



The carbon footprint of a public university campus in Mexico City

Rubén Mendoza-Flores, Rodolfo Quintero-Ramírez & Irmene Ortiz

To cite this article: Rubén Mendoza-Flores, Rodolfo Quintero-Ramírez & Irmene Ortiz (2019) The carbon footprint of a public university campus in Mexico City, Carbon Management, 10:5, 501-511, DOI: [10.1080/17583004.2019.1642042](https://doi.org/10.1080/17583004.2019.1642042)

To link to this article: <https://doi.org/10.1080/17583004.2019.1642042>



View supplementary material [↗](#)



Published online: 02 Aug 2019.



Submit your article to this journal [↗](#)



Article views: 36



View related articles [↗](#)



View Crossmark data [↗](#)

CASE REPORT



The carbon footprint of a public university campus in Mexico City

Rubén Mendoza-Flores^a, Rodolfo Quintero-Ramírez^b and Irmene Ortiz^b

^aLic. en Ingeniería Biológica, Universidad Autónoma Metropolitana-Cuajimalpa, México City, Mexico; ^bDepto. Procesos y Tecnología, Universidad Autónoma Metropolitana-Cuajimalpa, México City, Mexico

ABSTRACT

The Cuajimalpa campus of the Autonomous Metropolitan University (UAM) is located in the western region of Mexico City. In 2016, its global average population (students, faculty and staff) was around 2750 people. Campus policies include sustainability as one of its main aims. To evaluate and eventually reduce the environmental impact of the campus, its greenhouse gas (GHG) inventory was assessed and the carbon footprint was calculated, using the GHG protocol (GHGP): Scope 1: direct GHG emissions; Scope 2: indirect GHG emissions; and Scope 3: other indirect GHG emissions, on a calendar year basis. Scope 1 includes mobile and stationary sources and leakage of refrigerants; Scope 2 includes electrical energy usage; Scope 3 includes consumption of paper, food, water, gases, cleaning products, solvents, wastewater treatment, municipal and hazardous wastes and academic travel. In 2016, the campus produced around 3000 tons of CO₂ equivalent, with Scope 1, 2 and 3 accounting for 4%, 24% and 72%, respectively. Emissions analysis by activity indicated 51% for commuting; 24% for electricity usage; 14% for academic travel; 11% for other activities. The inventory will aid the establishment of policies for reduction and mitigation of GHG, resulting in environmental and potential economic benefits.

KEYWORDS

Carbon accounting; carbon footprint; university; greenhouse gas inventory; climate change

Introduction

The Universidad Autónoma Metropolitana (UAM) is a public university founded in 1971 and has five campuses located east, south, north, and west of Mexico City and in the metropolitan area. The Cuajimalpa campus (UAM-C) was founded in 2006 but temporary locations were used until the current campus was constructed in 2013, in Santa Fe, a western neighborhood of Mexico City. It consists of an eight-storey, 44,349.70 m² building. Until 1989, Santa Fe neighborhood was a zone of open dumps in exhausted sand mines. From 1983 to 1988, an 850 ha urbanization project to build a business improvement district [1] was developed in this western zone. The headquarters of leading national and international companies have been established here since the late 1980s, followed by a real estate boom of luxury apartments. Nowadays, this 900-ha zone has a residential population of 35,000 people and an average floating population of 233,000 people (temporary and permanent employees, students and visitors) [2]. Unfortunately, the growth of the zone resulted in serious problems of mobility and heavy traffic due

to commuting. The World Resources Institute (WRI) Chapter Mexico estimated that an employee working in Santa Fe could spend 26 days per year in commuting due to the limited access to the zone (only five main access routes) because of its geography (gullies) resulting in significant emissions of greenhouse gases (GHG) [3].

In the context of sustainable development and the mitigation of climate change, it is essential to estimate GHG emissions. The global goal of stabilizing the increase in the global average temperature to well below 2 °C above pre-industrial levels and of pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels was proposed in 2015 by the Paris Agreement of The United Nations Framework Convention on Climate Change [4]. The Mexican goal is to reduce by 50% the national GHGs emissions by 2050 [5]. In 2013, Mexico emitted 665 million tons of CO₂ eq, ranking 12th in terms of countries contributing to global emissions [5].

The Greenhouse Gas Protocol Initiative is a multi-stakeholder partnership of businesses, non-governmental organizations, governments, and other institutions convened by the WRI and the

World Business Council for Sustainable Development (WBCSD), a Geneva-based coalition of 170 international companies. The mission of this initiative, launched in 1998, is to develop internationally accepted GHG accounting and reporting standards for businesses and to promote their broad adoption [6]. The GHG inventory will help an organization to better manage the full spectrum of GHG risks and opportunities existing along its value chain [6].

As a public educational institution, UAM-C has a commitment to the environment and sustainable development. Therefore, the objective of this study was to generate the GHG inventory that could serve as a basis for developing a mitigation plan, thus contributing to climate change mitigation, as well as to the fulfillment of its social responsibility.

Methodology

Operatives and organizational limits

As proposed by the GHG protocol, the operational boundaries of the UAM-C concerning direct and indirect emissions were settled. The operative accounting included three groups: i) direct emissions (Scope 1) that come from sources owned or controlled by the organization; ii) indirect emissions (Scope 2), from the organization's consumption of purchased electricity; iii) other indirect emissions (Scope 3) corresponding to the activities within the organization, but originated from the sources that are not owned or controlled by it. Together, the three scopes provide a comprehensive accounting framework for managing and reducing direct and indirect emissions [6]. All the sources and activities considered are listed in Table 1 and fully described in the next sections.

Inventory

Mobile sources, stationary sources and refrigerant gas leakage were considered in Scope 1 and electric energy usage was considered in Scope 2. Scope 3 took into consideration the consumption of paper, meat in the dining halls, water, gases, cleaning products and solvents, as well as the generation and treatment of wastes (municipal and hazardous wastes and wastewater), business travel and commuting. The inventory includes the activities of the 10 experimental laboratories, seven dedicated to academic research and three dedicated to teaching.

Emission factors used for calculations were the available values for national emission factors or those selected accordingly from the literature. Emission factors used for each source are listed in Table 1S, in Supplementary Material.

Uncertainty

The accuracy level of a reported value can be due to measurement error, lack of available data, modeling assumptions or future estimation [7]. The inventory data reported in this study were obtained from registered or measured data, this being the case for most of the values since the UAM-C is a small campus. In each case, the source of the inventory data is provided. However, the contribution due to commuting (external transportation, Scope 3) was estimated from a survey and validated by studies on transportation in this region which, as mentioned above, is poorly served and has serious problems of mobility and heavy traffic due to business commuting.

The uncertainty due to the emission factors is introduced by the fact that many of them were not available specifically for the country; therefore, generic global factors were used accordingly to the IPCC.

Population

The population of the campus was divided into three groups: i) students, consisting of the total number of graduate and undergraduate students enrolled; ii) faculty, comprising the academic personnel in the three academic divisions (Social Sciences and Humanities, Communication and Design Sciences and Natural Sciences and Engineering); and iii) staff that includes employees in administrative, operative and maintenance roles. The population varies across the trimesters of the year. In 2016, the year used for this GHG inventory, the UAM-C had an average population of 2202 students, 240 faculty and 309 staff members according to the departments of school systems and human recourses.

Period of accounting

The calendar year of 2016 was used for the inventory. According to the 2016 school calendar, there were 212 working days, out of which 168 were days with teaching activities (school days). Therefore, it was considered that the student population attended the university only on school days, while the faculty and staff attended the university on all working days.

Table 1. Activities and their intensity by scope considered in the GHG inventory of the UAM-C in 2016.

Type	Source/activity	Compound/component	Intensity	Units
Scope 1. Direct emissions				
Fixed sources	Dining hall	LP gas	12,022	L
	Dressing room	LP gas	2,064	L
	Research and teaching laboratories	LP gas	80	L
Mobile sources	Vehicle fleet	Gasoline	11,800	L
	School transportation	Distance	33,600	km
Fugitive emissions	Refrigeration	Refrigerants	10.52	kg
Scope 2. Indirect emissions				
Electricity	Electric Energy	Electricity	1,564.53	MWh
Scope 3. Other indirect emissions				
Resource consumption	Water	Water	15,612	m ³
	Paper	Paper sheets	10.36	ton
		Paperboard and others	2.67	ton
	Meat consumption (dining hall)	Chicken	6,643.73	kg
		Pork	4,845.72	kg
		Beef	4,317.10	kg
		Fish	1,423.17	kg
	Gases (research activities)	Carbon dioxide	0.36	ton
		Methane	0.03	ton
	Solvents (research and teaching activities)	Acetone	35.00	L
		Chloroform	32.18	L
		Ethanol	258.00	L
		Hexane	36.00	L
		Petroleum ether	6.00	L
		Methanol	28.00	L
		Ethyl acetate	30.00	L
		Acetonitrile	12.00	L
		2-methyl-2 butanol	12.00	L
		Phenol	0.63	L
		Spray paint	3.60	L
		Xylene	5.21	L
		Dichloromethane	4.00	L
Municipal waste management	Recycling	Mixtures	36.81	L
		Liquid soap	4460	L
		Detergent powder	300	kg
		Bleach	190	L
		Paper sheets	220.3	kg
		Paperboard	1,282	kg
		PET	78	kg
		TETRAPACK	76.4	kg
		Glass	47.3	kg
		Iron	57	kg
		Aluminum	18.2	kg
		Other	51.7	kg
		Organic fraction from the dining hall (animal feed)	9,889.6	kg
Hazardous waste management	Landfill	Not recoverable	3,579.28	kg
	Thermal oxidation	Organic solvents	171.43	kg
		Aqueous solutions	171.43	kg
		Halogenate solutions	14.29	kg
		Glass	2.14	kg
		Empty containers	7.14	kg
		Solids	5.71	kg
Wastewater management	Aerobic wastewater treatment	Chemical oxygen demand (COD)	1.48	ton COD
Commuting	Private	Automobile	2,212,716.77	km
		Metro	4,257,314.79	km
		Urban bus	5,444,910.84	km
		Collective transport	127,997.70	km
		Interurban bus	1,469,190.99	km
Work trips: lodging and transport	Attendance at scientific meetings	Air transport	2,193,588.71	km
		Bus	18,399.96	km
		Automobile	6,859.72	km
		Lodging	1203	day
	Academic guests	Air transport	362,730.03	km
		Bus	2,234.84	km
		Lodging	130	day

Activities and emission factors considered in Scope 1

Fixed sources

These sources included the dining hall, dressing rooms/showers, and laboratories where liquefied petroleum gas (LP gas) was used for heating. This

information was obtained through the department of academic services and the laboratory personnel, and it was assumed that all the fuel bought was consumed. The emission factor for combustion of LP Gas used was the one published by the Mexican government [8].

Mobile sources

Vehicle fleet. In 2016, the UAM-C had a fleet of 11 gasoline vehicles, according to the department of transport and security. Vehicle fuel consumption averaged 10 km per liter per day. The annual consumption of gasoline was calculated from the volume used per day and the number of working days of the year. The emission factor for combustion of gasoline used was the one recommended by the Mexican government [8], and the heating value (MJ/L) was used as a conversion factor. Detailed characteristics of the fleet are provided in Table S2, in Supplementary Material.

School transportation. The university has two school transportation services that are provided by a private company and by the Mexico City government. These services are not owned by the University, but leased or requested for the exclusive transport of staff and students of the UAM-C. For this reason, they were considered as within the operational limits of the organization and thereby included as direct emissions. Both provide four round trips per day from the campus to the nearest subway station “Tacubaya” covering the distance of 12.5 km. It was considered that the trips were made during school days, resulting in an annual distance of 16,800 km. The emission factor used was based on the distance covered by urban buses using diesel [9]. The other means of commuting are described later in the document.

Fugitive emissions

We have identified 43 domestic refrigerators, 4 freezers, 2 ultra-freezers, 2 ice-makers, and one cold room at the campus, using three types of gases: R-134A, R-404A, and R-290. No air-conditioning equipment was identified whatsoever. According to the UAM-C department of maintenance, the equipment did not receive maintenance or refrigerant reload during 2016. Therefore, the data available for the leakage of refrigerant gases was the original charge of refrigerant. In consequence, the direct fugitive emissions from refrigeration were calculated according to the methodology proposed by the United States Environmental Protection Agency using the data on the original charge of refrigerant gases provided by the manufacturer of each piece of equipment [10].

Activities and emission factors considered in Scope 2

Electrical energy

The electricity used in the UAM-C was purchased from the Federal Electricity Commission (CFE), the government company. The total amount of electric energy consumption was calculated according to monthly records of the UAM-C administrative department. The emission factor used was that recommended by the Mexican registry of emissions [11].

Activities and emission factors considered in Scope 3

Water consumption

The total amount of water consumption was provided by the 2016 records of the UAM-C administrative department. A generic emission factor was used to calculate the GHG emissions [12].

Paper consumption

According to the department of administrative services, different types of paper, such as virgin office paper, recycled office paper, folders, cardboard boxes, photographic paper, cardboard, disposable napkins, handkerchiefs, and absorbent paper were used in 2016, and they were grouped into virgin and recycled paper. A generic emission factor for paper consumption was used considering that all the paper bought was indeed used [13]. The mass of each type of paper was calculated considering the type of paper, the number of purchased packages, the number of paper sheets, the size of one sheet, and paper density (g/m^2).

Food (meat) consumed in the dining hall

The dining hall is operated by the University and provides breakfast and lunch services. The most consumed types of meat in the university dining hall (beef, pork, fish, and chicken) were considered in the emissions inventory. The information relative to meat consumption was obtained through the records of the department of general services. Emission factors considered were reported by EWG, 2011 [14].

Gases for research activities

Carbon dioxide and methane were used in some research laboratories in experimental activities. In this case, the volumes of gases used were

provided by the laboratories and the emissions were calculated using the emission factor global warming potential (GWP) 100 years [10].

Solvents for teaching and research activities

A list of solvents and their approximate volumes used for teaching and research activities was provided by each laboratory; the amounts were converted to mass by using the density (g/L) of each compound. Some of these substances were in mixtures or were unknown solvents, and were considered as generic solvents. The emission factors from Data Base Ecolnvent 3.3 were used (SimaPro 8.3.0).

Cleaning products consumption

The cleaning products used in the university were multipurpose liquid soap, liquid hand soap, powder detergent, and bleach; the information regarding these products was provided by the department of general services. The emission factors per mass used for each type of soap were obtained from Data Base Ecolnvent 3.3 (SimaPro 8.3.0). In the case of liquid soap, the mass was obtained by multiplying the volume of soap by its density.

Municipal waste management

At the campus, there is a program called “SeparaAcción” to manage the generated wastes. According to the program personnel, solid waste is separated and sent to recycling while the non-recyclable waste is sent to a municipal landfill. The organic waste generated in the dining hall is donated to third parties where it is used as pig feed. The “SeparaAcción” program provided the information relative to the quantity of generated waste and the emission factors used were those proposed by Turner et al. 2015 [15].

Hazardous waste management

Hazardous waste is generated by the laboratories activities, but it is separated and later treated by an external organization through thermal oxidation. The information regarding the hazardous waste was provided by generators at the Natural Sciences and Engineering Division of the UAM-C and the emission factors used were from the University of Valladolid in 2015 [16].

Wastewater management

The aerobic plant to treat the wastewater generated at the campus is operated by an external enterprise. Unfortunately, the information on the wastewater treatment plant (WWTP) operation in 2016 was not available, so 2017 data were used considering that the campus population did not vary significantly from 2016. The values of chemical oxygen demand (COD) used were also from 2017, and the calculation of emissions considered the total of consumed water, the removed COD (input minus output values) and an emission factor provided by the Mexican government [8].

Commuting

The vehicles used for commuting were divided into two groups, public transport and private transport. The information regarding commuting was based on a previous internal study about the bioclimatic conditions of the campus (Internal report, data not published). This study reported a survey with a sample of 270 students, 62 faculty members, and 60 staff members; 81% of the sample declared using public transportation and the remaining 19% reported using private transport. The survey also included information about time, average distance, and origin of travel. The GHG emissions were calculated considering the annual average distance for faculty and staff (attending on working days), the yearly average distance for students (attending on class days) and the annual distance traveled by the school bus. The traveled distance was divided into four types: subway, urban bus, interurban bus, and urban van. The proportion of each transport type used was calculated simulating the routes in accordance with the origin of the population. The distance was then estimated by type of transport considering the population using each type. Private transport emissions were estimated according to the GHG protocol [9]. It was assumed that all journeys were made in gasoline automobiles fabricated in 2005 or earlier with 1.2 persons per vehicle [3].

Work trips: lodging and transportation

This category included trips by teachers and students to destinations outside the city for visits to companies and research institutions, as well as trips to congresses, symposiums, conferences and other scientific events. The trips made by guests from other cities, conferences and symposiums

Table 2. Emissions of GHG of UAM-C in 2016 by scope.

Scope	Source/activity	Emissions (ton CO ₂ eq)
Direct emissions	Fixed sources	24.16
	Mobile sources	83.06
	Fugitive emissions (refrigeration)	3.39
Indirect emissions	Electricity	716.55
Other emissions	Water consumption	5.37
	Paper consumption	16.52
	Meat consumption (dining hall)	108.67
	Gases (research activities)	0.88
	Solvents (teaching and research)	0.81
	Cleaning products consumption	31.70
	Municipal waste management	0.04
	Hazardous waste management	0.05
	Wastewater management	0.11
	Commuting (private transport)	525.45
	Commuting (public transport)	972.18
	Work trips: transport	423.84
	Work trips: lodging	43.49
TOTAL		2,956.28

organized by the UAM-C were also taken into consideration. The lodgings related to these activities were included as well. The information was extracted from the expense policies provided by the department of administrative services. The emissions were calculated considering the distances, and air and land travel emission factors [9,17].

Results and discussion

Inventory and emissions

The inventory of activities and their intensity for Scope 1, 2 and 3 is presented in Table 1 while the emissions for each scope are given in Table 2. A total of 2956 tons of CO₂ eq was emitted by the UAM-C in its activities in 2016. The 4%, 24% and 72% of the total emissions (i.e. 110, 716 and 2130 tons CO₂ eq) corresponded to Scope 1, Scope 2 and Scope 3, respectively (Figure 1a). Per activity, 32% corresponded to the use of public transport, 24% to the use of electric energy, 18% to the use of private transport, 3.7% to meat consumption and 2.8% to the use of mobile sources while the remaining 5.5% corresponded to other activities (Figure 1b). Many reports on the carbon footprint of Universities conclude that the activities of Scope 3 are the main contributions [18,19]. A discussion of comparative results with other universities is presented later on.

Scope 1

Given the fact that the devices used are mainly domestic fridges, the emissions generated by refrigerant leakage represented only 0.14% of the total emissions (3.39 tons CO₂ eq), primarily associated with ultra-freezers used in laboratories. In the case of mobile sources, the emissions represented

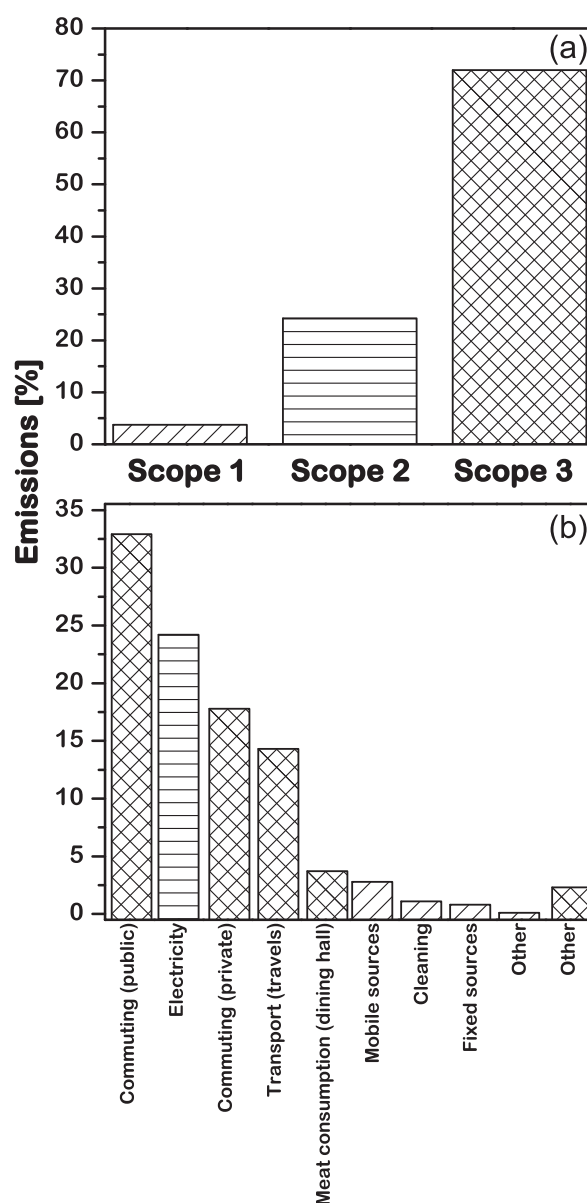


Figure 1. GHG emissions in 2016, (a) by scope and (b) by Sources/activities. ▨ Scope 1; ▤ Scope 2; ▩ Scope 3.

only 2.8% of the total emissions (83.06 tons CO₂ eq). However, these can be reduced by replacing gasoline vehicles with those using fuel with lower

emission factors, such as electric or natural gas vehicles, but the lack of infrastructure for this kind of vehicles in Mexico City in addition to the investment required should be considered. In the case of fixed sources, they represented 0.82% of the total emissions (24.16 tons CO₂ eq); here, the feasibility of replacing LP with natural gas with a smaller emission factor and better market prices needs to be considered. The emission of GHG factor for the combustion of natural gas is 12.5% lower than that for LP gas combustion [8].

Scope 2

Even though the consumption of electrical energy represented the second main emission source (24% of the total, 716 tons CO₂ eq), its distribution per activities at the university is unknown; thus, in order to identify reduction opportunities, it would be necessary to assess usage distribution. Therefore, the inventory needs to be refined with the identification of specific uses of electricity per activity and per department as a first step to propose reduction strategies.

Scope 3

The consumption of meat in the dining hall represented 3.7% of the total emissions (108.67 tons CO₂ eq). A hypothetical scenario, in which the consumption of meat one day a week would be substituted with that of vegetables (20% reduction of meat consumption per year) and considering that most of the vegetables have an emission factor of one order of magnitude lower than meat, this action could mitigate the emission of 19.55 tons CO₂ eq representing 0.66% of the total emissions.

Regarding the use of paper, 13 tons of paper per year generated 16.52 tons CO₂ eq and represented 0.5% of the total emissions. Although these emissions could be considered low, various actions have already been implemented in the university under the concept of green office, but their effectiveness will be evaluated in further studies of their carbon footprint.

Water consumption generated almost 5.37 tons CO₂ eq, which represents less than 0.3% of the total emissions; as in the case of electric energy consumption, the purpose and usage distribution must be assessed to identify reduction opportunities.

Municipal waste treatment generated only 0.038 tons CO₂ eq, which represents less than 0.001% of the total emissions, indicating that the management program of the campus allowed the

appropriate separation of almost 115.3 tons of waste. Comparing this scenario with a hypothetical situation in which all the waste is not separated but sent to landfill, the estimation is that separation and recycling represented mitigation of 4.5 tons CO₂ eq (85% of the potential emissions due to this source).

The hazardous waste treatment generated 0.05 tons CO₂ eq (<0.002% of the total). As the generated waste was sorted and the final disposal was entrusted to an external company that treated it appropriately, it is not necessary to take action to reduce the emissions.

The wastewater treatment generated almost 0.110 tons CO₂ eq that represents less than 0.004% of the total emissions. However, in the next inventory of GHG, the quality of data must be improved to generate even more accurate information.

In the case of GHG used in the laboratories, 0.88 tons CO₂ eq was emitted, representing less than 0.03% of the total emissions. Since the amount of gases used in the bioprocessing laboratory in research activity related to technologies for air pollution control is reduced, implementing actions to mitigate these emissions is considered unnecessary.

Emissions from solvents used in laboratories generated 0.810 tons CO₂ eq (<0.03% of total emissions). Ethanol was identified as the most used solvent (258 L/year), indicating an opportunity for mitigation with the implementation of a plan for reducing its use. On the other hand, the information regarding the use of solvents was obtained through personal communication and is approximate, so it is expected that implementing a formal registry of their use could improve the quality of the data of the GHG inventory.

The use of cleaning products generated 31.7 tons CO₂ eq (1% of the total emissions), and since it is quite limited, the emissions of these products are low, making any action for their reduction unnecessary.

Work travel generated 424 tons CO₂ eq (14.34% of the total) representing the fourth source of emission. Since these journeys are for academic and scientific purposes, they represent an opportunity to significantly reduce the emissions by implementing actions such as: avoidance of using air travels in short trips, and advice to the community on the impact of the use of flights. Another option is the use of video-conferences: when available, they would allow cost savings and better use of the professors' and guests' time.

Table 3. Comparative emissions of GHG of other universities.

University/Institution	Country	Year	Emissions (tons CO ₂ eq)					Reference
			Total	Per capita	By scope (%)			
					SP1	SP2	SP3	
University of Santiago de Compostela	Spain	2007	32,407.8	1.01	33.0	30.6	36.4	[21]
De Montfort University	UK	2008/09	51,080	1.99	6.0	15.0	79.0	[22]
University of Valencia	Spain	2010	58,517.8	0.88	6.3	20.0	73.6	[21]
National Autonomous University of Mexico. Engineering Institute	Mexico	2010	1577	1.47	5.0	42.0	53.0	[23]
University of Madrid. School of Forestry Engineering	Spain	2010	2147	1.87	8.3	32.7	59.0	[24]
Pontifical Catholic University of Rio de Janeiro. Gávea Campus	Brazil	2011	5,782	0.29	1.5	0.2	98.3	[25]
University of Talca. Curico campus	Chile	2012	1,568.6	1.00	16.0	16.0	68.0	[26]
University of Alberta	Canada	2012-13	325,351	6.51	52.0	40.0	8.0	[27]
Polytechnic University of Cartagena	Spain	2013	9,088.4	1.07	3.6	16.9	79.4	[21]
University of Valladolid	Spain	2014	22,080.5	1.11	24.6	30.2	45.2	[16]
Edith Cowan University	Australia	2015	24,797.6	1.73	4.0	69.0	27.0	[28]
University of Cambridge	UK	2016	102,049.9	3.50	20.0	52.0	28.0	[29]
University of California. Berkeley	USA	2016	151,650	2.90	44.2	28.1	27.7	[30]
University of Málaga	Spain	2017	24,831.6	0.66	2.0	57.0	41.0	[31]
Autonomous Metropolitan University. Cuajimalpa Campus	Mexico	2016	2,956.3	1.07	4.0	24.0	72.0	This study

SP: Scope.

Commuting represents the main activity, and generates 51% of the total emissions. The 2017 origin-destination survey in the Metropolitan area of the Mexican valley, performed by the National Institute of Statistics, indicated that 53.4% of the week-day trips are completed in public transport while 25.2% in private transports [20]. Another report by WRI-México indicated that 64% (545,000) of the total trips taking place in the area of Santa Fe is related to business activities, out of which 46% were performed using public transport, 41% in private transport, 8% in transport provided by the companies or institutions and 6% in taxis. However, the occupation for private automobiles was only 1.2 persons, therefore, they represented 87% of the vehicles circulating in the area [3]. Our results indicated that commuting by private transport resulted in the emission of 2.0 tons CO₂ eq per capita, 2.3 times that of public transport (0.436 tons CO₂ eq per capita). Mitigation actions must be thereby related to the use of public transport. However, these actions require the participation of both municipal (Cuajimalpa) and Mexico City government. Considering the geography of the area, with ravines and highways, the use of electric bicycles is an option to be evaluated.

Comparison with other universities

As an internationally significant sector, Higher Education Institutions have begun to address climate issues through carbon reduction policies on and off their estates. However, there have been very few research articles that document emissions arising from all (direct and indirect) attributable activities [18]. The emissions by scope and per capita of the UAM-C were compared with values of other universities in Table 3. The studies reported

in Table 3 used a similar methodology of the three scopes, the use of electricity and combustibles is taken into account in all studies and some activities such as the construction of new buildings are considered in some cases [16,21,31]. The main contribution, in most of the studies, is related to indirect emissions (Scope 3) attributable to commuting. One approach to compare different studies is the normalization per capita (considering the total population). This value for the UAM-C was 1.07 tons CO₂ eq, which is higher than those from the Pontifical Catholic University of Rio de Janeiro, the University of Malaga and the University of Valencia, 0.29, 0.66 and 0.88 tons CO₂ eq/per capita, respectively (Table 3) [21,25,31]. On the other hand, higher emissions per capita are reported by the Tongji University and the Norwegian University of Technology and Science (3.84 and 3.60 tons CO₂ eq/per capita) where other modeling approaches were used [32,33]. Their values are similar to the emissions of the University of Cambridge [29]. However, the main contributions to the carbon footprint, reported by the University of Alberta and the University of California - Berkeley for Scope 1, related to the energy consumed for heating [27,30]. It is the main difference with our university where a warm winter does not require heating. On the other hand, the emissions per capita of the UAM-C (1.07 tons CO₂ eq) is similar to those reported for the University of Santiago de Compostela, the University of Talca, Curico campus, the Polytechnic University of Cartagena and the University of Valladolid [16,21,26], but lower than those reported for other universities [22–24,27–30].

These reports are important references as benchmarks of emissions, but further efforts are required to address target reductions in emissions;

for example, higher education institutions in England have mandatory targets by 2020 to reduce their Scope 1 and 2 emissions by 34%, below a 2005/06 baseline, or some Scope 3 sources, such as water and waste, transport and procurement [18,34].

Recommendations

Since Scope 3 had the highest contribution to the emissions of the UAM-C, activities considered in this scope must be carefully registered in the next inventory of the campus, and the mitigation plan should mainly focus on them.

The estimation of emissions due to commuting (Scope 3) is one of the aspects with the most opportunities for improvements. An annual survey for a more accurate inventory was suggested to the authorities and also the UAM-C community participated in the annual survey of mobility within the region as well.

Since the Scope 2 emissions represented 24% of the total emissions, the reduction of electricity consumption is one of the areas with opportunities for improvement. An initial study of the investment required for UAM-C facilities adequation (i.e. LED lighting, solar panels, etc.) to reduce electricity consumption expenditure has been conducted (data not published) but also the reduction of the carbon footprint can be estimated as well.

An inventory by the academic division could also be also useful for the mitigation plan, since it would allow identifying differentiated opportunities for mitigation. Intuitively, it could be identified that the carbon footprint contribution of the science and engineering division is higher than that of Social Sciences and Design division, due to the use of chemicals, equipment and generation of hazardous wastes at the teaching and researching laboratories. Therefore, their mitigation efforts should be related to the rational use of chemicals and improvements of the waste disposal system implemented.

Another field of opportunity is the development of an emission factors database since there is a lack of data at the national level. It will contribute to the reduction of uncertainties.

Conclusions

The UAM-C emitted in 2016 almost 3000 tons of CO₂ eq, out of which 4% are related to Scope 1, 24% to Scope 2 and 72% to Scope 3. The main contributions to GHG emissions were the use of

vehicles for commuting (51%) and the use of electricity (24%). This study will serve us as a benchmark to establish the mitigation goals as an Institution and to design a mitigation plan, including the evaluation of the other four campuses of the UAM. A quality management plan should be also developed for more robust and accurate inventory and the assessment of the possible mitigation strategies. Also, the development of national emission factors would reduce the uncertainty of the results obtained. Finally, the commitment of the University authorities and community will be fundamental for the development of a program as our contribution to global actions for climate change mitigation.

Acknowledgments

The authors would like to thank UAM Cuajimalpa authorities and administrative and academic staff for their support in data collection.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Valenzuela A. Santa Fe (México): Megaproyectos para una ciudad dividida. Cuadernos Geográficos. 2007; 40:53–66.
2. WRI-Mexico (World Resources Institute- Mexico). 14 años escalando el impacto. 2016, El año de la transición de CTS EMBARQ México a WRI México. Informe Institucional. 2017. Available from: <http://www.wrimexico.org/sites/default/files/Informe%20Institucional%20WRI.pdf>.
3. WRI-México (World Resources Institute- México). Estudio de la movilidad en la Zona de Santa Fe en la Ciudad de México. 2015. Available from: <http://wri-ciudadades.org/sites/default/files/Estudio%20de%20movilidad%20en%20Santa%20Fe%20CDMX.pdf>.
4. UNFCCC (The United Nations Framework Convention on Climate Change). Paris agreement. 2015. Available from: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.
5. SEMARNAT-INECC (Ministry of Environment and Natural Resources and National Institute of Ecology and Climate Change). Mexico's Climate Change Mid-Century Strategy. 2016. Available from: https://unfccc.int/files/focus/long-term_strategies/application/pdf/mexico_mcs_final_cop22nov16_red.pdf.
6. WRI/WBCSD (World Resources Institute and World Business Council for Sustainable Development). The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. The Greenhouse Gas Protocol Initiative, USA and Switzerland. 2004.

- Available from: <https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf>.
7. Marland E, Cantrell J, Kiser K, et al. Valuing uncertainty part I: the impact of uncertainty in GHG accounting. *Carbon Manag.* 2014;5:35–42. doi:10.4155/cmt.13.75.
 8. DOF (Diario Oficial de la Federación). Acuerdo que establece las particularidades técnicas y las fórmulas para la aplicación de metodologías para el cálculo de emisiones de gases o compuestos de efecto invernadero. México. 2015. Available from: http://dof.gob.mx/nota_detalle.php?codigo=5406149&fecha=03/09/2015.
 9. GHGP (Green House Gas Protocol). Emission factors from cross-sector tools. Worksheet. 2017. Available from: http://www.ghgprotocol.org/calculation-tool-s#tools_for_countries_and_cities_id.
 10. US-EPA (US-Environmental Protection Agency). Direct fugitive emissions from refrigeration, air conditioning, fire suppression, and industrial gases. 2014. Available from: <https://www.epa.gov/sites/production/files/2015-07/documents/fugitiveemissions.pdf>.
 11. RENE (Registro Nacional de Emisiones). Aviso sobre el factor de emisión eléctrico para el reporte 2016. 2016. Available from: http://www.semarnat.gob.mx/sites/default/files/documentos/cicc/aviso_factor_de_emision_electrico_2015.pdf.
 12. UK emission factors, Government of the United Kingdom. Reporting – conversion factors. 2016. Available from: <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2016>.
 13. Victoria-EPA (Environmental protection Authority-Victoria, Australia). Greenhouse gas emission for office copy paper. 2013. Available from: <https://www.epa.vic.gov.au/~media/Publications/1374%201.pdf>.
 14. EWG (Environmental Working Group). Meat eaters guide: methodology 2011. EUA. Available from: https://static.ewg.org/reports/2011/meateaters/pdf/methodology_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf?_ga=2.63530411.540121783.1524182623-419444687.1524182622.
 15. Turner DA, Williams ID, Kemp S. Greenhouse gas emission factors for recycling of source-segregated waste materials. *Resour Conserv Recycl.* 2015;105:186–197. doi:10.1016/j.resconrec.2015.10.026.
 16. UVA (Universidad de Valladolid), Oficina de Calidad Ambiental y Sostenibilidad. La huella ecológica de la Universidad de Valladolid. 2015. Available from: http://www.uva.es/export/sites/uva/7.comunidaduniversitaria/7.09.oficinacalidadambiental/_documentos/LA-HUELLA-ECOLOGICA-EN-LA-UNIVERSIDAD-DE-VALLADOLID.pdf.
 17. US-EPA (US-Environmental Protection Agency). Emission Factors for Greenhouse Gas Inventories. 2015. Available from: https://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf.
 18. Robinson O, Tewkesbury A, Kemp S, et al. Towards a universal carbon footprint standard: a case study of carbon management at universities. *J Clean Prod.* 2018;172:4435–4455. doi:10.1016/j.jclepro.2017.02.147.
 19. Townsend J, Barrett J. Exploring the applications of carbon footprinting towards sustainability at a UK university: reporting and decision making. *J Clean Prod.* 2015;107:164–176. doi:10.1016/j.jclepro.2013.11.004.
 20. INEGI (Instituto Nacional de Estadística y Geografía). Encuesta Origen-destino en hogares de la Zona Metropolitana del Valle de México 2017. 2018. Available from: http://www.beta.inegi.org.mx/contenidos/saladeprensa/boletines/2018/EstSociodemo/OrgenDest2018_02.pdf.
 21. Hermosilla-Alcaraz A. Huella de Carbono en la Universidad Politécnica de Cartagena: En Busca de la Ecoeficiencia. Trabajo de fin de Master. Universidad Politécnica de Cartagena. 2014. Available from: <http://repositorio.upct.es/bitstream/handle/10317/5043/tfm384.pdf;jsessionid=F64576FA8DFF66190698035796BA9BED?sequence=1>.
 22. Ozawa-Meida L, Brockway P, Letten K, et al. Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study. *J Clean Prod.* 2013;56:185–198. doi:10.1016/j.jclepro.2011.09.028.
 23. Güereca LP, Torres N, Noyola A. Carbon Footprint as a basis for a cleaner research institute in Mexico. *J Clean Prod.* 2013;47:396–403. doi:10.1016/j.jclepro.2013.01.030.
 24. Alvarez S, Blanquer M, Rubio A. Carbon footprint using the compound method based on financial accounts. The case of the School of Forestry Engineering, Technical University of Madrid. *J Clean Prod.* 2014;66:224–232. doi:10.1016/j.jclepro.2013.11.050.
 25. Carvalho A, van Elk P, Romanel C. Greenhouse gas emissions inventory on Gávea Campus of PUC-Rio. *Eng Sanit Ambient.* 2017;22:591–595. doi:10.1590/s1413-41522017155865.
 26. Vásquez L, Iriarte A, Almeida M, et al. Evaluation of greenhouse gas emissions and proposals for their reduction at a university campus in Chile. *J Clean Prod.* 2015;108:924–930. doi:10.1016/j.jclepro.2015.06.073.
 27. University of Alberta. University of Alberta GHG inventory report, 2005–06 baseline and 2012–13 report. 2014. Available from: <https://cloudfront.ualberta.ca/~media/ualberta/vice-president-facilities-and-operations/documents/emso/ua-ghg-inventory-baseline-to-2012-13.pdf>
 28. Favacho S. Organizational Greenhouse Gas Inventory (Carbon Footprint) Report. Edith Cowan University 2016. Available from: https://www.ecu.edu.au/__data/assets/pdf_file/0011/658064/ECU-2015-Carbon-Footprint-Report.pdf (accessed 14 March 2018).
 29. UC (University of Cambridge). Environmental Sustainability Report 2017. 2017. Available from: https://www.environment.admin.cam.ac.uk/files/uoc_environment_and_sustainability_report_2017.pdf.
 30. UC-Berkeley (University of California Berkeley). GHG inventory. 2017. Available from: <https://sustainability.berkeley.edu/carbon-neutrality/calcap-ghg-inventory>.
 31. UMA (Universidad de Málaga). Vicerrectorado de Campus y Sostenibilidad. Huella ecológica de la

- Universidad de Málaga. 2017. Available from: http://www.sga.uma.es/images/pdf/informacion/HUELLA_ECOLÓGICA_UNIVERSIUNI_DE_MÁLAGA_2017.pdf.
32. Larsen HN, Pettersen J, Solli C, et al. Investigating the carbon footprint of a university – the case of NTNU. *J Clean Prod.* 2013;48:39–47. doi:[10.1016/j.jclepro.2011.10.007](https://doi.org/10.1016/j.jclepro.2011.10.007).
33. Li X, Tan H, Rackes A. Carbon footprint analysis of student behavior for a sustainable university campus in China. *J Clean Prod.* 2015;106:97–108. doi:[10.1016/j.jclepro.2014.11.084](https://doi.org/10.1016/j.jclepro.2014.11.084).
34. Robinson O, Kemp S, Williams I. Carbon management at universities: a reality check. *J Clean Prod.* 2015;106:109–118. doi:[10.1016/j.jclepro.2014.06.095](https://doi.org/10.1016/j.jclepro.2014.06.095).