOURCES

PARAMETER		UNIT	UPSTREAM	CORE	DOWNSTREAM	TOTAL
Primary energy resources – Renewable	Use as energy carrier	MJ, net calorific value	2.6E-02	2.9E-03	1.8E-01	2.0E-01
	Used as raw materials	MJ, net calorific value	3.4E-04	0	5.1E-05	3.9E-04
	TOTAL	MJ, net calorific value	2.7E-02	2.9E-03	1.8E-01	2.0E-01
Primary energy resources – Non-renewable	Use as energy carrier	MJ, net calorific value	2.4E-02	1.8E-02	7.6E-06	4.2E-02
	Used as raw materials	MJ, net calorific value	1.8E-05	0	7.6E-06	2.6E-05
	TOTAL	MJ, net calorific value	2.4E-02	1.8E-02	1.5E-05	4.2E-02
Secondary material		kg	2.6E-02	2.9E-03	1.8E-01	2.0E-01
Renewable secondary fuels		MJ, net calorific value	0	0	0	0
Non-renewable secondary fuels		MJ, net calorific value	0	0	0	0
Net use of freshwater		m3	7.0E-05	7.7E-07	9.2E-05	1.6E-04

Waste production and output flows

TABLE 6 INDICATORS DESCRIBING WASTE PRODUCTION

PARAMETER	UNIT	UPSTREAM	CORE	DOWNSTREAM	TOTAL
Hazardous waste disposed	kg	3.9E-07	2.8E-09	3.1E-07	7.1E-07
Non-hazardous waste disposed	kg	7.9E-04	6.7E-05	7.7E-04	1.6E-03
Radioactive waste disposed	kg	1.0E-07	6.0E-09	1.0E-06	1.2E-06

TABLE 7 INDICATORS DESCRIBING OUTPUT FLOWS

PARAMETER	UNIT	UPSTREAM	CORE	DOWNSTREAM	TOTAL
Components for reuse	kg	0	0	0	0
Material for recycling	kg	2.1E-05	7.3E-06	1.4E-04	1.7E-04
Material for energy recovery	kg	0	2.5E-06	2.2E-05	2.4E-05
Exported energy, thermal	MJ	0	0	0	0

4.1. RESULTS INTERPRETATION

TABLE 8 depicts the environmental profile of Solaris Urbino 18 electric bus over all stages of its lifecycle. The environmental impacts are the most significant in the use stage, originating from the energy consumption due to charging the battery of the bus. These impacts comprise from 27.7% to 68.6% in all categories, except abiotic depletion (elements) and water scarcity potential. These two categories are mainly concerned with consumption of materials and freshwater, which contribution is consequently lower in this stage. The environmental profile of Urbino 18 electric bus is shown in FIGURE 9.

TABLE 8 ENVIRONMENTAL IMPACTS BY LIFE CYCLE STAGE

LIFE CYCLE STAGE	GWP*	POCP	AP	EP	ADP-EL	ADP-FF	WSP
Raw Material acquisition	18.8%	42.5%	63.1%	33.4%	65.9%	18.3%	47.7%
Raw material transport	0.7%	2.7%	1.1%	2.1%	0.0%	0.8%	0.0%
Bus manufacturing	1.8%	2.1%	1.3%	2.1%	0.1%	1.8%	0.5%
Transport to client	0.4%	0.3%	0.1%	0.2%	0.0%	0.5%	0.0%
Bus use	66.2%	42.0%	27.7%	50.5%	4.4%	68.6%	9.4%
Bus maintenance	10.4%	9.9%	6.3%	11.0%	29.4%	9.6%	42.0%
End of life	1.7%	0.6%	0.3%	0.6%	0.1%	0.4%	0.4%

*Global warming potential (100y) | Photochemical oxidation | Acidification potential | Eutrophication potential | Abiotic depletion potential – Elements | Abiotic depletion potential – Fossil fuels | Water scarcity potential

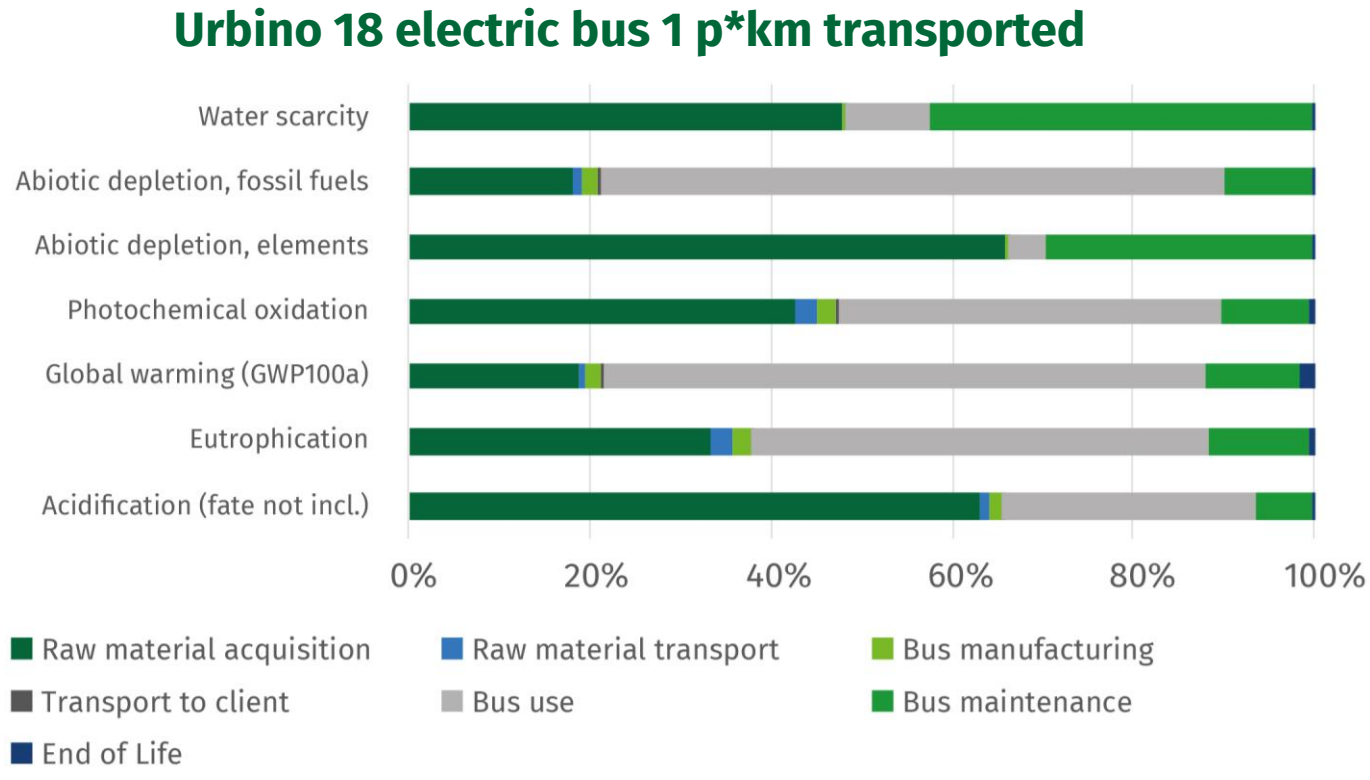


FIGURE 9 ECO PROFILE OF E18 BUSE

4.2. SENSITIVITY ANALYSIS

Solaris Urbino 18 electric bus operates in multiple cities all over Europe. For the base case scenario in the operation stage, the average low voltage European electricity (residual) mix was used. However, to obtain more detailed environmental profile of the operation stage, it is necessary to study the influence of geographical location. For this reason, a sensitivity analysis was performed varying the impact of the electricity consumed during the use stage of the bus, depending on the country of use. The following scenarios were assessed: Spain, Europe, Poland, Germany, France and Sweden (see FIGURE 10).

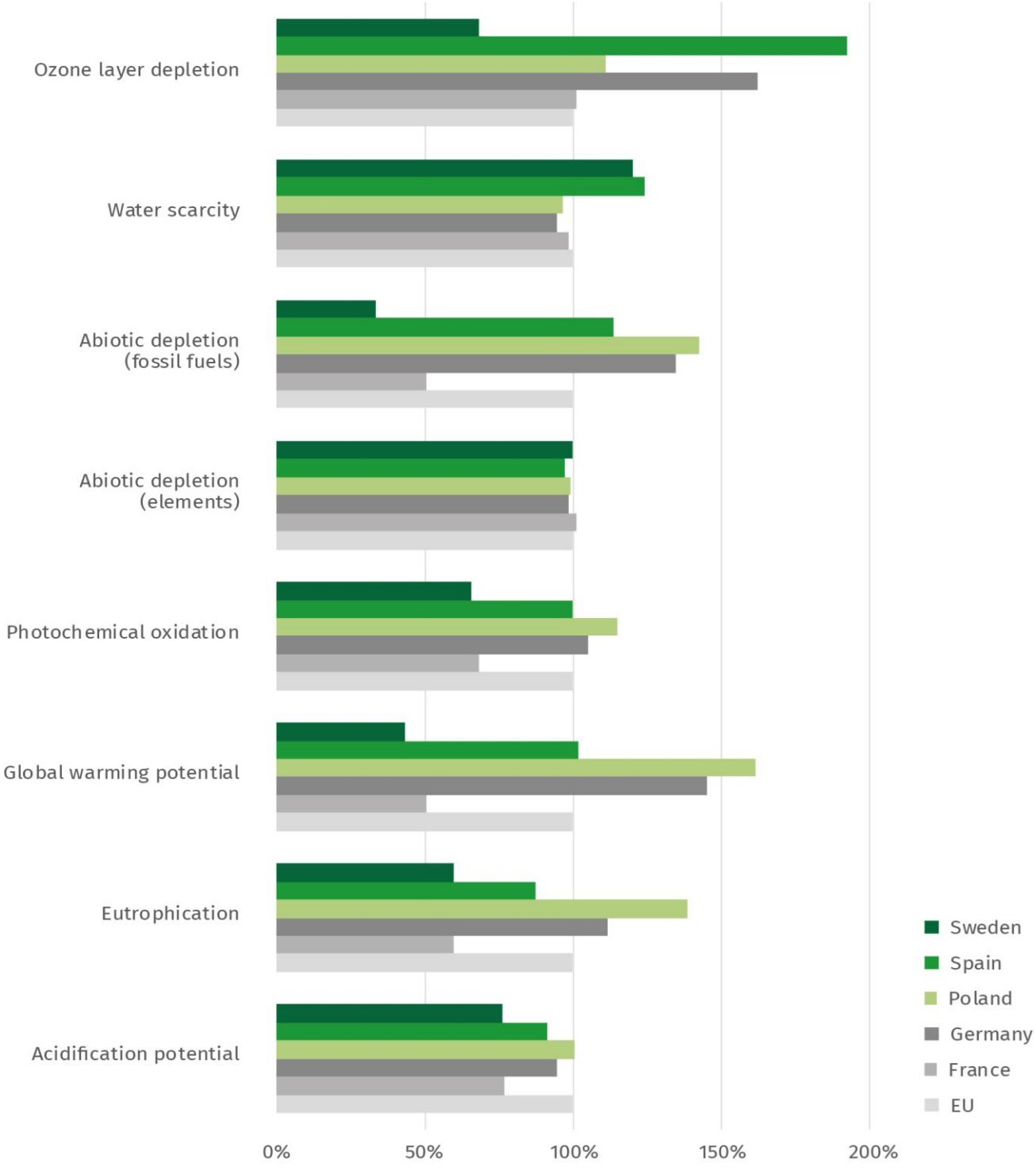


FIGURE 10 SENSITIVITY ANALYSIS OF TOTAL BUS PER FUNCTIONAL UNIT – DEPENDING ON THE USE COUNTRY

Overall, it can be concluded that the use stage location is of vital relevance for this type of product, since the impacts are highly sensitive to the environmental impact of the electrical mix consumed when charging the batteries. The climate change potential of each p*km transported, can have up to 66% less impact in the most favourable use case (Sweden), or even have an impact up to 61% higher in the most unfavourable use case (Poland). In ozone depletion and water scarcity category Spain performs the worst. In the rest of the categories Poland had a dominating impact (although results are comparable for all countries for abiotic depletion and comparable to the EU for acidification). Sweden and France have in general a low environmental impact. The impacts of Spain and Germany are quite close to the EU average.

5. INFORMATION ON THE VERIFICATION SYSTEM

The EPD owner has the sole ownership, liability and responsibility of the EPD. The verifier and the programme operator do not make any claim nor have any responsibility of the legality of the product. Note that EPDs of the same product category but from different programmes may not be comparable.

Programme	The International EPD® System EPD International AB | Box 210 60 | SE-100 31 Stockholm | Sweden www.environdec.com | info@environdec.com
Program Operator	EPD International AB
Registration Number	S-P-05329
EPD Version	1.0
Publication Date	31 March 2022
Validity	30 March 2027
Scope	Cradle-to-grave
Geographical Validity	Europe
Product Category Rules	PCR 2016:04 – UN CPC 49112- 49113 Public and private buses and coaches. Ver 2.0
Review of the Product Category Rules (PCR) conducted by	The Technical Committee of the International EPD® System Chair: Maurizio Feschi Contact via: info@environdec.com
Product Category Rules (PCR) prepared by	The Technical Committee of the International EPD® System PCR Moderator: Gorka Benito Alonso, IK INGENIERIA Contact via: g.benito@ik-ingenieria.com
Product group code	UN CPC 49112 and 49113
Independent verification of the data and declaration, as per ISO 14025:2006	☐ EPD process certification ☒ EPD verification
The procedure for monitoring the EPD during its validity period requires external verification	☒ Yes ☐ No
Verifying entity	Leo Breedveld, 2B Srl Contact via: breedveld@to-be.it Approved by: The International EPD® System
LCA study conducted by	TNO innovation for life www.tno.nl
Name of the company and contact	SOLARIS Solaris Bus & Coach sp. z o.o. Obornicka 46, Bolechowo-Osiedle 62-005 Owińska, Poland www.solarisbus.com

FIGURE 11 INFORMATION ON THE VERIFICATION SYSTEM

6. EXTERNAL REFERENCES

SOLARIS

www.solarisbus.com

Solaris Sustainability Report

Solaris_Sustainability_Report_2020.pdf_(solarisbus.com)

*EPD Chapter 1 – Solaris Introduction and EPD Chapter 2 – Solaris Urbino 18 electric bus were provided by the Solaris Team (reference to the email on 1 December 2021 from Weronika Krzywicka-Styzińska, Environmental Projects Coordinator Solaris)

Additional information on the International EPD® System

www.environdec.com

The International EPD® System is based on a hierarchical approach using the following international standards:

– ISO 9001, Quality management systems

– ISO 14001, Environmental management systems

– ISO 14040, LCA – Principles and procedures

– ISO 14044, LCA – Requirements and guidelines

– ISO 14025, Type III environmental declarations

www.iso.org

PCR:

PRODUCT CATEGORY RULES (PCR). Public and private buses and coaches. Product Category Classification: UN CPC 49112 & 49113. PCR 2016:04 VERSION 2.0 DATE 2020-12-04

Database used for the LCA:

An LCA model has been made using the Simapro 9 software tool and the Ecoinvent 3.7.1 life cycle inventories database.

www.simapro.com

www.ecoinvent.org

TNO

www.tno.nl

7. VERSION HISTORY OF EPD

VERSION 1.0, 2022: First registration