FLEXITY™ TRAM

EPD®

Environmental Product Declaration in accordance with ISO 14025

EPD registration number: S-P-00521
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ALSTOM
• mobility by nature •

ALSTOM, AT THE FOREFRONT OF SUSTAINABILITY

Alstom develops and offers a range of systems, equipment and services for the rail sector and considers its mission to support the transition towards global sustainable transport systems that are inclusive, environmentally-friendly, safe and efficient.

As a promoter of sustainable mobility, Alstom places environmental issues at the heart of its Research and Development strategy, constantly designing solutions and products which are less energy-consuming, quicker to install, cheaper to maintain, with higher lifespan and reduced carbon footprint.

For more than 25 years, the company has systematically introduced Ecodesign in its engineering procedures. Today, Alstom can rely on a team of Ecodesign engineers to ensure the environmental performance of its product portfolio and is able to develop innovative solutions tackling key environmental challenges.

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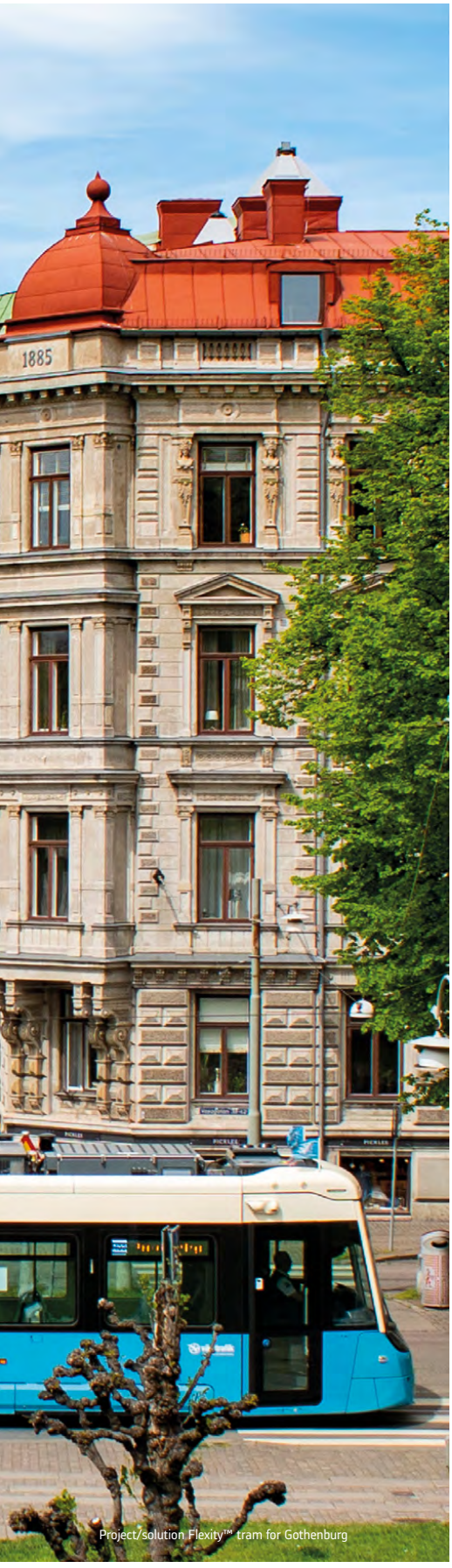


Project/solution Flexity™ tram for Gothenburg

SUSTAINABLE MOBILITY

ENVIRONMENTAL MANAGEMENT

ISO 14001

Alstom has an environmental management system fully in place and targets 100% of manufacturing sites and regional centers with over 200 employees to be certified according ISO14001:2015 Standard for Environmental management.

In the environmental management system, Alstom is including the life cycle perspective of products, from concept to end-of-life including maintenance and energy consumption. Alstom offers innovative solutions that respect the environment and meet the mobility needs according to a socially responsible model.

To continuously improve Alstom products and ways of working, environmental targets for sites and products are implemented and regularly evolved following experience feedback and best practice.

COMMUNICATING ENVIRONMENTAL PERFORMANCE

ISO 14025

Alstom communicates the environmental performance of products through Environmental Product Declarations (EPDs) following the International EPD® System. EPDs are developed in line with the Product Category Rules for Rolling Stock (PCR 2009:05) as well as the principles and procedures of ISO 14025:2006. They are based on Life Cycle Assessment methodology and function as an externally validated communication tool, providing complete transparency to the benefit of our customers and other stakeholders. The external validation is carried out by independent verifiers approved by the technical committee of the International EPD® System.

Life cycle assessment (LCA) is a technique assessing the environmental impact associated with all stages of a product's life from cradle to grave (i.e. from raw material extraction through materials processing, manufacturing, distribution, use, repair and maintenance, and disposal or recycling).

FLEXITY™ TRAMS FOR GOTHENBURG

The Flexity™ product platform sets a high standard for environmentally sustainable inner-city transportation. This Environmental Product Declaration provides a detailed insight into the environmental impact of the Flexity™ M33 trams for Gothenburg transit authority, Göteborgs Spårvägar AB, throughout its complete life cycle.

The new vehicles replace a part of the current fleet and provide environmentally friendly, high-capacity transportation to accommodate the rapidly growing population in Gothenburg and the surrounding region. Passengers with reduced mobility will benefit from the low-floor vehicles, which also provide dedicated space for wheelchairs, offering a convenient and comfortable ride for everyone.

MAIN FACTS

The Flexity™ M33 vehicles are designed to support the further development of the growth of the city's 160-kilometre light rail transit system, which is the largest in Sweden.

The vehicles will operate at speeds up to 70 km/h with space for 75/62 seated passengers and 145/158 standees for Type A (unidirectional) and Type B (bi-directional) respectively.

KEY BENEFITS OF FLEXITY™ M33 TRAMS

A SAFER ENVIRONMENT

A vehicle developed with a strong emphasis on our commitment to eliminating hazardous substances in the product as well as during production providing a safer environment for our customers, passengers and employees.

A SATISFACTORY WORKING ENVIRONMENT

A cab optimized and studied to provide a satisfactory working environment for the driver, including separate air conditioning control.

HIGH ENERGY EFFICIENCY

Alstom's energy-efficient Flexx™ Eco bogies and propulsion system from Kiepe-Electric will reduce maintenance costs and increase energy efficiency while further enhancing passenger comfort by minimizing noise.

A VEHICLE DESIGNED FOR ALL

A vehicle designed for all, the low-floor vehicles provide obstacle-free access to passengers, space for wheelchairs, and are supported by an electromechanical boarding device. Special seating including tip-up seats and XL-seats for priority passengers provide additional flexibility in everyday operation.

DESCRIPTION OF THE PRODUCT

MAIN CHARACTERISTICS

	Vehicle data
Type of vehicle	Flexity™ tram
Configuration	3-cars; low-floor
Length / Height / Width	33 m / 3.620 m / 2.650 m
Maximum axle load	8.5 metric tonne
Weight (empty)	Type A/B: 47 500 / 48 750 kg
Vehicle weight (loaded, 4 pers./m²)	Type A/B: 64 300 / 65 700 kg
Gauge	1.435 m
Wheel diameter (new wheels)	630 mm
Doors per side	Type A: 6 / Type B: 10
Door width	1 300 mm
Seats	Type A: 75 (+5) / Type B: 62 (+8)
Total capacity (4 persons/m²)	Type A: 220 / Type B: 220
Wheelchair places	2
Voltage	750 V DC
Motor	6 motors (each 120 kW)
Energy consumption	Type A / B: 4.84 / 4.89 kWh/km
Maximum operation speed	70 km/h
Maximum acceleration	0.6 m/s²
Maximum deceleration	1.4 m/s²

Carbody:
Steel structure

Comfort:
Efficient air-conditioning ventilation system in both passenger saloon and driver cab

Propulsion and electrical equipment:
Energy recovery through braking

Material selection:
Materials selected to be recoverable at end-of-life

NOISE EMISSIONS

The noise levels for Flexity™ M33 tram were determined in accordance to the ISO 3095.

	Unit	dB(A) (1.2 m/3.5 m)
Standstill noise partial load	LpAeq,T	≤ 52/55
Standstill noise full load	LpAeq,T	≤ 59/62
Starting noise	LpAFmax	≤ 75
Braking noise	LpAFmax	≤ 75
Pass-by noise at 60 km/h	TEL	≤ 77
Pass-by noise curve R20 m	LpAFmax	≤ 78
Pass-by noise curve R25 m	LpAFmax	≤ 78

LIFE CYCLE DESCRIPTION

Environmental impacts of Flexity™ M33 trams for Gothenburg have been characterized through the realization of an LCA in accordance with ISO 14040:2006 methodology, and the requirements of the PCR Rolling stock, UN CPC 495, 2009:05, version 3.04.

The GaBi Software-System and Databases for Life Cycle Engineering (Sphera Solutions GmbH, 2021) were used to perform this life cycle impact assessment. The used GaBi databases have reference years between 2017-2020 and are valid to 2023.

FUNCTIONAL UNIT

The functional unit for the performed LCA is transport of 1 passenger over 1 km using a 3-car Flexity™ M33 Type B light-rail vehicle in service for 30 years operating on Line 6 between Kortedala and Länsmansgården in Gothenburg, with an average running distance of 100 000 km per year. All assumptions on vehicle auxiliary systems load are following the methodology and operational profiles used for the energy consumption simulation. This is also the base for calculating the impacts for all maintenance activities during the vehicle's service life.

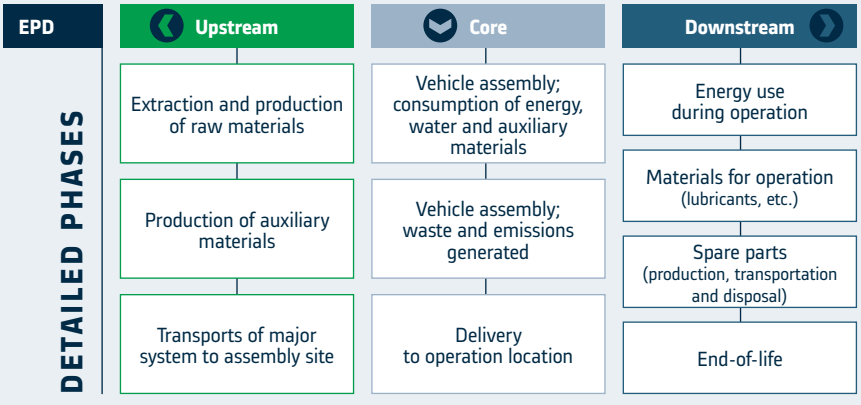
LIFE CYCLE BOUNDARIES

Material and energy production used upstream is considered to be country specific based on data from the supply chain. Site-specific data covering the production in 2019 for the assembly of bogies in Siegen (Germany) has been included. Transportation of vehicle sub-systems is also included in the calculation of the different impact categories.

The Core module considers the impacts from final vehicle assembly in Bautzen (Germany) as a result of the used energy and auxiliary materials. Generated waste and emissions as well as the impacts from final transportation of the vehicle to the Customer are also included. Data related to production in 2019 was considered.

The power supply for the vehicle operation is considered to be Bra Miljöval Vind from Vattenfall as delivered to Göteborgs Spårvägar AB in 2020. Data for maintenance materials used is based on the planned preventive maintenance of the vehicle over its entire life.

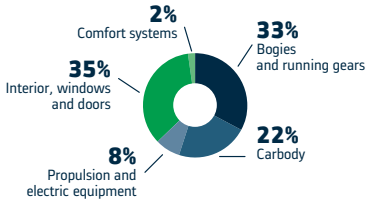
The end-of-life phase of the life cycle is modelled according to technology available today applying the UNIFE methodology. It is assumed that the vehicle will be dismantled and disposed of in Sweden (Europe). The potential benefit from material recycling and energy recovery is not included calculation of the environmental impacts.



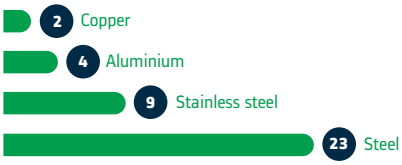
BILL OF MATERIALS

(mass in kg)	Upstream (vehicle)	Downstream (spare parts)	TOTAL
Metals	38 494	27 148	**65 642**
Electric and Electronic Equipment (EEE)	839	1 649	**2 487**
Polymers - filled and unfilled	2 408	581	**2 989**
Elastomers	993	1 098	**2 091**
Composites	35	5	**40**
Glass / Safety Glass	1 599	2	**1 601**
Oil, grease, etc.	21	1	**21**
Acids, Cooling agents, etc.	19	17	**36**
Modified Organic Natural Materials (MONM)	3 382	2 363	**5 745**
Other	921	542	**1 462**
TOTAL	**48 711**	**33 404**	**82 115**

Rolling stock manufacturing: Share of mass by PCR categories

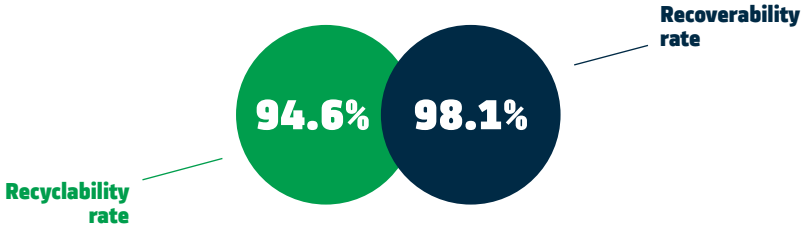


Rolling stock: Top four metals for manufacturing
(metric tonne)



A RECYCLABLE SOLUTION

Using materials featuring high recyclability and considering disassembly early in the design phase maximise the overall recoverability of the Flexity™ M33 tram for Gothenburg vehicle. Material recycling and energy recovery aggregate to a 98.1% recoverability rate by applying the UNIFE Recyclability and Recoverability calculation methodology for rail vehicles.



HAZARDOUS SUBSTANCES

Alstom's standard for management of hazardous substances incorporates the European regulations (including REACh) and railway sector principles through the RISL (Railway Industry Substances List), which has been considered during the design of the vehicle as well as for chemicals used during maintenance.
In some areas, use of hazardous substances according to RISL has been unavoidable due to functional and safety requirements, including lead in electronics and brass details as well as the refrigerant gas mix used for the HVAC. However, no hazardous substances are used in any prohibited applications at the time of production of the Flexity™ M33 tram for Gothenburg vehicles.

ENERGY CONSUMPTION DURING OPERATION

The energy consumption of the Flexity™ M33 tram for Gothenburg Type B vehicle is 4.89 kWh/km. Energy consumption data is based on a simulated run on Line 6 between Kortedala and Länsmansgården with 45 intermediate stops and a total length of 24.8 km. The assumption is that the vehicle is fully loaded with 220 passengers, and all auxiliary and passenger comfort systems operating at normal conditions. Regenerative braking is included with up to 2.22% depending on the environmental conditions.

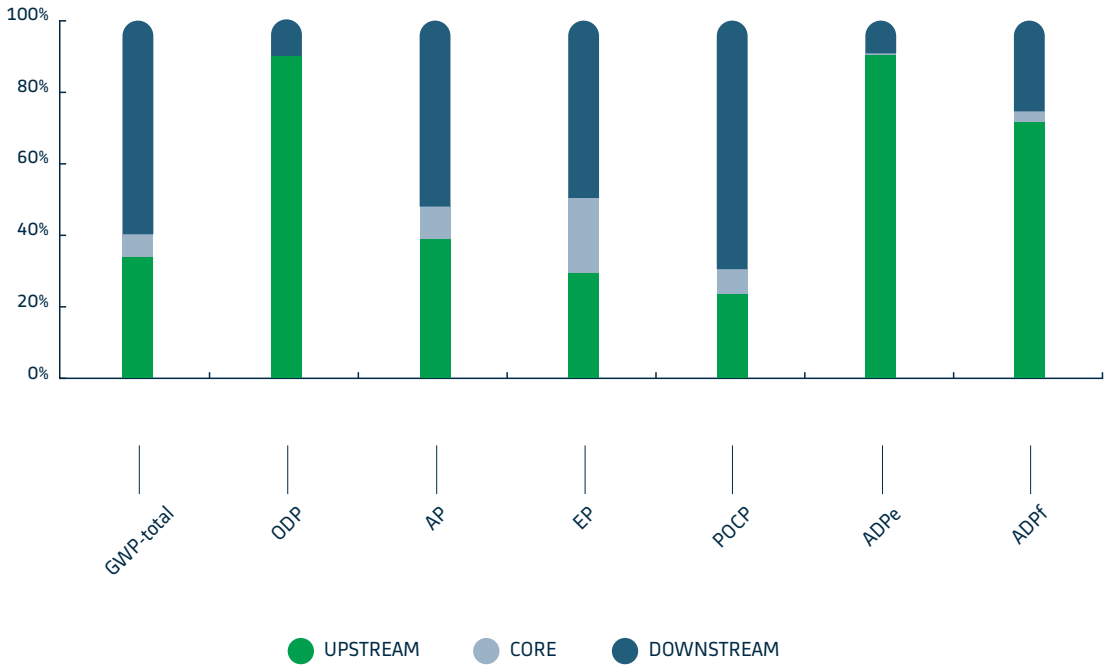
Göteborgs Spårvägar AB uses wind energy from Vattenfall AB labelled with "Bra Miljöval". The environmental impact from the electricity generation has been modelled based on the information in the provided Environmental Product Declaration from Vattenfall for the yearly production for 2020. The values for Delivered amount of electric power to the customer where used, corresponding to GHG emissions of 15.5 g CO_2-eq/kWh.

	Operation
Distance travelled per year	100 000 km
Vehicle lifetime	30 years
Number of passenger	220
Energy consumption	0.022 kWh /pass. km

ENVIRONMENTAL PERFORMANCE

CONTRIBUTION OF EACH PHASE TO THE ENVIRONMENTAL IMPACTS

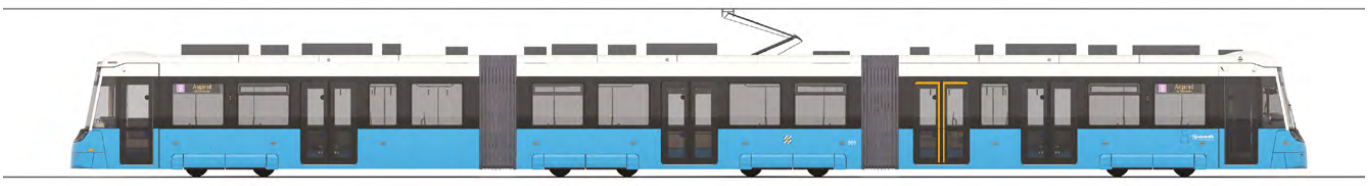
The relative contribution from each phase of the life cycle of Flexity™ M33 tram for Gothenburg vehicle, for each impact category, is shown in the figure below.



CONFIGURATIONS

Life cycle description information and environmental performance results published in this EPD correspond to the reference design configuration developed by Alstom.

To know the performance associated to other possible configurations of the solution, please contact Alstom.



ENVIRONMENTAL IMPACTS

Indicator per functional unit	Unit	Upstream	Core	Downstream	TOTAL
Global warming potential (GWP) - Total	kg CO_2 eq. /pass. km	2.40E-04	4.67E-05	4.26E-04	**7.13E-04**
Global warming potential (GWP) - Fossil	kg CO_2 eq. /pass. km	2.48E-04	4.17E-05	4.31E-04	**7.21E-04**
Global warming potential (GWP) - Biogenic	kg CO_2 eq. /pass. km	-8.63E-06	3.50E-06	-5.13E-06	**-1.03E-05***
Global warming potential (GWP) - Land use and land use change	kg CO_2 eq. /pass. km	3.30E-07	1.44E-06	1.02E-07	**1.87E-06**
Emission of ozone-depleting gases (ODP)	kg CFC 11-eq /pass.km	2.50E-14	1.03E-19	2.76E-15	**2.78E-14**
Acidification potential (AP)	kg SO_2 eq. /pass. km	1.08E-06	2.53E-07	1.44E-06	**2.77E-06**
Eutrophication potential (EP)	kg PO_4^{3-} eq. /pass. km	7.43E-08	5.32E-08	1.26E-07	**2.53E-07**
Photochemical oxidant creation potential (POCP)	kg C_2H_4 eq. /pass. km	8.84E-08	2.60E-08	2.62E-07	**3.76E-07**
Depletion of abiotic resources-elements (ADPe)	kg Sb-eq /pass.km	1.01E-08	4.30E-11	1.03E-09	**1.12E-08**
Depletion of abiotic resources-fossil fuels (ADPf)	MJ /pass.km	3.27E-03	1.44E-04	1.16E-03	**4.57E-03**

* The Total value for GWP-biogenic is negative over the entire life-cycle of the vehicle as a result of the amount of MONM used in the vehicle design (manufacturing and maintenance) as well as the material recycling factor (95%) based on UNI-LCA-001:00 calculation method. As a result, only 5% of all MONM used during the vehicle lifetime is considered to be incinerated, thus releasing a small fraction of the bound amount of biogenic CO_2. Normally, biogenic CO_2 emissions have a net-zero effect on GWP from a life-cycle perspective over long periods of time.

GLOBAL WARMING POTENTIAL

These indicators calculates the contribution to global warming of the planet by the emission of greenhouse gases.
GWP is expressed as: GWP-fossil, GWP-biogenic,GWP-land use and land use change (luluc),and GWP-Total (the sum of the other three GWP indicators).

The result is expressed in kg CO_2 equivalents.

ACIDIFICATION POTENTIAL

This indicator calculates the potential atmospheric acidification caused by emission to air of gas with an acidifying effect.

The result is expressed in kg SO_2 equivalents.

PHOTOCHEMICAL OXIDANT CREATION POTENTIAL

This indicator calculates the potential of certain gases (NOx, CO, VOCs, etc.) to create ozone in the troposphere under the effect of solar radiation.

The result is expressed in kg ethylene equivalents.

EMISSION OF OZONE-DEPLETING GASES

This indicator calculates the contribution made by the discharge of specific gases responsible for ozone layer depletion.

The result is expressed in kg CFC-11 equivalents.

EUTROPHICATION POTENTIAL

This indicator calculates the eutrophication of water caused by the emission of specific substances (discharge of phosphoric, nitrogenous and organic matter).

The result is expressed in kg phosphate equivalents.

DEPLETION OF ABIOTIC RESOURCES-ELEMENTS

This Indicator calculates the depletion of natural non-fossil resources.

The result is expressed in kg of Sb equivalents.

DEPLETION OF ABIOTIC RESOURCES-FOSSIL FUELS

This indicator calculates the depletion of natural fossil resources.

The result is expressed in MJ.

USE OF RESOURCES

Parameter		Unit	Upstream	Core	Downstream	TOTAL
RENEWABLE RESOURCES						
Primary energy resources	Use as energy carrier	MJ, net calorific value /pass. km	1.71E-04	1.37E-03	8.02E-02	**8.18E-02**
	Used as raw materials	MJ, net calorific value /pass. km	7.49E-04	1.77E-05	3.32E-04	**1.10E-03**
	TOTAL	**MJ, net calorific value /pass. km**	**9.20E-04**	**1.39E-03**	**8.06E-02**	**8.29E-02**
NON-RENEWABLE RESOURCES						
Primary energy resources	Use as energy carrier	MJ, net calorific value /pass. km	7.07E-04	9.25E-05	2.37E-04	**1.04E-03**
	Used as raw materials	MJ, net calorific value /pass. km	2.85E-03	6.75E-05	1.22E-03	**4.13E-03**
	TOTAL	**MJ, net calorific value /pass. km**	**3.55E-03**	**1.60E-04**	**1.45E-03**	**5.17E-03**
Secondary material		kg /pass. km	N/A	N/A	N/A	**N/A**
Renewable secondary fuels		MJ, net calorific value /pass. km	N/A	N/A	N/A	**N/A**
Non-renewable secondary fuels		MJ, net calorific value /pass. km	N/A	N/A	N/A	**N/A**
Net use of fresh water *		m^3 /pass. km	9.31E-04	7.08E-05	2.63E-04	**1.27E-03**

* The Net use of fresh water does not constitute a "water footprint" as potential environmental impacts due to the water use in different geographical locations has not been captured.

WASTE

Parameter	Unit	Upstream	Core	Downstream	TOTAL
Hazardous waste disposed	kg /pass. km	9.52E-08	8.81E-13	2.10E-10	**9.54E-08**
Non-hazardous waste disposed	kg /pass. km	3.40E-05	3.48E-06	2.10E-05	**5.85E-05**
Radioactive waste disposed	kg /pass. km	9.87E-08	5.64E-09	1.96E-08	**1.24E-07**

OUTPUT FLOWS

Parameter	Unit	Upstream	Core	Downstream	TOTAL
Components for reuse	kg /pass. km	N/A	N/A	N/A	**N/A**
Material for recycling	kg /pass. km	N/A	N/A	1.16E-04	**1.16E-04**
Materials for energy recovery	kg /pass. km	N/A	N/A	3.84E-06	**3.84E-06**
Exported energy, electricity	MJ /pass. km	N/A	N/A	N/A	**N/A**
Exported energy, thermal	MJ /pass. km	N/A	N/A	N/A	**N/A**

PROGRAMME RELATED INFORMATION AND VERIFICATION

This Environmental Product Declaration (EPD) is based on a product Life-Cycle Assessment according to ISO 14040:2006/ISO 14044:2006 and is compliant with the requirements set in ISO 14025:2006.

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):
Rolling stock, PCR 2009:05, version 3.04, UN CPC 495

PCR review was conducted by:
The Technical Committee of the International EPD® System. Chair: Gorka Benito Alonso.
The PCR review panel may be contacted via info@environdec.com.

Independent verification of the declaration and data, according to ISO 14025:2006:

☐ EPD Process Certification (internal)

■ EPD Verification (external)

Third party verifier:
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Approved by:
The International EPD® System

EPD®s within the same product category but from different programs may not be comparable.

Programme:	The International EPD® System EPD International AB Box 210 60 SE-100 31 Stockholm Sweden www.environdec.com
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