INNOVIA ART 200

Environmental Product Declaration

The Climate is Right for Trains

BOMBARDIER

Design for Environment
Environmental sustainability at the core

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 lifecycle.

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

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.

# of product development ›

“Our long term experience in providing transit system solutions enables us to respond to our customer's needs in full”

At Bombardier Transportation we combine our technical know-how in the systems field to produce exceptional products and services. Our high standards and goals of continuous improvement for our products and services help strengthen our relationships with our partners, suppliers, and our customers. One of our missions is to lead through innovation and outstanding product safety, efficiency and performance. Our *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. This Environmental Product Declaration will provide you with valuable and relevant information on the environmental impact of all life cycle phases of the *INNOVIA* ART 200 train, a highly recyclable and sustainable product that our customers, shareholders and employees can be proud of.

Eran Gartner
President, Systems Division
Bombardier Transportation

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 *INNOVIA* ART 200 vehicle through all phases of the 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] UNIFE (Transport & Environmental Working Group). Product Category Rules (PCR) for preparing an environmental product declaration (EPD) for rail vehicles. International EPD ® System, 2009

INNOVIA ART 200
Advanced rapid transit

The *INNOVIA* ART advanced rapid transit technology was designed from inception as a fully automated driverless system, and has a proven track record around the world.

The *INNOVIA* ART 200 vehicle was the second generation of this highly reliable transit system technology. Within Bombardier's product portfolio the *INNOVIA* ART system fills the gap between metros and light rail vehicles; allowing for a lighter weight vehicle operating at short headways and high commercial speeds, increasing the system carrying capacity to economically provide intermediate capacity in the range of 5,000 to 30,000 passengers per hour per direction.

The initial Vancouver SkyTrain Expo Line (28.9 km) employed a fleet of 150 *INNOVIA* ART 100 vehicles. With the advent of the Millennium Line (20.3 km) in 2002, the fleet was increased with an additional 60 *INNOVIA* ART 200 [1100-1200 series] vehicles. This EPD refers to the recent re-order of 48 *INNOVIA* ART 200 [1300-1400 series] vehicles; a fleet expansion for Vancouver SkyTrain's rail transit network.

Vehicle Specifications	
Primary power supply	600 Vdc
Mass[2] (max.)	21,500 kg
Length (coupler face to drawbar face)	17,350 mm
Overall width at platform height	2,500 mm
Overall width at seat height	2,650 mm
Height	
Top of rail to top of A/C Unit	3,275 mm
Top of rail to floor	800 mm
Floor to ceiling	2,038 mm
Wheel Diameter	585 mm
Truck wheelbase	1,900 mm
Auxiliary power supply	230 Vac, 60 Hz, 3ø
Low-voltage power supply	48 Vdc

[2] Weight depends on customer specific equipment request, values in table based on empty car

Technical Information

Implementing DfE to product development has a commanding impact on vehicle design, resulting in high overall recyclability and energy efficiency of the *INNOVIA* ART 200 vehicle.

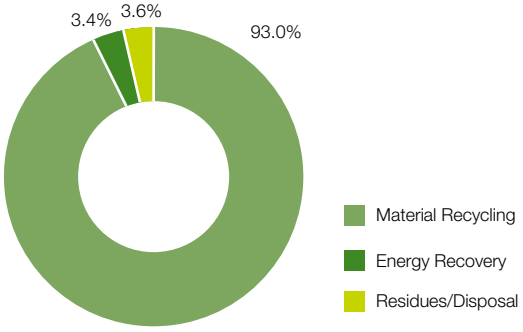
Material Content

The table details the material content of the *INNOVIA* ART 200 vehicle and all the materials required for maintenance during 30 years of operation. Materials are classified according to ISO 22628:2002 based on 2-car trains.

Material (kg)	Manufacturing	Maintenance	Total
Metals	36,922.7	1,635.1	38,557.8
Polymers	1,619.6	33.7	1,653.3
Elastomers	299.0	–	299.0
Glass	699.9	–	699.9
Fluids	204.1	–	204.1
MON	696.9	–	696.9
Others	1,959.2	1,988.3	3,947.5
Total	42,401.4	3,657.1	46,058.5

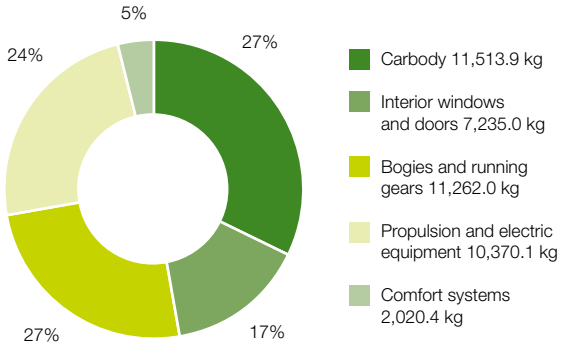
Recyclability and Recoverability

The use of modular design with a selection of highly recyclable materials facilitates upgrades for individual components, while permitting the ease of recycling once the vehicle is taken out of service. The projected recyclability and recoverability at the end of life phase of the *INNOVIA* ART 200 vehicle are 93.0% and 96.4% by weight respectively, following ISO 22628:2002 methodology.[3]



Modular Structure

The *INNOVIA* ART 200 vehicle is classified as an Urban Passenger Service Vehicle. The figure below shows the vehicle's modular structure according to the classification of EN 15380-2 (2:2006) and is based on 2-car trains.



Energy Efficiency

Bombardier has invested in the development and improvement of an in-house software tool which simulates and optimizes the design of power distribution and energy consumption for transport systems; allowing the calculation of the energy consumption of vehicles with a high degree of accuracy. The model analyses information such as fleet performance, train speed profiles, power supply and distribution system load flows, effects of onboard and wayside energy storage devices, train schedules, and routing.

[3] See Definitions

The *INNOVIA* ART 200 vehicle length is 17.3 metres over the couplers. Propulsion Technology used is Linear Induction Motor. Wayside power system receptivity of 100% was used for the energy consumption calculations. This is a reasonable assumption with the short headway operation of the system and the large power rail size increasing the probability of a motoring train being near a regenerating train during peak operation. The passenger loading factor of 20% corresponds to 33 seated passengers per car.

	kWh/vehicle[4]-km
Propulsion Energy Consumption	**3.10**

Results are valid only for assumed parameters. Under practical conditions, depending on operating parameters, these may vary.

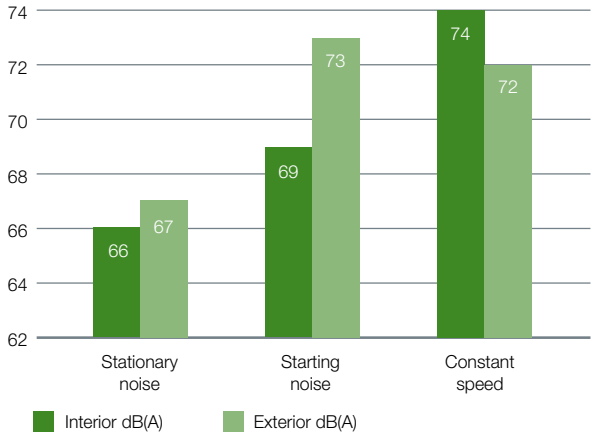
Auxiliary energy consumption data represent the minimum and maximum values, where the load factor is 20%. For the regional conditions in Vancouver, these values range from a minimum of 3.8 kW per car to a maximum of 34 kW per car and depend on ambient temperature, passenger load, and other factors. They are not applicable to any other systems or vehicles and should not be used for comparisons to other systems and/or vehicles.

The reported propulsion and auxiliary energy consumption values pertain to the Vancouver Millennium Line only with a track length of 20.3 km.

Auxiliary Energy Consumption	kWh/vehicle[5]-km
Minimum	**0.17**
Maximum	**1.52**

Noise

Interior and exterior sound level measurements follow ISO 3381 (2:2005) and ISO 3095 (2:2005) methodology, with the exception of the distance at which the measurements were taken. For the outside stationary noise the measurement was taken at a distance of five metres. The outside noise levels for starting and constant speed were taken at a distance of 15 metres.



[4] Vehicle defined as a two-car consist

Highlighted Features

Applying life cycle thinking when developing the *INNOVIA* ART 200 vehicle has allowed us to maximize environmental efficiency while meeting passenger requirements and expectations.

Exterior and Interior Design

The *INNOVIA* ART 200 vehicle includes new exterior and interior designs. The exterior design of the *INNOVIA* ART 200 vehicle includes new paint colors. The new color palette boasts of vibrant blues, brilliant yellows, as well as, subtle gray and black undertones. These colors permit the vehicle to integrate into the urban environment. For added safety, the interior features an anti-slip floor.

Linear Induction Motor Propulsion

The *INNOVIA* ART 200 vehicle features automated driverless operation in all-weather conditions using innovative Linear Induction Motor (LIM) propulsion technology. Rather than propelling the wheels, the LIM is a "direct drive" propulsion system that provides both propulsion and braking forces.

Radially Steered Bogies

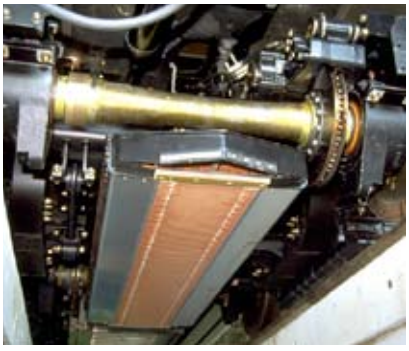
The *INNOVIA* ART vehicle radially steered bogie provides much more accurate steering than a conventional rigid bogie or conventional "steerable" bogie, with the result that flange contact is avoided even in small radius curves, providing less noise and reduced wheel and rail wear.

Material Selection

Bombardier has a structured way of working with substances that are harmful to environment and health, and in particular, we focus on how these substances should be controlled in, and also phased out of, our products. By applying the Bombardier Transportation Prohibited & Restricted Substance list, we limit the use of such materials and substances in our products.

Automatic Train Control

Advanced moving-block train control allows *INNOVIA* ART transit systems to provide driverless unattended train operation at short headways, enabling *INNOVIA* ART systems to provide high passenger carrying capacity with shorter trains, while reducing passenger waiting time. Full driverless automation also allows very flexible system operation, such that trains can be inserted and removed



from service from the central control room without concerns about scheduling of drivers or train attendants and provides outstanding system safety, demonstrated in over 24 years of safe operation in Vancouver.

New Seating Layout

The improved 2+1 seating layout allows for a wider center aisle increasing the amount of passengers the vehicle can carry.

Additional Stanchions

Along with increasing vehicle capacity the number of stanchions has increased, giving passengers the added comfort of additional places to hold for support. The stanchions are coloured an attractive high contrast yellow to assist visually impaired passengers.

Accessibility

Wider doors and aisles allow more accessibility to those traveling in wheel chairs, with strollers, and larger items.

Reduced Brake Wear

LIM propulsion technology permits adhesion-independent transmission of propulsion and braking forces largely eliminating the need for traction between the wheels and the rails except in high load, high grade and final stop conditions, allowing for less wear of the brake pads.

Low Maintenance and Operating Cost

INNOVIA ART vehicles operate with very low maintenance and operating cost. The *INNOVIA* ART vehicle operates on small curves and steep grades to facilitate greater use of less expensive elevated guideway, it permits smaller, less expensive stations, and reduces operating costs. When compared to systems that carry more people, published data[5] shows the *INNOVIA* ART vehicle costs less to operate and maintain for every passenger carried.

Light Weight Body

In terms of vehicle mass per passenger carried, the *INNOVIA* ART 200 vehicle is significantly lighter than comparable rail transit vehicles, in part due to the light weight aluminum car shell and the lower mass of the LIM bogies compared to conventional rotary motor bogies. Reduced vehicle mass reduces the amount of energy consumed.

[5] Bombardier Document No. 10041/TTS/01-2008/en, based on data published by the US Federal Transit Administration

A life cycle perspective
Environmental profile

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

Resource efficiency, waste generation, and overall environmental impact are estimated throughout all life cycle phases of the *INNOVIA* ART 200 vehicle, following ISO 14040:2006 methodology.

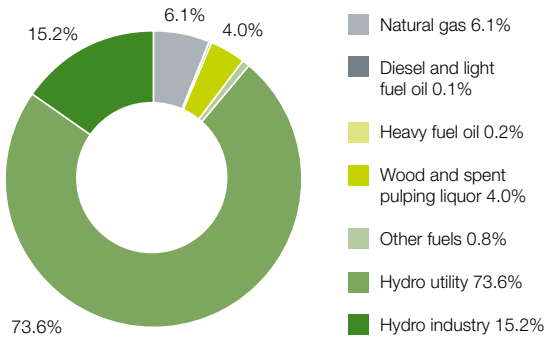
The results are based on an operational lifetime of 30 years on the Vancouver Millennium Line track. All assumptions on vehicle operation and auxiliary systems load are based on EC Contract No. FP6-031458: 2009, following the methodology and operational profiles used for the energy efficiency simulation.

A value of 20kW was chosen as the total nominal effect of auxiliaries and is an arbitrary value representing the possible conditions in Vancouver, with HVAC and floor heaters operating according to the regional seasonal changes. It should be noted that this value is no substitute for actual auxiliary energy consumption values and should not be used as such.

The end of life phase of the life cycle is modeled according to technology available today. The potential benefit from material recycling and energy recovery is not included in the environmental impact tables.

Power Supply

The British Columbia average power grid mix was used to model the use phase of the LCA, with 1kWh produced corresponding to 0.12kg of CO_2 equivalents emitted.



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.

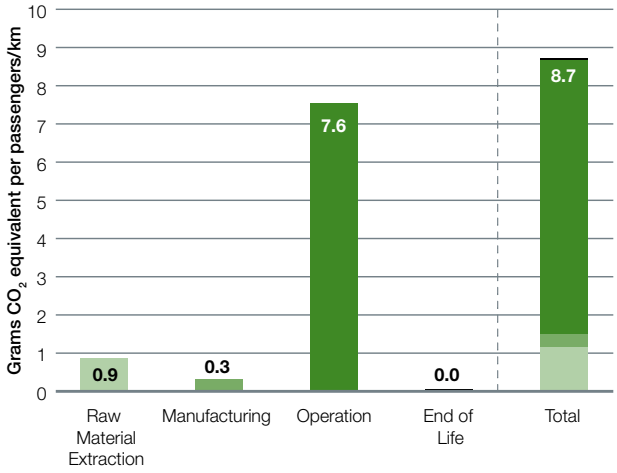
The unique transparency that an LCA provides allows us to identify key factors of our design choices and enables us to optimise the environmental efficiency and minimise the carbon footprint of our products.

Screen shot of the Design for Environment exhibit displayed at InnoTrans 2010 – showing design optimisation through a life cycle perspective.

Carbon Footprint

The carbon footprint of a passenger travelling for one kilometre on the *INNOVIA* ART 200 vehicle 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 results in lowering emissions down to 8.7 g of CO_2 equivalents per passenger/km. The chart details the contribution of each life cycle phase as the mass of CO_2 equivalents emitted.



‹Environmental Impact›

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 *INNOVIA* ART 200 vehicle. 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 *INNOVIA* ART 200 vehicle. Overall resource consumption is highest for the use phase of the life cycle with an operational lifetime of 30 years.

Renewable resources	Upstream module	Core module	Downstream module		Total
	Raw material extraction and component production	Final assembly	Use	End-of-life	
Material [kg/pass·100km]					
Water	7.00E^{-01}	6.28E^{-01}	5.98E^{+00}	5.80E^{-03}	7.32E^{+00}
Air	3.57E^{-01}	1.72E^{-01}	3.64E^{+00}	5.89E^{-03}	4.17E^{+00}
Carbon dioxide	1.39E^{-03}	3.09E^{-06}	9.12E^{-04}	2.16E^{-06}	2.30E^{-03}
Others	1.78E^{-05}	1.89E^{-12}	1.30E^{-06}	1.50E^{-12}	1.91E^{-05}
Energy [kJ/pass·100km]					
Biomass	3.15E^{-05}	–	7.20E^{-06}	–	3.87E^{-05}
Geothermics	1.79E^{-02}	1.19E^{-02}	1.06E^{-03}	2.76E^{-07}	3.08E^{-02}
Hydropower	1.31E^{-01}	1.35E^{-02}	2.66E^{+01}	1.71E^{-04}	2.68E^{+01}
Solar energy	1.32E^{-02}	1.11E^{-04}	8.28E^{-03}	2.80E^{-05}	2.16E^{-02}
Wind power	6.53E^{-03}	1.37E^{-04}	2.14E^{-03}	1.92E^{-04}	9.00E^{-03}
Others	6.38E^{-05}	9.49E^{-07}	1.09E^{-04}	1.98E^{-07}	1.74E^{-04}

Note: Vaules of 0.00 are indicative of small amounts, while a dash (–) represents values equal to zero.

Non-renewable resources	Upstream module	Core module	Downstream module		Total
	Raw material extraction and component production	Final assembly	Use	End-of-life	
Material [kg/pass·100km]					
Inert landmass	2.82E^{-01}	9.64E^{-03}	3.45E^{+00}	2.68E^{-03}	3.74E^{+00}
Metal ores	1.70E^{-01}	3.66E^{-05}	5.11E^{-02}	3.04E^{-07}	2.21E^{-01}
Other minerals	1.16E^{-02}	5.02E^{-04}	5.25E^{-02}	1.03E^{-04}	6.47E^{-02}
Others	1.74E^{-05}	4.49E^{-10}	5.10E^{-07}	1.20E^{-12}	1.79E^{-05}
Energy [kJ/pass·100km]					
Crude oil	3.09E^{-01}	1.54E^{-01}	4.28E^{-01}	4.88E^{-04}	8.92E^{-01}
Hard coal	2.91E^{-01}	3.71E^{-02}	1.13E^{-01}	1.76E^{-03}	4.43E^{-01}
Lignite	6.84E^{-02}	1.28E^{-03}	3.67E^{+00}	1.98E^{-03}	3.74E^{+00}
Natural gas	2.25E^{-01}	1.24E^{-01}	4.17E^{+00}	8.29E^{-04}	4.52E^{+00}
Uranium	1.49E^{-01}	1.78E^{-02}	1.20E^{-01}	2.98E^{-03}	2.90E^{-01}

Note: Vaules of 0.00 are indicative of small amounts, while a dash (–) represents values equal to zero.

Waste Generation

Generated waste during the *INNOVIA* ART 200 vehicle life cycle is 99.8% non-hazardous and mainly originates from energy production required for operation.

Waste [kg/pass·100km]	Upstream module	Core module	Downstream module		Total
	Raw material extraction and component production	Final assembly	Use	End-of-life	
Hazardous	5.00E^{-03}	1.92E^{-04}	4.54E^{-04}	1.22E^{-04}	5.77E^{-03}
Non-hazardous	4.27E^{-01}	8.51E^{-03}	3.26E^{+00}	3.85E^{-03}	3.70E^{+00}
Total	4.32E^{-01}	8.70E^{-03}	3.26E^{+00}	3.98E^{-03}	3.70E^{+00}

Environmental Impact Categories

The environmental impact of the *INNOVIA* ART 200 vehicle throughout its life cycle is quantified through environmental impact categories based on the CML 2001 methodology framework. For information on the environmental impact categories see Definitions

Environmental Impact Category	Upstream module	Core module	Downstream module		Total
	Raw material extraction and component production	Final assembly	Use	End-of-life	
Acidifcation Potential (AP) [kg SO_2 equiv.]	4.15E^{-04}	2.97E^{-04}	3.69E^{-03}	1.23E^{-06}	4.40E^{-03}
Eutrophication Potential (EP) [kg PO_4^{3-}equiv.]	4.23E^{-05}	1.14E^{-05}	1.78E^{-04}	1.39E^{-07}	2.31E^{-04}
Global Warming Potential (GWP, 100 years)[kg CO_2 equiv.]	8.55E^{-02}	2.57E^{-02}	7.58^{-01}	1.21E^{-03}	8.70E^{-01}
Ozone Depletion Potential (ODP, 20 years) [kg CFC 11 equiv.]	4.31E^{-09}	4.79E^{-10}	3.03E^{-09}	8.01E^{-11}	7.90E^{-09}
Photochemical Ozone Creation Potential (POCP) [kg C_2H_4 equiv.]	3.68E^{-05}	1.63E^{-05}	2.03E^{-04}	9.05E^{-08}	2.57E^{-04}

Environmental Management

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

Bombardier Transportation testing facility in Kingston, Ontario

Bombardier 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 increase resource and energy efficiency, reduce waste and prevent environmental incidents. We have achieved multi-site certification under the ISO 14001:2004 standard. Each site must be certified individually prior to its inclusion in matrix certification.

Environmental Management System	Site	ISO 14001[6]
Bombardier Transportation Systems	Kingston, Ontario, Canada	July 17, 2009
Bombardier Transportation North America	Sahagun, Mexico	March 27, 2006
Bombardier Transportation North America	St. Bruno, Quebec, Canada	March 27, 2006
Bombardier Transportation Systems	Pittsburgh, Pennsylvania, USA	March 05, 1999

[6] Issue date of first certificate, all certificates are valid at date of publication

Definitions

Acidification Potential (kg SO_2 equiv.): Acidification originates from the emissions of sulfur 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.

Carbon Footprint: See Global Warming Potential which is often also referred to as Carbon Footprint.

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, 100 years (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 Layer 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: The mass fraction in percent of the rail product that can be recycled and/or reused at the end of life phase of the rail product life cycle.

Recoverability: The mass fraction in percent of the rail product that can be recycled, reused and/or utilized for energy generation at the end of life phase of the rail product life cycle.

PCR Review was conducted by the Technical Committee of the International EPD® system:

Joakim Thornéus (Chair)
Swedish Environmental Management Council
email: joakim@environdec.com

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.

This EPD is valid until 2013-06-01.

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UN CPC 49520
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EPD®

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