SPACIUM

Environmental Product Declaration

The Climate is Right for Trains

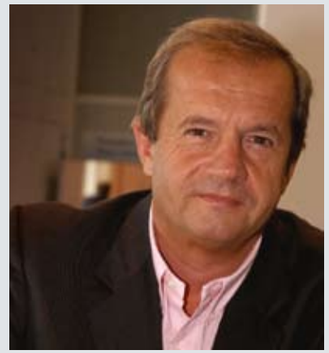
BOMBARDIER

Design for Environment -
environmental sustainability at the core of product development

« Rail transportation has a high efficiency and natural advantage whether we are talking about capacity, energy, space or time. Nevertheless it is Bombardier's aim to further strengthen this natural advantage and we therefore always work to continuously improve the environmental efficiency of our vehicles. The *BOMBARDIER ECO4* portfolio is one way to ensure that our products have outstanding environmental performance by combining energy efficient technology with optimal safety, reliability and cost efficiency.

Our vehicles are designed for a wide range of passengers: children, youth, adults and elderly people. We therefore also put a strong focus on minimising the use of hazardous materials and related toxic emissions as well as materials that are complex to recycle.

This Environmental Product Declaration will provide you with valuable and relevant information on the environmental impact throughout all life cycle phases of the *SPACIUM* train. »



Jean Bergé
President,
Bombardier Transportation France

At Bombardier Transportation we are dedicated to developing products and services that combine energy efficient technology, optimal safety, reliability and cost efficiency. They are designed for sustainable mobility throughout their life cycle.

The integration of environmental sustainability into product development has a long proven history at Bombardier Transportation, where it has a core function in designing state-of-the-art rail transportation equipment.

Our unique Design for Environment (DfE) approach, applying a complete life cycle perspective, is central to our product responsibility strategy. Maximising energy and resource efficiency, minimising hazardous substances and related toxic emissions as well as enhancing the overall product recyclability rate is the result of a high quality working process applied to product design and cascaded down our supply chain.

The Bombardier Transportation Design for Environment Centre of Competence, together with our entire DfE expert network, acts as a catalyst by providing the essential tools, expertise and central coordination in projects worldwide.

Transparent communication of environmental efficiency

We choose to communicate the environmental efficiency of our products through Environmental Product Declarations (EPDs) following the international EPD® system. EPDs are part of *the BOMBARDIER* ECO4** portfolio and provide full transparency to the benefit of our customers. An EPD is a communication tool providing relevant, verified and comparable information to meet customer and market requirements. The international EPD® system has the ambition to help and support organisations developing EPDs in a structured and reliable way according to ISO 14025.

This EPD gives an insight into the environmental efficiency of the SNCF Francilien commuter train, built on the *BOMBARDIER* SPACIUM** platform, through all phases of the vehicle life cycle. It follows ISO 14025:2006 as well as the Product Category Rules for Rail Vehicles (PCR 2009:05, version 1.1)[1] and is validated by an independent external verifier approved by the technical committee of the international EPD® system.

More information on the international EPD® system is available at www.environdec.com.

[1] Product Category Rules (PCR) for preparing an environmental product declaration (EPD) for rail vehicles, UNCPC CODE: 495, PCR 2009:05, version 1.1, International EPD Consortium (IEC).

The SPACIUM train - helping cities breathe

The *SPACIUM* train is a rapid, flexible vehicle designed to provide maximum seating capacity, superior passenger comfort, improved access and an attractive interior design.

Based on the principles of modularity and flexibility, the *SPACIUM* train belongs to a product family that meets all requirements of suburban operation whilst addressing infrastructure constraints.

The vehicle can be adapted to meet various platform lengths with seven and eight-car versions and is designed to adapt to all voltages of the European networks. It also provides a high level of reliability by incorporating proven technology that is already in commercial service. The trains can travel at a speed of 140 kilometres per hour.

The *SPACIUM* train is an articulated vehicle, composed of compact, extra-wide cars, providing particularly spacious passenger areas. The train is designed to offer excellent passenger comfort and safety whilst providing maximum seating capacity. According to interior layout and the number of cars, between 800 and 1,000 passengers can be accommodated, over half of whom are seated.

Large vestibules, combined with wide doors and gangways, provide excellent access for travellers and improve passenger flow. The train's entrance is positioned to match 920 mm high platforms, with end-cars accessible to wheelchairs from 920 mm high platforms. Panoramic windows and large gangways create a transparent and open atmosphere.

SNCF ordered 172 seven and eight-car *SPACIUM* trains for the Ile-de-France region and specified stringent requirements making this train a point of reference in terms of environmental performance.

Vehicle Specifications[2]	
Primary power supply	dual voltage 25 kVac & 1.5 kVdc
Mass 8 cars (max.)[3]	240 t
Length (8 cars)	112.5 m
Overall width	3.06 m
Height	
Top of rail to top of A/C Unit	4,280 mm
Top of rail to floor	985 mm
Floor to ceiling	2,038 mm
Wheel Diameter	840 mm
Truck wheelbase	1,900 mm / 6'3"
Auxiliary power supply	400 Vac, 3-phase
Low-voltage power supply	72 Vdc

[2] Based on one empty car.
[3] Weight depends on customer specific equipment request.

Technical information

Implementing environmental sustainability within product development has a commanding impact on vehicle design, resulting in the high overall recyclability and energy efficiency as well as the low noise levels of the *SPACIUM* train.

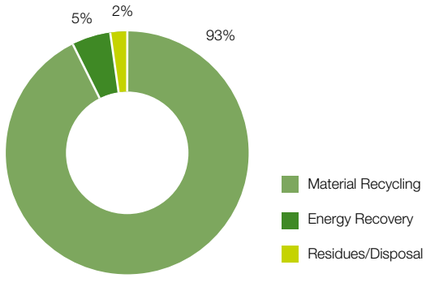
Material content

The table details the material content of the *SPACIUM* train as well as all materials required for maintenance during a 40 year operation. Materials are classified according to ISO 22628:2002. Recycled material content has been estimated to approximately 35% by weight for an 8-car configuration.

Materials used (kg) Based on 8-car trainset	Manufacturing	Maintenance	Total
Metals	209,083	131,387	340,470
Polymers	13,117	13,327	26,444
Elastomers	6,504	7,169	13,673
Glass	5,479	4,647	10,126
Fluids	1,800	3,052	4,852
MON	1,690	3,216	4,906
Others	4,679	35, 803	40,482
Total	242,352	198,601	440,953

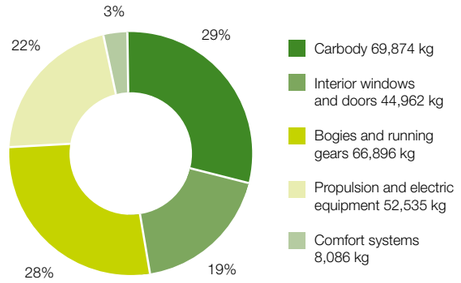
Recyclability and recoverability

Using materials featuring high recyclability, marking major plastic components and considering disassembly and dismantling early in the design phase maximise the overall product recyclability and recoverability rate. The *SPACIUM* train is delivered with a recycling manual which facilitates the end of life treatment and ensures that the process follows a high standard in terms of quality and safety. The projected recyclability and recoverability rate at the end of life phase of the *SPACIUM* train are 93% and 98% by weight respectively, following ISO 22628 methodology.



Modular structure

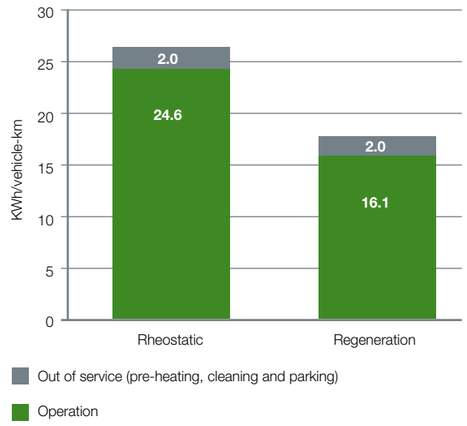
The *SPACIUM* train is classified as a suburban passenger service vehicle. The table shows the vehicle modular structure.



Energy efficiency

Regenerative braking, LED technology, using passenger counting to optimise HVAC system efficiency and a sustained effort to reduce weight throughout the design phase, all contribute to maximising the energy efficiency of the *SPACIUM* train.

The projected energy consumption is based on a simulation for the operational profile of the Paris Gare de Lyon-Corbeil Essonnes route, including curves, altitude, time table and characteristics of the electric supply system[4]. All assumptions on vehicle operation and auxiliary systems are based on EC Contract No. FP6-031458[5]. The load considered is 906 passengers, that correspond to a full seat occupancy and 4 passengers/m² in the standing areas. In the simulation two different operational scenarios are considered: regeneration, where all braking energy is generated in the catenary and rheostatic, where all electricity is dissipated.



The reported figures include energy consumed for propulsion and operation of auxiliary systems on board the *SPACIUM* train as well as pre-heating/pre-cooling, cleaning and parking. Values are per vehicle, for a covered distance of 1km. Note that the model used tends to overestimate the energy consumption. It is expected that the energy consumed would be lower in actual conditions, especially if the driver applies an energy efficient driving style.

Noise

The *SPACIUM* train fulfils the TSI Noise requirements with a large margin. Exterior sound level measurements follow ISO 3095 methodology[6].

Noise	Exterior dB(A)
Standstill	< 68
Starting	< 82
Pass by (80 km/h)**	< 81

**measured on a TSI Noise reference track.

[4] Bombardier Document No. 3EST000213-3881 Performances véhicule NAT.
[5] « Specification and verification of energy consumption for railway rolling stock » - Railenergy WP 2.2: Input to future UIC/UNIFE Technical Recommendation (EC Contract No. FP6 - 031458).
[6] Bombardier Document No. IF-934-0292-4 Bruit en environnement et en cabine de conduite pour l'homologation du train - Rapport d'essais de type.

Highlighted features

Applying life cycle thinking when developing the *SPACIUM* train has allowed us to maximise environmental efficiency while meeting passenger requirements and expectations.

High capacity
An extended width of 3.06 m provides higher seating capacity while maintaining passenger comfort. Increasing vehicle capacity reduces the frequency of journeys required to operate a specific route, making the *SPACIUM* train a highly energy efficient regional commuter vehicle.

Material selection
Screening out materials having an impact on health and environment is a main focal point in product design. Applying a Project Prohibited & Restricted Substances List[7], combining requirements from Bombardier Transportation and SNCF, has resulted in the near elimination of Chromium VI as well as formaldehyde emitting materials.

[7] Bombardier Document No. 3EST 7-3118 NAT Project Prohibited & Restricted Substances List.

LED lighting
Besides contributing to comfort and aesthetics, LED lighting reduces replacement intervals and energy consumption by a factor of eight when compared to traditional technology.

Energy recuperation
The *SPACIUM* train is equipped with an electrical braking system that significantly reduces the need for mechanical braking and recovers the braking energy by reintroducing it into the catenary. Electrical braking also results in a dramatic reduction in brake dust emissions.

ECO4 compatibility
As one of Bombardier's latest train developments, the *SPACIUM* train is compatible with Bombardier's *ECO4* technologies which, when combined, can provide energy savings of up to 50%. *ECO4* technologies include the *BOMBARDIER* EBI** Drive 50, a driver assistance system that guides drivers to operate the train with a view to optimised energy usage and the ThermoEfficient Climatisation System, a system that ensures passenger comfort while saving considerable amounts of energy.

Low interior and exterior noise
Low noise is achieved through optimised wheel design featuring wheel-mounted brake discs that provide damping and a smooth running surface. The noise from electrical equipment and cooling systems has also been reduced to a minimum through systematic noise control management and the use of silent-running systems and components.

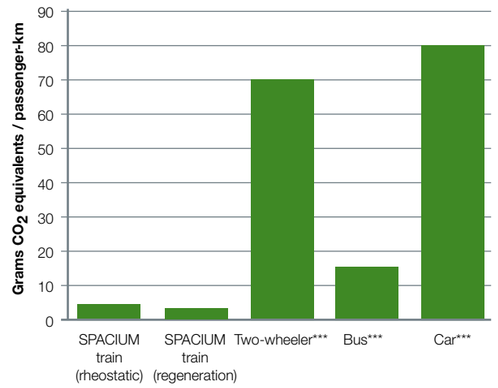
Low interior noise levels are achieved through low noise interior systems, insulated floors and elevated gangway bellows.

High recyclability
The *SPACIUM* train features materials with high recyclability and a high content of recycled materials. At the end of life phase of the vehicle life cycle, the recyclability and recoverability rate of the *SPACIUM* train is 93% and 98% by weight respectively.

Major plastic components are marked to ensure they can be efficiently identified, separated and processed for recycling at their end of life. This is done following ISO 11469 and associated standards.

Facilitated cleaning
The cantilever seating system, without attachments to the floor, creates additional floor space for increased safety and facilitates cleaning. Interior decor has been protected against vandalism with anti-graffiti paneling, tear-resistant seats and scratch-resistant windows, minimising the use of environmentally hazardous cleaning products over the *SPACIUM* train life cycle.

Low CO_2 emissions
The high energy efficiency of the *SPACIUM* train and the low carbon intensity of the French electricity mix result in very low CO_2 emissions at operation. When compared to travelling with other means of transportation such as buses, cars and two-wheelers, up to 96% of resulting CO_2 emissions per passenger/km could be avoided.



*** Based on "Efficacités énergétique et environnementale des modes de transport" (Deloitte-ADEME 2008). Data for regional service with 75% occupation rate.

A life cycle perspective -
environmental profile of the SPACIUM train

At Bombardier we apply a life cycle perspective to the design of our products, highlighting the significance of different design options and elucidating the true overall environmental impact these options have.

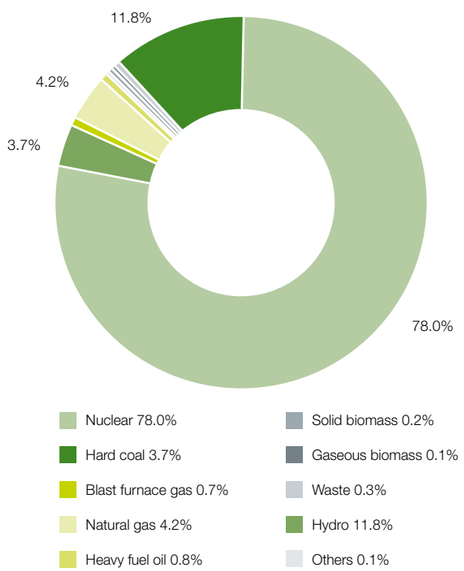
Resource efficiency, waste generation and overall environmental impact are estimated throughout all life cycle phases of the *SPACIUM* train, following ISO 14040:2006 methodology[8]. The results are based on an 8-car *SPACIUM* train in service for 40 years, with average running distance of 200,000 km per year.

All assumptions on vehicle operation and auxiliary systems load are based on EC Contract No. FP6-031458, following the methodology and operational profiles used for the energy consumption simulation. Two different scenarios are considered in the study: regeneration, where all braking energy is generated in the catenary and rheostatic, where all electricity is dissipated. The end of life phase of the life cycle is modelled according to technology available today. The potential benefit from material recycling and energy recovery is not included in the environmental impact tables.

[8] Bombardier Document No. IF-934-0288-1 Analyse du cycle de vie de la rame NAT.

Power supply

The French average power grid mix was used to model the use phase of the LCA.



Optimising environmental efficiency through a life cycle perspective

Life cycle thinking is an integrated part in the design process at Bombardier. We apply the Life Cycle Assessment (LCA) methodology following the ISO 14040 standard to analyse our products' environmental impact throughout all life cycle stages, raw material extraction, manufacturing, operation and end of life. The unique transparency that an LCA provides allows us to identify key factors of our design choices and enables us to optimise the environmental efficiency and minimise the carbon footprint of our products.

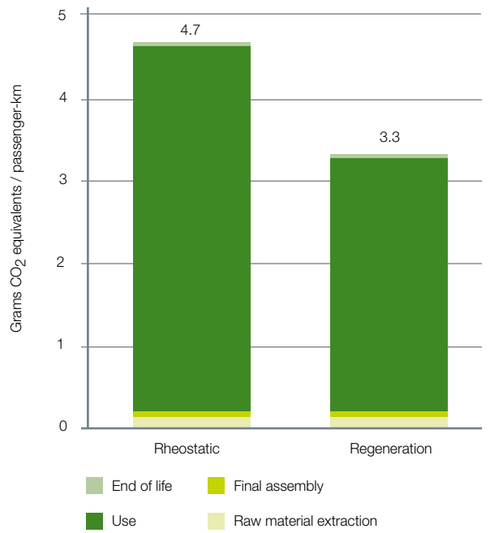
Design optimisation through a life cycle perspective focusing on water consumption over all life cycle phases.

Carbon footprint

The carbon footprint of a passenger travelling for one km on the *SPACIUM* train is the result of an allocation of the total amount of greenhouse gases (GHG) emitted over all phases of the vehicle life cycle. The total mass of emitted GHGs is allocated to CO_2 equivalents.

High energy efficiency during operation and low carbon intensity of the French electricity mix result in emissions as low as 4.7 grams and 3.3 grams of CO_2 equivalents per passenger/km respectively for the regeneration and rheostatic operational scenarios.

The chart details the relative contribution of each life cycle phase as % of the total mass of CO_2 equivalents emitted.



‹Environmental impact in detail›

Renewable and non-renewable resource consumption, waste generation and values for environmental impact categories provide a detailed insight into the life cycle impact of the *SPACIUM* train. Results are reported per passenger, for a covered distance of 100 km.

Resource efficiency

The following tables detail renewable and non-renewable material and energy resource utilization throughout all life cycle phases of the *SPACIUM* train. Overall resource consumption is highest for the use phase of the life cycle.

Waste generation

Generated waste during the *SPACIUM* train life cycle is 99.9% non-hazardous and mainly originates from energy production required for operation.

Environmental impact categories

The environmental impact of the *SPACIUM* train throughout its life cycle is quantified through environmental impact categories based on the CML 2001 methodology framework. For explanation of the environmental impact categories see ‹ Definitions ›.

Renewable resources	Upstream module	Core module	Downstream module			Total	
	Raw material extraction and component production	Final assembly	Use		End-of-life		
			Rheostatic	Regeneration		Rheostatic	Regeneration
Materials [kg/pass.100km]							
Water	9,78E-02	3,03E-02	5,13E+00	3,51E+00	3,67E-03	5,27E+00	3,65E+00
Air	4,63E-02	5,85E-02	1,95E+00	1,34E+00	5,98E-03	2,06E+00	1,45E+00
Carbon dioxide	2,82E-04	3,48E-05	1,17E-02	8,03E-03	6,60E-07	1,20E-02	8,35E-03
Nitrogen	7,30E-06	2,52E-12	4,34E-06	4,34E-06	4,68E-13	1,16E-05	1,16E-05
Others	1,56E-06	0,00E+00	2,22E-06	2,22E-06	0,00E+00	3,78E-06	3,78E-06
Energy [MJ/pass.100km]							
Hydropower	1,82E-02	5,01E-03	1,72E+00	1,18E+00	4,98E-05	1,75E+00	1,20E+00
Biomass	2,79E-04	7,55E-07	3,43E-04	3,07E-04	6,22E-08	6,22E-04	5,86E-04
Wind power	8,61E-04	1,49E-04	4,84E-02	3,31E-02	5,56E-05	4,95E-02	3,42E-02
Solar energy	2,71E-03	3,28E-04	1,10E-01	7,56E-02	8,47E-06	1,13E-01	7,86E-02
Geothermics	2,36E-03	8,43E-06	3,38E-03	2,47E-03	8,17E-08	5,75E-03	4,84E-03
Others	3,71E-08	0,00E+00	3,41E-08	3,41E-08	0,00E+00	7,12E-08	7,12E-08

Non-renewable resources	Upstream module	Core module	Downstream module			Total	
	Raw material extraction and component production	Final assembly	Use		End-of-life		
			Rheostatic	Regeneration		Rheostatic	Regeneration
Materials [kg/pass.100km]							
Inert rock	5,05E-02	2,49E-03	7,72E-01	5,35E-01	7,85E-04	8,26E-01	5,89E-01
Natural Aggregate	7,23E-05	7,12E-05	1,12E-02	7,65E-03	1,17E-05	1,14E-02	7,80E-03
Limestone (calcium carbonate)	1,24E-03	8,05E-05	8,83E-03	6,26E-03	3,56E-05	1,02E-02	7,62E-03
Others	2,98E-02	1,24E-04	1,52E-02	1,40E-02	3,79E-05	4,52E-02	4,39E-02
Energy [MJ/pass.100km]							
Uranium	2,14E-02	9,82E-02	3,37E+01	2,30E+01	8,66E-04	3,39E+01	2,31E+01
Crude oil	4,11E-02	2,27E-03	5,09E-01	3,55E-01	3,88E-04	5,53E-01	3,98E-01
Hard coal	6,26E-02	6,02E-03	1,99E+00	1,37E+00	5,43E-04	2,06E+00	1,44E+00
Lignite	9,69E-03	3,67E-04	8,45E-02	5,89E-02	5,93E-04	9,51E-02	6,96E-02
Natural gas	3,80E-02	7,91E-02	1,54E+00	1,05E+00	2,98E-04	1,65E+00	1,17E+00

Waste [kg/pass.100km]	Upstream module	Core module	Downstream module			Total	
	Raw material extraction and component production	Final assembly	Use		End-of-life		
			Rheostatic	Regeneration		Rheostatic	Regeneration
Hazardous	6,83E-04	3,54E-05	1,24E-02	8,49E-03	7,04E-05	1,32E-02	9,28E-03
Non-hazardous	7,38E-02	3,52E-03	7,76E-01	5,40E-01	5,88E-03	8,59E-01	6,23E-01
Total	7,45E-02	3,56E-03	7,88E-01	5,49E-01	5,95E-03	8,72E-01	6,33E-01

Environmental impact category	Upstream module	Core module	Downstream module			Total	
	Raw material extraction and component production	Final assembly	Use		End-of-life		
			Rheostatic	Regeneration		Rheostatic	Regeneration
Acidification Potential	6,17E-05	1,32E-05	1,58E-03	1,09E-03	4,58E-07	1,65E-03	1,16E-03
Eutrophication Potential	5,81E-06	1,96E-06	1,24E-04	8,54E-05	5,91E-08	1,32E-04	9,32E-05
Global Warming Potential	1,33E-02	6,75E-03	4,51E-01	3,09E-01	1,08E-03	4,72E-01	3,31E-01
Ozone Depletion Potential	5,71E-10	2,65E-09	9,10E-07	6,20E-07	2,33E-11	9,14E-07	6,24E-07
Photochemical Ozone Creation Potential	5,91E-06	3,23E-06	1,07E-04	7,43E-05	3,79E-08	1,17E-04	8,35E-05

‹Environmental management›

Bombardier Transportation site in Crespin, France

In order to keep the commitment of delivering superior products, solutions, and services Bombardier Transportation utilises clearly defined business processes and a common integrated Business Management System.

Bombardier Transportation has a comprehensive Business Management System in place throughout its manufacturing and service sites. As it is aligned and based on continuous improvement, we believe this management system to be critical in helping us to increase resource and energy efficiency and reduce waste.

The Bombardier Transportation site in Crespin, France, has achieved certification under the ISO 14001:2004 standard.

Regardless of the system, we follow the practice that each site must be certified individually prior to its inclusion in matrix certification. Sites that have not yet achieved certification are, however, in conformance with our integrated business system that is aligned with ISO 14001 requirements, which is checked by independent internal auditors. Besides achieving certification for our own sites, we also encourage our suppliers to implement an environmental management system.

‹Definitions›

Acidification Potential (kg SO_2 equiv.): Acidification originates from the emissions of sulphur dioxide and oxides of nitrogen. In the atmosphere, these oxides react with water vapor and form acids which subsequently fall down to the earth in the form of rain or snow, or as dry depositions. Acidification potential translates the quantity of emission of substances into a common measure to compare their contributions to the capacity to release hydrogen ions.

Eutrophication Potential (kg $[PO_4]^{3-}$ equiv.): Nutrients (mainly nitrogen and phosphorus) accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen resulting in oxygen deficiency. Eutrophication potential translates the quantity of emission of substances into a common measure expressed as phosphates.

Global Warming Potential (kg CO_2 equiv.): Some of the gases in the earth's atmosphere (in particular water vapor and carbon dioxide) have an ability to absorb infrared radiation. They do not prevent sunlight reaching the earth's surface, but they do trap some of the infrared radiation emitted back into space causing an increase in the surface temperature. Global Warming Potential, GWP100, translates the quantity of emission of gases into a common measure to compare their contributions – relative to carbon dioxide – to the absorption of infrared radiation in 100 years perspective. Carbon footprint is a commonly used term for GWP.

Ozone Depletion Potential (kg CFC 11 equiv.): Ozone forms a layer in the stratosphere protecting plants and animals from harmful UV-radiation. The ozone level has declined as a consequence of CFCs and halons released into the atmosphere. A depletion of the ozone layer will increase the UV-radiation at the ground level. Ozone depletion potential, ODP, translates the quantity of the emission of gases into a common measure to compare their contributions relative to the freon R-11 to the breakdown of the ozone layer.

Photochemical Ozone Creation Potential (kg C_2H_4 equiv.): Photochemical ozone, or ground level ozone, is formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. Ground level ozone forms readily in the atmosphere, usually during hot summer weather. Photochemical ozone creation potential, POCP, translates the quantity of emission of gases into a common measure to compare their contributions – relative to ethene – to the formation of photochemical oxidants.

Recyclability and Recoverability: The recyclability and the recoverability rate of a new rail vehicle are expressed as a percentage by mass of the rail vehicle that can potentially be recycled, reused or both (recyclability rate), or recovered, reused or both (recoverability rate).

Recycled material content: The recycled material content is the amount of material originating from a recycling process at a recycling plant or a material recovery facility.

PCR Review was conducted by the technical committee of the international EPD® system:

Joakim Thornéus (Chair)
Swedish Environmental Management Council
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Independent verification of the declaration and data, in accordance to ISO 14025:2006

☐ Internal ☒ External

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Environmental Product Declarations within the same product category, but from different programs may not be comparable.

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www.theclimateisrightfortrains.com

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