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Measurement of the Carbon Footprint in the Company Sistemas Operativos Móviles, Transmilenio

Medición de la huella de carbono en la empresa sistemas operativos móviles, transmilenio

Carlos Díaz[1], William Rodríguez[2], Esp. Erik Pinzón[3], Adm Stephanie Vega[4]

[1] *Universidad del Bosque, Bogotá, Colombia, cardiro@gmail.com*
[2] *Universidad Distrital Francisco José de Caldas, Bogotá, Colombia, willirodel@gmail.com*
[3] *Universidad Distrital Francisco José de Caldas, Bogotá, Colombia,* epinzon@somos.co
[4] *Universidad Distrital Francisco José de Caldas, Bogotá, Colombia, svega1216@gmail.com*

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Abstract

One of the main environmental problems affecting the current world is related to climate change; high CO_2 emissions of greenhouse gases have intervened directly with this change. The purpose of this study was to measure the carbon footprint that supposes the quantification of greenhouse gases by using the basic principles and requisites of the ISO 14.064-1: 2006 standard; specifications aimed at the organizational level to quantify and notify greenhouse gas emissions. The study was conducted in the company Sistemas Operativos Móviles, Transmilenio, which has an active fleet of 160 articulated buses.

Key words: Carbon dioxide, Greenhouse gases (GHG), carbon footprint

Resumen

Una de las principales problemáticas ambientales que afecta el mundo actual está relacionada con el cambio climático, las altas emisiones de CO2 como parte de los gases de efecto invernadero, han intervenido directamente con este cambio. El propósito de este estudio es realizar la medición de la Huella de Carbono que supone la cuantificación de los gases de efecto invernadero, mediante la utilización de los principios básicos y requisitos de la norma ISO 14.064-1: 2006; Especificaciones con orientación, a nivel de la organización, para la cuantificación y notificación de las emisiones de gases efecto invernadero. El estudio tiene lugar en la empresa Sistemas Operativos Móviles, Transmilenio, que cuenta con una flota activa de 160 buses articulados.

Palabras clave: Dióxido de carbono, Gases Efecto Invernadero (GEI), huella de carbono

1. Introduction

The special report by the Inter-government Group of Experts on Climate Change (IPCC, for the term in Spanish) on emissions scenarios projects an increase of global greenhouse gases (GHG) emissions between 25 and 90% (CO_2-eq) between 2000 and 2030 [1].

The report by the IPCC working group, titled Climate Change 2014: Impact, adaptation, and vulnerability details the impact of climate change to date, concluding that responding to climate change supposes making decisions on the actions and possible risks in a changing world [2].

Colombia is not alien to this theme, which is why the IPCC made an inventory of greenhouse gases for 2004 and concluded that the Colombian contribution to global emissions is around 0.37% of the world's total [3]. According to the Colombian Ministry of the Environment and Sustainable Development, the volume of these emissions has shown a tendency to increase over time. Between 1990 and 2004, the emissions increased by 39%, over 180 million tCO_2eq of the total emitted in the world that reaches 49 billion tCO_2eq [4].

The sectors contributing the most to GHG emissions in 2004 were: agriculture (38%); energy (37%),

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highlighting the transportation sector with (12%), and use of soil, change of use of soil and forestry with (14%) [5]. For Colombia, the mobilization process causes 21,601,200 tCO_2eq of the national total.

This document seeks to recognize the GHG emitted onto the atmosphere through the use of emission factors for the company Sistemas Operativos

Móvibles, Transmilenio. The company has an active fleet of 160 articulated buses, being one of the most used means of mass transportation in Bogotá, Colombia.

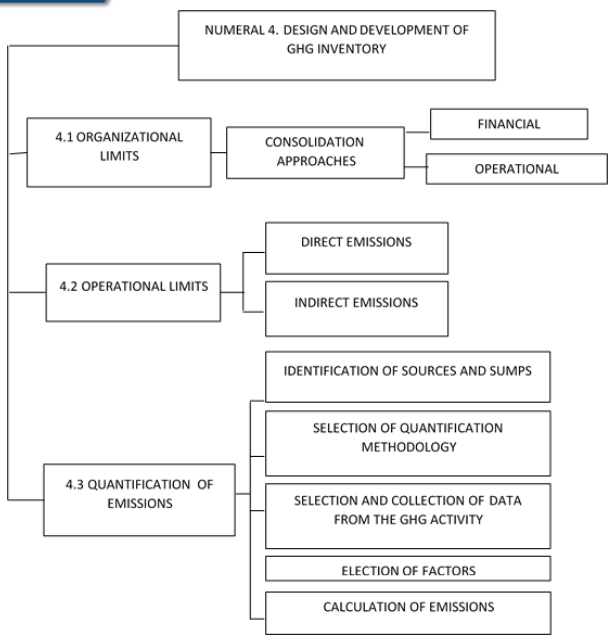
1.1 Carbon footprint

The carbon footprint analyzes GHG emissions during the life cycle of any product or service; it encompasses raw materials, production, and distribution, that is, the product or service in all its links and, thus, quantify the total emissions produced [6].

Calculation of the GHG emissions released onto the atmosphere as a consequence of any activity is what we denominate carbon footprint [7]. Measurement of the carbon footprint is done by following the ISO 14064-1:2006 standard guidelines, which contain technical specifications for the quantification and the report of GHG emissions at organizational levels [8]. After that, a measurement model was developed for the company to guarantee continuity to the annual quantification of emissions and, thus, evaluate the critical points with the greatest generation of GHG, achieving the development of mitigation programs and contributing to diminished levels of emissions produced nationally. As indicated by Marta Martín, responsible for the consultancy and training department of the consulting company dedicated exclusively to energy efficiency (CREARA), "what is important is that from the our carbon footprint it is possible to know where the GHG come from, which allow us to implement measures to diminish harmful gases emitted onto the atmosphere" [9].

2. Materials and methods

Graphic 1 describes the methodology based on the ISO 14064-1 standard: quantification and report of GHG emission and removal at organizational levels. This methodology is later used in measuring the carbon footprint of the company Sistemas Operativos Móvibles, TransMilenio.



Graphic 1. ISO 14064-1 Methodology
Source: Authors, 2014. Compiled from the norm [10]

2.1 Organizational limits

To define the organizational limits, it is important to know how the company is constituted and over which of its activities (financial and/or operational) it exerts control [11].

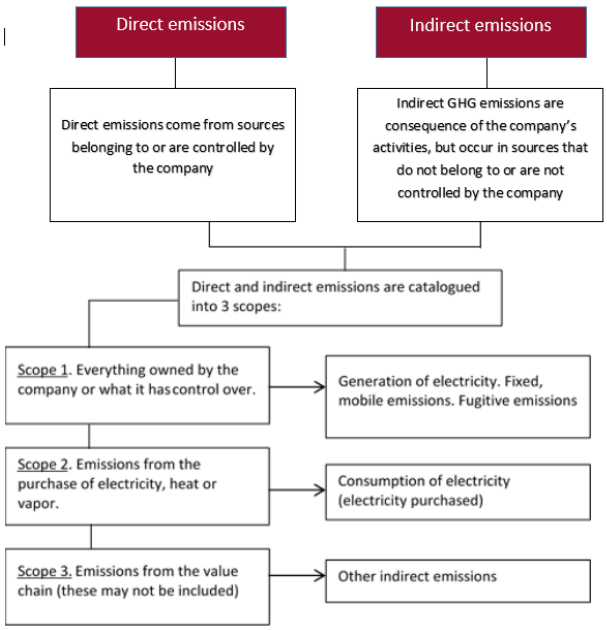
The company, Sistemas Operativos Móviles, was founded in 2002 under the legal structure of joint stock Company, backing the new transportation modality implemented in the city of Bogotá, by bidding as route operator in phase II and obtaining the contract with TransMilenio S.A. for *Patio Américas* (Bogotá).

Its main object and social activity is the mass transportation of passengers in the city of Bogotá, through the availability and maintenance of the fleet of buses. Its main activities include: fuel supply, washing of buses, motor repair, change of spare auto parts, body maintenance (body work and paint), management of tires, and administrative management of all these activities for the good operation of the fleet of buses and of the organization.

2.2 Operational Limits

Establishment of operational limits includes identification of GHG emissions associated to the operations of the organization, these emissions are classified as shown in Graphic 2. To establish the operational limits of the processes that generate missions in the company, an analysis of the internal procedures

was carried out to study the inputs (materials, raw material, energy, etc.), processes (transformation, procedures, activities), and outputs (wastes, residues, emissions) to determine the emission sources for the mobilization of the fleet. Graphic 3 shows the operational limits, determined from the analysis of the procedures.

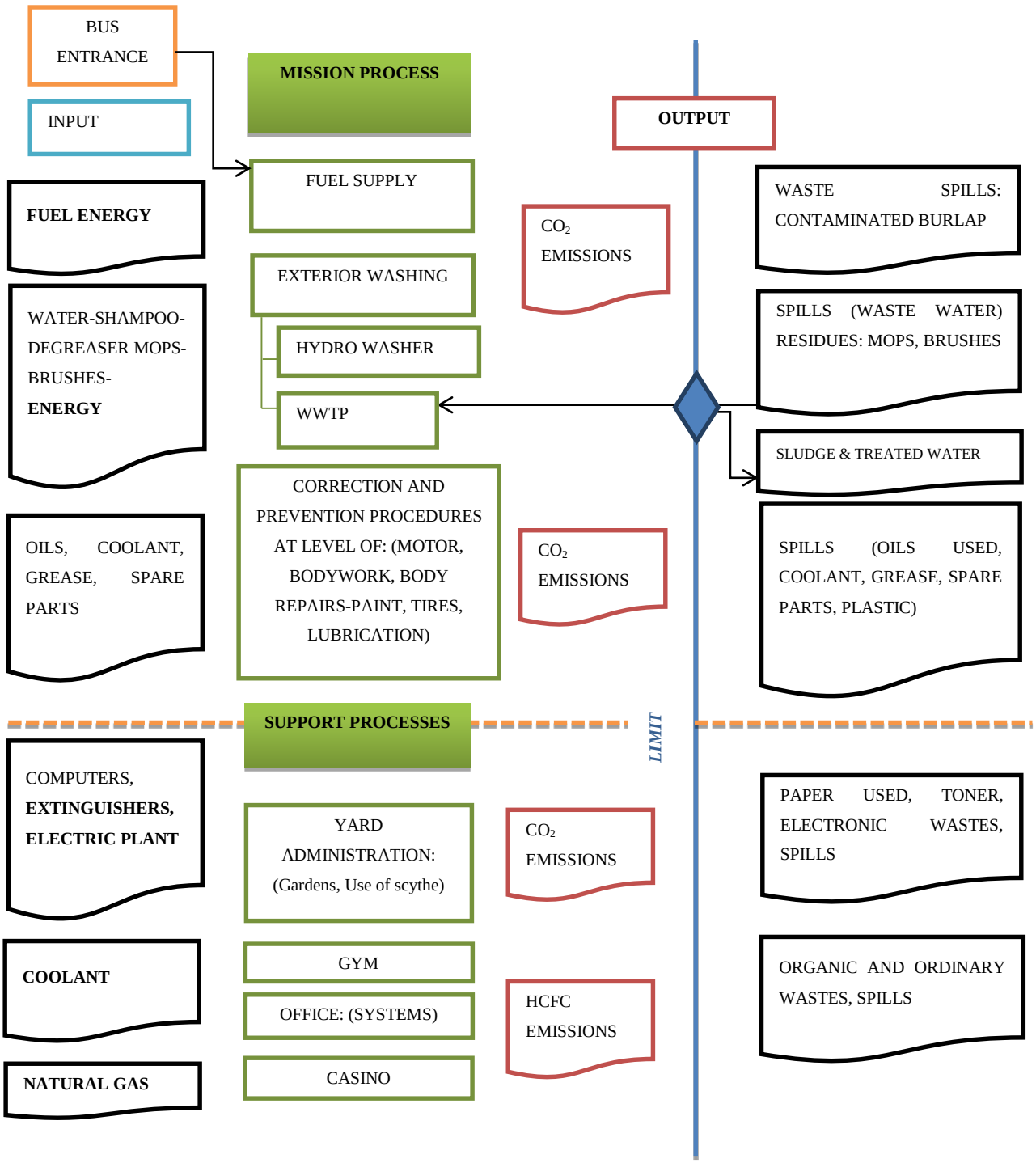


Graphic 2. Classification of emissions
Source: Authors, 2014. Compiled from the norm (ISO 14064-1)

Table 1. Identification of emission sources

	Vehicle preparation			Emission	Type of emission	Scope
Mission processes	Fuel supply	Fuel supply fleet SOMOS K S.A.	Biodiesel (8%) Diesel (92%)	CO_2	Direct emissions	1
		Energy consumption, EDS	Electricity	CO_2	Indirect emissions Electricity purchased	2
	Washing of Buses(This area is handled by a third company, SOMOS assumes the cost of energy)	Energy consumption	Electricity	CO_2	Indirect emissions Electricity purchased	2
	Preventive and corrective maintenance	Maintenance of motor and adjacent systems	Coolant	NA	-	
		Energy consumption	Electricity	CO_2	Indirect emissions Electricity purchased	2
Building	CASINO(This area is handled by a thitd company wich assumes the cost of natural gas and the energy is paid by SOMOS k)	Energy consumption	Electricity	CO_2	Indirect emissions Electricity purchased	2
	Electric plant	Industrial stove	Natural Gas	CO_2	Direct emissions, Fixed combustion (third parties)	3
		Fuel consumption	Biodiesel (8%) Diesel (92%)	CO_2	Direct emissions Fixed Combustion	1
	Administration	Energy consumption	Electricity	CO_2	Indirect emissions Electricity purchased	2
		Consumption of paper	Paper	-	Other indirect emissions	3
		Air conditioning	Coolant	HCFC-22	Fugitive emissions	3
		Company Trips	Fuel	CO_2	Other indirect emissions	3
		Use of extinguishers	CO_2 and CHCL2-CF3	CO_2	Fugitive emissions	1
	Maintenance of infrastructure	Use of soythe	Gasoline	CO_2	Direct emissions, mobile combustion	1

Source: Authors, 2014.



SOURCE: Authors, 2014.

Graphic 3. Operational limits of Transmilenio

2.3 Quantification of Emissions

Quantification of emissions leads to the following steps or procedures:

2.3.1 Identification of emission sources

According to the classification of type of emissions (Graphic 2), and upon defining the operational limits (Graphic 3), we proceed to identify emission sources with their corresponding scope, as shown in Table 1.

2.3.2 Selection of the quantification methodology

The method used to quantify GHG emissions is a calculation based on the use of emission factors. The factors permit estimating GHG emissions from the available data of activities (like tons of fuel consumed, tons of product produced, energy consumed); the general formula to apply the emission factors is shown by the following:

Level of Activity * Emission factors = GHG emissions (1)

2.3.3 Data selection and collection

The data collected to quantify the carbon footprint were taken from 2012 and 2013 through the checklist tool (Table 2), which permits compiling in simple manner the data required [12].

Table 2. Check list for data collection

Check list - collection of consumption data			
Documents to evaluate:	Transmilenio reports, codensa invoices, fenosa natural gas invoices, petty cash reimbursements, technical data sheet for coolant, paper ream purchase bill, and terpel reports.		
Item	***Description***	***Amount***	***Unit***
1	**Mission process**		
1,1	**Fuel supply**		
1,1,1	Consumption of biodiesel for 160 articulated buses		Gal/year
1,1,2	Consumption of biodiesel electric plant		Gal/year
1,2,3	Energy consumption		Kwh/year
1,2	**Washing**		
1,2,1	Gasoline consumption. Hydro washer		Gal/year
1,2,2	Energy consumption		Kwh/year
1,3	**Maintenance area**		
1,3,1	Energy consumption		Kwh/year
2	**Support processes**		
2,1	**Administrative building**		
2,1,1	Energy consumption		Kwh/year
2,1,2	Consumption of coolant		Lb/year
2,1,3	Business trips		Trips/year
2,1,4	Consumption of paper		Sheets/year
2,2	**Casino**		
2,2,1	Natural gas consumption		M^3/year
2,2,2	Energy consumption		Kwh/year
2,3	**Maintenance of infrastructure**		
2,3,1	Energy consumption		Kwh/year
2,3,2	Fuel consumption (scythe)		Gal/year

Source: Authors, 2014

The check list was used to gather information from different GHG emission sources in company areas; Tables 3 and 4 present the data collected for 2012 and 2013.

Table 3. Collection of data for 2012

Sistemas Operativos Móviles, Transmilenio				
	Description	**Consumptions**	**Unit**	**2012**
Scope 1. Direct emissions	**Mobile sources**			
	158 articulated vehicles	Biodiesel (8%) diesel (92%)	(gal/year)	2,046,039.19
	Use of scythe	Gasoline	(gal/year)	128.4566336
	Fixed sources			
	Electric plant	Biodiesel (8%) diesel (92%)	(gal/year)	82.55
	Fugitive sources			
	Extinguishers	Co_2	(lb/year)	60
	Extinguishers	Chcl2-cf3+(sk1)	(lb/year)	24.47
	Air conditioning / systems. 1) 12.000 btu	Hcfc-22 coolant	(lb/year)	1.1023
Scope 2. Indirect emissions	Energy acquired	Electricity	(kwh/year)	641,200.00
Scope 3. Other indirect emissions	**Consumption of paper**			
	White bond paper		Thousands of sheets/year	192.00
	Industrial stove	Natural gas	(m^3/year)	3507.00
	Air transport / trips			
	Bogotá - b/q - bogotá	b/q - bogotá- b/q	(trips/year)	6.5
	Bogotá - pereira - bogotá	pereira - bogotá - pereira	(trips/year)	1
	Bogotá- cartagena-bogotá	cartagena-bogotá-cartagena	(trips/year)	19
Scope 3. Other indirect emissions	Bogotá-cali-bogotá	cali-bogotá-cali	(trips/year)	3
	Bogotá-medellín-bogotá	medellín-bogotá-medellín	(trips/year)	3
	Bogotá-pasto-bogotá	pasto-bogotá-pasto	(trips/year)	1
	Bogotá-cartagena-b/q-bogotá		(trips/year)	5
	Bogotá-lima-bogotá		(trips/year)	5
	Bogotá-santo domingo-bogotá		(trips/year)	7

Source: Authors, 2014.

2.3.4 *Election of emission factors*

An emission factor is a representative value that seeks to relate the amount of a contaminant emitted onto the atmosphere with an amount associated to the launching of this contaminant. [13]. The compendium of emission factors has been published since 1972 by international entities, like: the Environmental Protection Agency (EPA) and IPCC among others [14].

For Transmilenio, collection of emission factors was obtained from reliable sources issued by reliable authorities like: the Energy Mining Planning Unit (UPME, for the term in Spanish), IPCC, the International Civil Aviation Organization (ICAO), and from Secretaría Distrital de Ambiente (SDA). Tables 4 and 5 show the collection of the emission factors for the company.

Table 4. Emission factors

	EMISSION FACTOR	**UNIT**	**BIBLIOGRAPHIC SOURCE OF THE FACTOR**
Biodiesel (8%) diesel (92%)	0.009444578	T co_2 / gal	Emission factor for colombian fuels (fecoc) 2003, bearing in mind the process of conversion to gallons of co_2
Gasoline	0.008151631	T co_2 / gal	
Natural gas	0.0018624138	T co_2 / m^3	
R-22 coolant	0.684	T co_2 / lb	Secretaría distrital de ambiente- storm calculator user 2,2
Electricity	0.000153	Tco_2/kwh	Emission factor of energy extracted from the energy international agency (eia) for colombia (153 g co_2/kwh) 2012 [15]
Paper	0.00085	T co_2 / thousands of sheets	Secretaría distrital de ambiente- storm calculator user 2,2 [16]
Co_2 extinguisher	0.000453592	T co_2/lb	Ipcc
Chcl2-cf3 extinguisher	0.0349266	T co_2/chcl2-cf3	Ipcc

Table 5. Collection de data 2013

Sistemas Operativos Móviles, Transmilenio				
	Description	**Consumptions**	**Unit**	**2013**
Scope 1. Direct emissions	**Mobile sources**			
	160 articulated vehicles	Biodiesel (8%) diesel (92%)	(gal/year)	2,142,664.51
	Use of scythe	Gasoline	(gal/year)	89.2728795
	Fixed sources			
	Electric plant	Biodiesel (8%) diesel (92%)	(gal/year)	120.241
	Hydro washer	Gasoline	(gal/year)	16.7484149
	Fugitive sources			
	Extinguishers	Co_2	(lb/year)	60
	Extinguishers	Chcl2-cf3+(sk1)	(lb/year)	36.37
Scope 2. Indirect emissions	Air conditioning / systems 1) 12,000 btu 2) 24,000 btu	Hcfc-22 coolant	(lb/year)	3.5253
	energy acquired	Electricity	(kwh/year)	588,400.00
Scope 3. Other indirect emissions	**Consumption of paper**			
	White bond paper		Thousands of sheets/year	192.00
	Industrial stove	Natural gas	(m^3/year)	4811.00
	Air transport / trips			
	Bogotá – b/q - bogotá	b/q - bogotá- b/q	(trips/year)	13
	Bogotá - pereira - bogotá	pereira - bogotá - pereira	(trips/year)	48
	Bogotá - cartagena cartagena- bogotá		(trips/year)	2
	Bogotá-valledupar-riohacha-bogotá		(trips/year)	1
	B/q-bogotá-cartagena		(trips/year)	1

Source: Authors, 2014.

.

Table 6. Emission factors per trips

Emission factors trips			**T of co_2 eq/trip**
Origin	**Destination**		
Bogotá	Lima	Bogotá	0.30475
Bogotá	Santo domingo	Bogotá	0.25258
Bogotá	Barranquilla		0.08018
Bogotá	Barranquilla	Bogotá	0.16051
Bogotá	Cartagena		0.08037
Bogotá	Cartagena	Bogotá	0.16074
Bogotá	Medellín		0.02792
Bogotá	Medellín	Bogotá	0.05585
Bogotá	Cali		0.04908
Bogotá	Cali	Bogotá	0.09814
Bogotá	Pereira	Bogotá	0.08259
Bogotá	Pasto	Bogotá	0.13094
Bogotá-valle	Riohacha	Bogotá	0.33211
Bogotá-carta	Barranquilla	Bogotá	0.18273
Barranquilla	Bogotá	Cartagena	0.16055

Source: Authors, 2014. Compiled from [17]

2.3.5 Calculation of the carbon footprint

To obtain the total emissions in units of $tCO_2eq/year$, equations were used according to the quantification methodology that states: level of activity, multiplied by the emission factor. The formulas are shown ahead:

a) Formula to calculate emissions through fuel consumption:

Consumption of biodiesel (gal/year)	*	Emission Factor 0.00944578(t of CO_2/ gal)	=t	CO_2/ gal	(2)

a) Formula to calculate emissions through natural gas consumption:

Gasoline consumption (gal/year)		Emission factor 0.008151631 (t of CO_2/gal		t CO_2 eq/year	(3)

b) Formula to calculate emissions through energy consumption:

Energy consumption (kWh/year)	*	Emission factor 0.000153 (t of CO_2/kWh)	=	tCO_2 eq/year	(4)

c) Formula to calculate emissions through coolant consumption:

Coolant consumption (lb/year)	*	Emission factor 0.684 (t of CO_2/lb)	=	tCO_2 eq/year	(5)

d) Formula to calculate emissions through consumption of CHCL2-CF3, extinguisher:

Consumption of CHCL2-CF3 (lb/year)	*	Emission factor 0.0349266 (t of CO_2/lb)	=	tCO_2 eq/year	(6)

e) Formula to calculate emissions through consumption of paper

Consumption of paper (Thousands of sheets/year)	*	Emission factor 0.00085 (t of CO_2/Thousands of sheets)	=	tCO_2 eq/year	(7)

f) Formula to calculate emissions through trips.

Natural gas consumption (m^3/year)	*	Emission factor 0.001862413 (t of CO_2/m^3	=	tCO_2 eq/year	(8)

g) Formula to calculate emissions through trips

Destination * No. Of tickets (trips/year)	*	Emission factor (According to destination) (t of CO_2/trips)	=	tCO_2 eq/year	(9)

3. Results

Carbon footprint measurements for the company Sistemas Operativos Móviles showed for 2012 a total of 19,441.22 tCO_2eq. These values classified by emission sources are shown in Table 7.

Table 7. Results of emissions 2012

Sistemas Operativos Móviles, Transmilenio 2012					
	Description	**Unit**	**Emission factors**	**Unit**	**Emissions**
	Mobile sources	**(gal/year)**			**T of co_2 eq/year**
Scope 1. Direct emissions	160 articulated vehicles	2046039,19	0.009444578	Tco_2/gal de diesel	19,323.976
	Use of scythe	128.4566336	0.008151631	Tco_2/m3 de gasoline	1.04713057
	Fixed sources				
	Electric plant	82.55	0.009444578	Tco_2/m3 de diesel	0.779678231
	Fugitive sources	(lb/year)			
	Extinguishers	60	0.000453592	Tco_2/lb	0.02722
	Extinguishers	24.47	0.0349266	Tco_2/chcl2-cf3	0.854654
	Air conditioning / systems 1) 12,000 btu 2) 24,000 btu	1.1023	0.684	Tco_2/lb of coolant	0.7539732
	Total direct emissions				**98.1036**

Source: Authors, 2014.

Table 7. Results of emissions 2012

Sistemas Operativos Móviles, Transmilenio (2)						
2.	**Energy acquired**	**(kwh/year)**	**631,200.00**	**0.000153**	**Tco2/kwh**	**0.1632**
Scope 3. Other indirect emissions	**Consumption of paper**					
	White bond paper	Thousands of sheets/year	192.00	0.00085	Tco_2/sheet	0.1632
	Industrial stove	(m^3/year)	3507.00	0.00186241	Tco_2/m^3	6.531485197
	Air transport / trips	**(trips/year)**		**Emission factors**	**Tco_2/trip**	
	Bogotá – b/q - bogotá b/q - bogotá- b/q	6.5		0.16051	1.0043315	
	Bogotá - pereira - bogotá pereira - bogotá – pereira	1		0.08259	0.08259	
	Bogotá - cartagena cartagena - bogotá	19		0.16074	3.05406	
	Bogotá- Cali- Bogotá- Cali	3		0.09814	0.29442	
	Bogotá- Medellín- Bogotá- Medellín	3		0.05585	0.16755	
	Bogotá Pasto- Bogotá- Pasto	1		0.13094	0.13094	
	Bogotá – Cartangena- Barranquilla- Bogotá	5		018273	0.91365	
	Bogotá- Lima-Bogotá	5		0.30475	1.52375	
	Bogotá Santo Domingo	7		0.25258	1.76806	
	Total other emissions					**15.6730**
Total co_2 emissions 2012						**19,441.22**

Source: Authors, 2014.

Table 8. Result of emissions 2013

Sistemas Operativos Móviles, Transmilenio 2013						
Scope 1. Direct emissions	**Description**	**Unit**	**2013**	**Emission factors**	**Unit**	**Emissions**
	Mobile sources					**T of co_2 eq/year**
	160 articulated vehicles	(gal/year)	2,142,664.51	0.009444578	Tco_2/gal de diesel	20,236,561.66
	Use of scythe	(gal/year)	892.728.795	0.008151631	Tco_2/m3 de gasoline	0.727719559
	Fixed sources					
	Electric plant	(gal/year)	120.241	0.009444578	Tco_2/m3 de diesel	1.135.625.479
	Hydro washer	(gal/year)	167.484.149	0.008151631	Tco_2/gal of gasoline	0.136526895
	Fugitive sources					
	Extinguishers	(lb/year)	60	0.000453592	Tco_2/lb	0.02722
	Extinguishers	(lb/year)	36.37	0.0349266	Tco_2/chcl2-cf3	1.270.280
	Air conditioning / systems 1) 12,000 btu 2) 24,000 btu	(lb/year)	35.253	0.684	Tco_2/lb of coolant	24.113.052
	Total direct emissions					**20,242.27**

Source: Authors, 2014

Table 8. Result of emissions 2013

Sistemas Operativos Móviles, Transmilenio 2013 (2)						
2.	Energy acquired	(kwh/year)	588,400.00	0.000153	Tco2/kwh	**900.252**
Scope 3. Other indirect emissions	**Consumption of paper**					
	White bond paper	Thousands of sheets/year	192.00	0.00085	Tco_2/sheet	0.1632
	Industrial stove	(m^3/year)	4811.00	0.00186241	Tco_2/m^3	896.005.451
	Air transport / trips					
	Bogotá – b/q - bogotá b/q - bogotá- b/q	(trips/year)	13	0.16051	Tco_2/trip	208.663
	Bogotá - pereira - bogotá pereira - bogotá – pereira	(trips/year)	48	0.08259	Tco_2/trip	396.432
	Bogotá - cartagena cartagena - bogotá	(trips/year)	2	0.08037	Tco_2/trip	0.16074
	Bogotá-valledupar-riohacha-bogotá	(trips/year)	1	0.33211	Tco_2/trip	0.33211
	B/q-bogotá-cartagena	(trips/year)	1	0.16055	Tco_2/trip	0.16055
	Total other emissions					**1.582.760.451**
Total co_2 emissions 2013						**20,348.12**

Source: Authors, 2014

Carbon footprint measurements for the company Sistemas Operativos Móviles showed for 2013 a total of 20,348.12 tCO_2eq. These values classified by sources are shown in Table 8.

4. Conclusions

For base year 2012, emissions through fuel consumption present a total of 19,323.97 tCO_2eq and through energy consumption a total of 98.10 tCO_2eq, with these emission sources being the most representative for a total organizational carbon footprint of 19,441.22 tCO_2eq.

For 2013, the carbon footprint was equivalent to 20,348.12 tCO_2eq; this was due to the increase of the fleet and, hence, the amount of fuel consumed, which increased by around 96,625.32 gal. This consumption corresponds to the emission of 912.58 tCO_2eq; with respect to emissions from energy, consumption diminished by 52,800 kWh that correspond to the reduction of 8 tCO_2eq/year.

Implementation of projects aimed at mitigating fuel consumption will reduce GHG emissions considerably.

Even though direct comparisons cannot be made of the emissions quantified with the total national emissions, because we have different years, it could be said that if we took as a starting point the emissions data provided by Colombia for 2004, which is 0.37% (180,010,000 tCO_2eq), the 20,348.12 tCO_2eq/year for 2013 from the company Sistemas Operativos Móviles correspond to 0.011% of the 0.37% of the country's emissions.

Although the total emissions through fuel consumption represent 98% of the total emissions, 0.5% is caused by the use of electric energy, reflecting inefficiency regarding the application of low-consumption technologies.

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