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# Potential for implementation of Environmental Sustainability Management (ESM) in a Higher Education Institution in Brazil: A case study

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***Keywords***— ***ecological footprint, indicators, public institution.***

***Abstract***— *The positioning of leaders at the Leaders Summit on Climate held this year, makes Brazil rethink series of actions related to the environmental issue. For HEIs, as opinion makers and responsible for the qualification of professionals who work in different areas, it is indispensable this discussion to be made in their environments as well. However, there are few with effective environmental management system or able to present a parameter that clearly shows their concern about the sustainable issue. Some universities have already structured systems involving the dean office. This work aims to identify the main difficulties in the localization of the items that constitute each of these footprints internally in a Higher Education Institution (HEI), by determination of different environmental footprints (ecological, water and carbon) . A preliminary survey shows that in some cases, simple control would assist in the quantitatively follow-up of fuel expenses, among others.*

## I. INTRODUCTION

### *Environmental sustainability in Higher Education Institutions (HEIs)*

To what refers to sustainability in HEI, there are numberless works that address the subject (Zaleniene and Pereira, 2021; Carrillo-Sanchez *et al*, 2021; Vaidya *et al*, 2021; Ridhosari and Rahman, 2020; Versteijlen *et al*, 2017; Li *et al*, 2015; Banai and Theis, 2011). Su and collaborators (2018), in their studies on the performance of the universities in the communities, present the calculation of some global indicators, such as the total energy footprint, the carbon footprint and the water footprint, comparing them to other universities. These results can serve as a reference for public policy makers and environmental managers who seek to implement sustainability in universities and other communities (D'adamo et al, 2020; D'adamo, 2019). Gua and collaborators (2019), in a research on the quantification of the environmental footprint in a university campus, identified the environmental footprints (energy, water resources), allowing the creation of policies that encourage the use of alternative energy sources, helping the decision-makers in relation to the sustainability issue.

Marques and co-authors (2018) carried out an important collection of information about indicators in universities, whose results can be checked on website International Sustainable Campus Network (ISCN, 2021). In this work, the authors identify a set of sustainability characteristics from the analysis of the university practices, enabling the Brazilian Universities to compose their own sustainability indicators, metrics and parameters, in line with the UN Sustainable Development Agenda by 2030.

Abdala and collaborators (2018) defend the idea of creating an Environmental Management Plan for all university Campuses. Nishimura and Malheiros (2018) make a comparative analysis of the integration of sustainability at Universidade Leuphana de Lüneburg with the School of Engineering in São Carlos of EESC/USP, highlighting the fundamental role of sustainability in Higher Education Institutions and how this topic is developed in different contexts (territorial, economic, political, social and environmental). Pantaleão and Cortesse (2018) analyze the global ranking system established by UI GreenMetric World University Ranking (UI GreenMetric), based on 6 categories, namely: Management involvement via HEI policy in relation to the sustainability issue; energy management; waste management; water management; transport management, and involvement of the different courses in the sustainability issue. The advantage of this proposition is to stimulate the academic debate on the subject, in addition to presenting data which may serve as a reference for other HEIs that wish to follow the same path in the design or the adaptation of their campuses, contributing to the transformation of individuals, societies and cities through education.

Yañez and co-authors (2020) present the evolution of the carbon footprint in the different campuses of the Universidade de Talca. For this purpose, they based on the method established by the GHG Protocol, which separates emissions into three scopes: Direct, indirect and other indirect emissions. This indicator also enables comparison between other HEIs, providing metric for monitoring of the efficiency of the actions aimed at the sustainability improvement. Ortegon and Acosta (2019) present the creation and the use of an ecological footprint indicator for the management of actions associated with sustainability in the Colombian universities. In this work, a non-exhaustive list of the different methods for determination of the ecological footprint indicator is presented. In their studies, the authors concluded that ISO 14064 and the Greenhouse Gas (GHG) protocol would be the main methodologies for measurement of the carbon footprint at the universities.

Different authors report use of the carbon footprint as an indicator for monitoring and management of actions associated with environmental sustainability in different HEIs (Karuchit, 2020; Rodrigues, 2019; Mendoza *et al*, 2019; Filimonau *et al*, 2020; Li et al , 2020).

### *Global indicators or programs to help the management of the environmental sustainability actions*

The environmental performance management issue is a subject studied before the implementation of the series of standards ISO 14000. In the 1990s, upon the implementation of the quality programs in Brazil and the intensification of the environmental legislation, the different industrial segments started considering the environment issue as important and subject to substantial fines. Upon the inclusion of the ISO 14000 series, different environmental performance indicators were incorporated. Initially, the companies verified the legal parameters monitored by the federal environmental bodies (Brazilian Institute of the Environment and Natural Resources, IBAMA) through the regulations of the National Environment Council (CONAMA) and the parameters set by the bodies of all state of the federation (Instituto Estadual do Ambiente, INEA, for Rio de Janeiro, and Companhia Ambiental do Estado de São Paulo, CETESB, for São Paulo). Upon the realization of the different international conferences, the requirements related to the release standards became more restrictive. Thus, the countries acted for improvements in the environmental performance. The search by different actors for parameters or indicators that would express the efficiency of the environmental management better started (Martini and Gusmão, 2009).

The realization of Rio+10 in 2002 generated a balance of the lessons learned and the practical results obtained from the agreements signed by the countries that participated in Rio-92 (1992). The main discussed points took into account the affirmation of the sustainable development issue, a concept that promotes the interdependence between economy, environment and society, enabling different segments to start the search for parameters that express better how to show the concern, the performance and the improvements obtained in relation to sustainability to the society (Martini and Gusmão, 2009).

### *Ecological footprint*

As presented by Ribeiro and co-authors (2008), this indicator means “the load capacity refers specifically to the maximum load that can be safely and persistently imposed on the environment by the society”. In the methodology proposed by the authors, the indicator incorporates all types of energy and considers only the most important revenues. The model considers five items: Appropriation of renewable resources, extraction of non-renewable resources, absorption of tailings, soil destruction and depletion of water resources. And it operates with average consumption and productivity values, involving five categories of territory or defined area (biodiversity territory, built territory, energy territory, bio-productive land territory and bio-productive ocean area). As restrictions, the work informs that the system does not act in the social dimension of sustainability and does not consider the interference of social actors. The authors mention that the method is simplistic, because it is not capable of capturing all aspects of reality, as it does not involve all variables of each system. A refinement of the research using the terms 'Ecological footprint in higher Education Institution' reveals only 14 references. Lambrechts, W. and Liedekerke L.V (2014) present the ecological footprint calculation discussing the possibilities to use this tool for operations in campus, educational purposes and development of policies. In this work, the ecological footprint has been determined for all components, namely: Energy, water consumption, generated waste, mobility (employees, teachers and students), the consumables, the main (paper books, computers), the occupation of the infrastructure (buildings and equipment) and food. The results show the contribution of each considered item, enabling more effective management. In the search for environmental management system for HEI, Genta and co-authors (2019) determined the ecological footprint using the same methodology developed by Lambrechts and Liedekerke (2014) for different scenarios, in a campus with more than 30 thousand students. A survey has been carried out with the community on how people imagine the spaces of HEI of the future, how the design of the classrooms and the outdoor areas could meet the new requirements of education and research of the future, in order to favor the interdisciplinary work, the technology transfer and the knowledge sharing, preserving energy, water and all other natural resources. The research considered energy consumption (electric and fossil), water consumption, mobility, waste and food. Based on the data, a comparison was made among the different ecological footprints, enabling identifying of the sources of highest contribution that should be monitored in order to reduce the environmental impact of the campus.

In their studies about environmental indicators, Nunes and co-authors (2013) assessed the uncertainty in the determination of the ecological footprint. For this purpose, they used the methodology proposed by Wackernagel and Rees (1996), based on HEI in Portugal with 4,950 people. The evaluation concludes that the methodology is useful for evaluation of ecological footprints in several segments, including HEI.

***Water footprint***

As shown by Hoekstra and co-authors (2011), the concern about water consumption is not related only to what the individuals spend daily, but their habits as well. From the clothes they use to the food they eat. When observing HEI, it can be compared to a small community, where different actors contribute to water consumption. The water footprint is defined as the total volume of water used during the production and the consumption of goods and services, as well as the direct and indirect consumption in the production process (UFCG, 2021). As presented by Vanham (Year), the water footprint measures both the consumption of fresh water as a resource and its use to assimilate waste.

Hoekstra *et al*. show that the water footprint can be classified according to the categories presented in Figure 1.

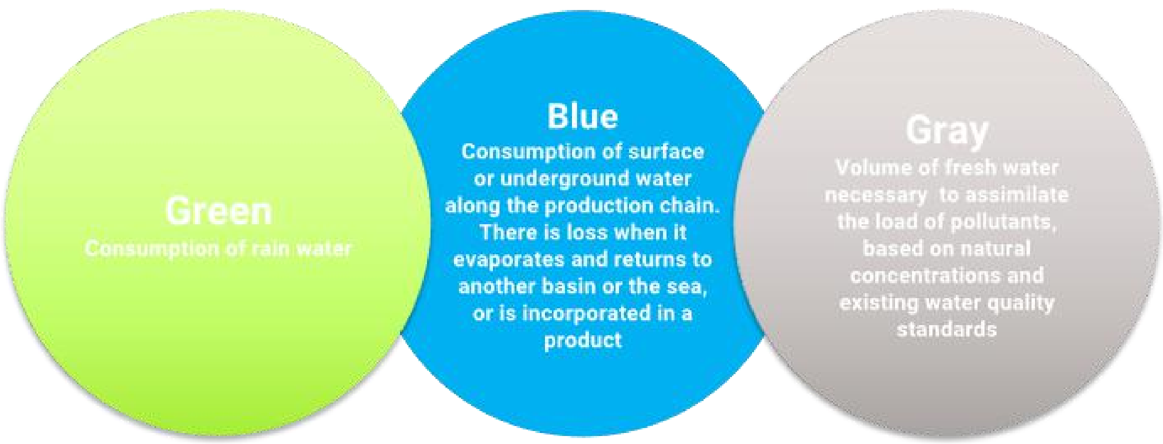


*Fig.1. Water footprint classification*

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The purpose of the knowledge about the water footprint is to explain the scarcity or the pollution of the water and its respective impacts among the developed activities. It enables identification of actions that must be taken to assure the sustainable use of the water resources.

Based on the methodology presented by Hoekstra and co-authors (2011), HEI can be interpreted in different ways, considering the footprint per consumer (student), the footprint by the community (HEI as a whole), or the footprint in a delimited area.

The assessment of the environmental footprint involves:

- Definition of the goal and the scope (whether individual, group, municipality, etc.)
- The determination of the footprint
- The assessment of the water footprint sustainability
- Action plan

Vaidya and co-authors (2021) determined the water footprint considering three parameters: Water, energy and food. The determination considers the direct and the indirect expenses. The work shows water footprint per capita of around 513.19 liters. This value was obtained considering:

a) Energy footprint

$WF_{energy} = \sum n_i.Ec_i\ (UCWE_i)$ where $Ec_i$ is the energy consumption and $UCWE_i$, the corresponding factor in terms of water volume

b) Footprint related to food

$WF_{food} = \sum n_{i.}FP_{i(}UCWE_i)$ where FP is the type of food consumed and $UCWE_i$ the corresponding factor in terms of water volume

c) The water footprint of the Campus, considering the value obtained from the control of the water, energy and fuel consumption of the university itself (among other controls related to academic activity).

The total water footprint is equal to the sum of the calculated footprints. In the work, it is informed, for example, that the university had 11 buses to transport students. The correspondence coefficients were taken from works written by Hoekstra and co-authors (2011).

In another work, Gu and co-authors (2019) present the determination of different ecological footprints (energy, water and carbon). As already presented by Vaidya and co-authors (2021), the water footprint is calculated considering three components: The direct water footprint, which corresponds to the water consumed within the campus; the energy water footprint, which is equivalent to the water footprint related to the energy consumption (in this case, for each type of energy – electric and fuel), and the water footprint of the food preparation. The total is equivalent to the sum of the three footprints.

***Carbon footprint***

Yañez and co-authors (2020) determined the carbon footprint using the Greenhouse Gas (GHC) Protocol, carried out in three scopes: Direct, indirect and other indirect emissions.

By using this method, the consumption of each type of energy (electric and fuel) is transformed using an emission factor associated with the respective category, namely: kg $CO_2eq/m^3$, $tCO_2/kWh$, $kgCO_2$/traveled km. The sum of these values defines the carbon footprint, where Xi and Fi are the amount of energy (LPG, diesel and electricity) and the GHG emission factor per type of energy, respectively. This indicator enables identification of the items which effectively impact the $CO_2$ emissions directly or indirectly.

$$CF\,(t\,CO_2e) = \sum_{i=1}^{n} (Xi \times Fi)$$

## II. METHODOLOGY

The present work was based on a preliminary survey about research related to the determination of the ecological footprint in different HEIs, in Brazil or abroad. Therefore, a search was made in the Scopus database for to its relevance in the academic world, disregarding gray literature. With the results from the search, a screening was made aiming to collect only articles related to higher education institutions. By reading more specific publications, procedures and data necessary for consideration in the studied HEI were obtained. This stage was essential, once the analyzed HEI lacks a lot of data.

Thus, the calculations for determination of indicators (ecological, water and carbon footprint) are taken as estimates based on parameters from the literature. The composition of the HEI case study scenario was built based on the collection of data obtained from the Campus administration and official information available on the world wide web.

**Case study**

***Location of HEI, State University of Rio de Janeiro (UERJ)***

Situated in the city of Rio de Janeiro, UERJ is located in the Maracanã district, the central district of the city of Rio de Janeiro, served by different modes of public transport (railway system, subway system and different bus lines). Figure 2 shows the localization of the Campus.


*Fig.2. Localization of UERJ, Campus Maracanã.*

The total area of the campus is 289,629 $m^2$, 120 $m^2$ of which correspond to the garden area. A total of 18,606 students, 2,251 teachers and 4,080 servants. The campus contemplates 33 academic units, 156 departments and 557 laboratories (UERJ, 2019).

Its organizational structure operates with Superior Council that reports to the Dean and sub-deans (pro-deans), there are the dean advisory bodies, the different administrative bodies, and finally, the academic units. Unlike a company, where the sector responsible for the environmental part is well defined, public HEIs in Brazil have established the sectors responsible for health and safety, with the environmental part integrated into one of these sectors. The responsibility for the monitoring of the facilities (electricity, water, control of garbage collection, gardening, etc.) is under the responsibility of the city hall which administers the Campus. The different academic units are responsible for the specific studies or prompt initiatives associated with the environmental issues (scientific initiation projects, extension projects, course graduation monographs, master's and doctor´s degree theses).

The purpose of this study is to see the sustainable profile of the aforementioned HEI, which is public, in relation to the indicators water consumption, land use and greenhouse gas emissions. This study will help to identify the situation of the analyzed HEI regarding the impacts pursuant to its activities, enabling its ranking in relation to other HEIs which might adopt similar monitoring of environmental parameters. The work will also assure the identification of the main problems to be faced for the creation of a management program, contributing to the financial cost reduction.

## III. RESULTS AND DISCUSSIONS

In a survey made on the world wide web and on the official site of the Institution, it was found that there was not defined and broadly disclosed environmental management policy. The actions associated with the environmental issues are prompt and not integrated. Through interviews and information collected from the Administration, it was found that the Campus Administration takes actions to reduce the energy consumption. For example, installation of solar panels in the university canteen to heat washing water in the kitchen and installation of a pilot system for collection of condensed water from the air conditioners to use in gardening.

In preliminary consultations, important initiatives of the Institutes can be seen at HEI, such as collection of rainwater. Although they are pilot projects and restricted to academic and research level, they show potential for future deployment. In addition to these initiatives, certain graduate and postgraduate programs address the environmental issue. This topic is constantly the focus of scientific initiation, master's and doctor´s degree projects within HEI.

The assessment of the curriculum of the graduate courses offered at HEI revealed the existence of 7 courses that adhere to the environmental topic (Biological Sciences, Chemical Engineering, Chemistry, Mechanical Engineering, Cartographic Engineering, Geography and Tourism). The level of adherence was based only on the finding of courses offered that commented on "environment", "ecology" or "sustainability". The subject flowcharts were collected from the pages of the respective courses. It shall be pointed out that the number of mentioned subjects may be higher, once the curriculum of 3 courses was not provided. The curriculum is available only for 60% of the analyzed courses. Only 11 mandatory subjects of this contingent explicitly adhere to the environmental topic. There are also 12 elective courses available to be offered. The Biological Sciences course offers the highest number of them, both mandatory and optional.

***Carbon footprint***

The determination of the carbon footprint adopted in this work followed the methodology presented by Yañez *et al* (2020). Scope 1 GHG emissions were estimated, i.e.:

Stationary combustion – fuel burned by stationary equipment owned or leased by the small business to operate under their management, for example: boilers, generators, furnaces.

Mobile combustion – fuel burned by mobile equipment, such as car, truck, pickup, forklift. In this case, the studied HEI does not control the volume of fuel consumed, but the movement of financial resources, which is limited by the budget. Initially, an estimated average monthly value of diesel and gasoline will be considered. It is admitted that the gas consumption is restricted to the canteen

Fugitive emissions - initially they will not be accounted for as there is no effective maintenance program with information that enables estimation to be made

Note: Expenses for the student travel: As shown above, the localization of the campus is central and well served by different modes of public transport. Thus, as a preliminary assessment, a survey was made among students from the institution to identify the neighborhood where they live and the means of transportation used. These data will enable estimation of fuel expenses related to the travel of the students to the campus.

For emissions due to the use of energy (scope 2), for the electric energy consumption, the monthly/annual survey made by the Campus Administration was considered.

For other indirect emissions considered in scope 3 (emissions generated by employees and professors traveling to work, travel of employees), the data was collected from the human resources sector of HEI.

The emission factors used in the determination are shown reduced in Table 1.

*Table 1. Factors used to determine the equivalent emissions of CO2 source Pablo Yañez P., Sinha A. and Vásquez Z.(2020).*

| Unit considered | Source | Emission factor (GHG) |
|---|---|---|
| University Canteen | Natural Gas (l) | 1642 kg $CO_2/m^3$ |
| IES Vehicles | Diesel / Gasoline (l) | 2646 $kgCO_2$ / $m^3$ (diesel)<br>2241 $kgCO_2$ / $m^3$ (gasoline) |
| Electric systems *(IES) | (kWh) | 0.3972 t $CO_2$ / MWh |
| Paper | Consumption / student.day | 0.939 kg $CO_2$/kg |
| Residue for treatment | (kg) | 0.421 $CO_2$/kg |
| Residue for Recycling | (kg) | 0.400 $CO_2$/kg |

***Calculation of carbon footprint***

Scope 1

| Type of Fuel (by IES) (*) | Consumption/month | Total $m^3$ (year) | $tCO_2$ equiv | Factor |
|---|---|---|---|---|
| Gasoline | 3000 (liters) | 36 | 80.676 | 2241 kg $CO_2/m^3$ |
| Diesel | 1000 (liters) | 12 | 32.112 | 2676 kg $CO_2/m^3$ |
| Gas (**) | 0.00243 kg/meal*day | 691 | 1135.09 | 1642 kg $CO_2/m^3$ |
| Total 1 | | | 1247.96 | |

(*) Not considered students and professors traveling to access the campus

(**) Estimated expenses at the university canteen (UC)

| Item | Average consumption (per meal) | Reference |
|---|---|---|

| | | |
|---|---|---|
| Water | 24.8 L (Range from 20 to 30 L) | Silva K.M.B (2019) |
| Electric energy | 1.28 kWh (0.2 – 1.3) | |
| Gas | 0.00243 kg/meal | |

The total number of effective days per year was estimated based on the official 2020 calendar (DOU, 2020). According to it, in Brazil, there were 254 business days, with 9 national holidays and 52 weekends.

Regarding the number of meals served, due to lack of information, an estimate of the ratio meal/total number of students was made as shown in Table 2.

*Table 2. Study of the average meal supply capacity in university canteens.*

| Estimation (Meal; day / student) | Work | Source |
|---|---|---|
| 500 / 8352 = 0.06 | University canteen - challenges to serve meals to UFRA community and not the garbage collectors | https://progep.ufra.edu.br/attachments/697_ESTUDO%20DE%20CASO%2003.pdf |
| 7180 /48045 = 0.15 | DAC University Canteen - UC | https://www.ru.unb.br/index.php/186-categoria-ru-em-numeros |
| 704 / 1767=0.9 | Proposal of a Policy for the University Canteens at UNESP | https://www2.unesp.br/Home/cope/documentos/propostaru_11_2016.pdf |
| 7000/47254 = 0.15 | The "big tray" beyond the canteens: achievements and challenges of one of the largest university canteens in the country | http://www.uff.br/?q=noticias/27-03-2019/o-bandejao-para-alem-dos-refeitorios-conquistas-e-desafios-de-um-dos-maiores |
| 1000/15185 = 0.06 | School Canteen | http://www.unirio.br/prae/nutricao-prae-1/setan/restaurante-escola |

Using a conservative mean(0.1 meals / student).

Total students in the Maracanã campus - 18,606 (data obtained in the survey made by the Department of Academic Affairs (DAA) 2021 of the studied HEI, with this total, it will be estimated that UC of HEI provides a total of 1860 meals / day

With these considerations, the consumptions for UC are:

Electric energy/year = (1.28 kWh/meal*1860ref/day*254days/year = 604,723 kWh/year)

Natural gas/year = (0.00243 kg/ref*1860 ref/day*254days/year = 1148 kg/year

Considering gas density of 2.5 kg/m$^3$

*Gas consumption = 459m$^3$/year*

Based on the calculations made, it is estimated that the carbon footprint of the studied HEI related to scope 1 gases is equivalent to 6710.1 t$CO_2$ eq/student

Scope 2

| Item | Estimated annual consumption | t$CO_2$ equivalent | Factor |
|---|---|---|---|
| Electric energy canteen (*) | 604.723 MWh/year | 240.19 | 0.3972 t$CO_2$/MWh |
| Electric energy Campus (**) | 16313.22 MWh/year | 6479.6 | |

(*) reference Silva K.M.B (2019)

(**) Estimated consumption of the consumption in the campus (actual data was not provided by the Administration of the studied HEI campus)

| Average value | Reference |
|---|---|
| 96.17 kwh/$m^2$ | Universidade Federal do Vale do São Francisco https://portais.univasf.edu.br/secad/relatorios-e-indicadores/consumo-de-energia-eletrica-1, access 05/06/2021 |

Estimate= 96.17*(169629 $m^2$ built area) = 16313.22 MWh/year

Scope 3

Scope 3 expenses involve knowledge about expenses related to employees' trips and travel, student travel, and waste treatment expenses.

As in the studied HEI there are no controls related to waste generation, both in the campus and in the university canteen, a search was made on the internet, as shown in Tables 3 and 4.

*Table 3. Bases for estimation of waste generation in an academic canteen.*

| Work | Mean | Reference |
|---|---|---|
| Solid waste generation indexes in large industrial canteens | Composition 72.5% organic matter and 27.4% recyclables. The average waste generation index was 59.3g/meal, highlighting the return with the highest contribution (19.6g/meal) and the clean leftover stage as the smallest waste producer (12.5g/meal) | Ribeiro, M.L *et al*(2018) |
| Diagnostic of the solid waste produced at the ufrn university canteen | Average per capita of solid waste 0.2 Kg. | Carneiro *et al*(2010) |
| Generation of organic solid waste in a university canteen in São Paulo/SP | Per capita of the leftover-intake in the period was 60.8±9.4g | Domingues *et al* (2016) |
| Analysis of the solid waste generated in the university canteen of the institute of nature and culture at ufam | Average 60g per capita/day | Sanches *et al* (2016) |
| Waste generated in the university canteen in a public university in Alto Solimões, Amazonas, Brazil | Average 67g per capita | Silva *et al* (2021) |
| Solid waste management: a study at the university canteen of UFRPE considering the environmental agenda in the public administration | The total leftover-intake per capita in the first six months 2018 was 17.23g | Gonçalves M.M and Albuquerque L.L (2018) |
| Generation of organic, recyclable and tailings waste by the university canteen in Area 1 of the USP Campus in São Carlos: diagnostic and proposal for adequate disposal | 59.4 g per capita | Miranda, G.S (2018) |

| |
|---|
| Mean of waste generation of 50 grams per capita in a university canteen will be considered<br>On page https://super.abril.com.br/mundo-estranho/quanta-comida-uma-pessoa-adulta-come-em-um-ano/ the following annual food consumption information is also stated: Milk – 163 liters / Meat – 47.5 kg / Banana – 33 kg / Raw rice – 30 kg / Coffee – 8 liters / Tomato – 11 kg / Bread – 18 kg / Salt – 3.5 kg / Onion – 15 kg / Lettuce – 11 kg |

*Table 4. Estimate of common waste generation in HEIs in Brazil.*

| Reference | Average value | Access |
|---|---|---|
| Diagnostic of the urban solid waste at a private university | At the university between 0.12 g/inhabitant day and 65 g/inhabitant day | Lins, E.A.M *et al*(2018) |
| Generation and Composition of Solid Waste in University Campus | 0.47 kg/day.user | Ishak N,R., Mahayuddin S.A and Mohamed, M.R (2013) |
| A review of waste generation, characterization and solid waste management practices using bottoms-up approach in educational buildings. | 59.20 g/user/day | Talsania P and Modi, N (2019) |
| An average value of 57gr/day*student will be considered (RSU of residence is higher due to the inclusion of the food waste, among others, and will not be computed) | | |

Estimate of the waste generation for treatment

Total = 57gr/day*student*254 days*18606 students = 267.37 t

Calculation of the carbon footprint for Scope 3

| Item | Estimated consumption | $tCO_2$ equivalent | Factor |
|---|---|---|---|
| Residue for treatment | 267.37 t/year | 113.4 | 0.421 kg $CO_2e$/kg |
| Paper (*) | 54.32 t/year | 51 | 0.939 kg $CO_2e$/kg |
| Student travel expenses (**) | NC | NC | - |
| Residue for Recycling (***) | PET 400 kg/month<br>PP 180 kg/month | 2.78 | 0.400 kg $CO_2e$/kg |

(*) Bases for identification of the average paper consumption by students in HEI

Due to the lack of control over the consumption of paper in the Campus, its average value was calculated based on the references shown in Table 5.

*Table 5. Bases for estimation of the paper consumption in the studied HEI.*

| Researched work | Mean | Reference |
|---|---|---|
| Diagnostic of A4 paper consumption: the case of the Minas Gerais Federal Institute - campus Governador Valadares-MG | 2 to 3 sheets/ day.student | Penna *et al* (2014) |
| Analysis of A4 paper consumption in the dean´s office of UFMG: proposal for rational use, cost reduction and environmental impacts | 2 sheets / student.day | Macedo, D.M.L (2016) |
| Assessment of the impact of the paper consumption | 4 sheets / day.student | Bonifácio, M.A *et al* |

| | | |
|---|---|---|
| in a higher education institution | | (2016) |
| Double-sided printing: reduction in the paper consumption at UNIMEP | 1 sheets / day.student | Carvalho, A.L (2011) |
| The A4 paper at Universidade Federal de Goiás - Regional Catalão: an approach to the use of this consumable with environmental sustainability bias | 1 sheets / day.student | Santos,J.P (2017) |

| | | |
|---|---|---|
| Diagnostic of the impact of the paper consumption: An analysis of the Ecological Footprint in the Campus of Tupã, UNESP | 2 to 3 sheets / day.student | Pires L.F *et al*(2016) |
| Based on the survey, this work will consider between 2 to 3 sheets / student.day | | |

(**) (not considered NC)

(***) Survey of the Campus Prefecture

Paper footprint: Base operating with the average value of 2.5 sheets/student.day

Total = (18606)*(2.5)*(254/500) (paper/ream) = 23629 reams/year

PEpaper = (23629)*(1t/435 reams) = 54.32 t

Preliminary carbon footprint = 6886.68 / 18606 = 0.46 $tCO_2eq$ / student.year

Carbon Footprint = 0.37 $tCO_2eq$ / student.year

Within the range if compared to the reference, not considering the expense for transport (range 0.5 to 0.9 t $CO_2eq$ / student)

***Water footprint***

The water footprint for HEI was determined according to the methodology presented by Vaidya and co-authors (2021), which has already been commented. Preliminarily, as the analyzed HEI does not have several control mechanisms, the consumption of food and water will be estimated based on data available in Scopus and/or Science direct databases).

The estimated consumption of fuels used internally in the analyzed HEI was determined based on the information provided by the transport sector of the university. The time spent by students in transit to travel to the university was estimated based on geographic and official data provided by HEI.

The university provides data indicating the municipalities and the districts where students live. From this survey, considering that the university is central and served by different modes of public transport, the criteria for determination will be:

- Students who live in distant places with access to the train system: The average traveling distance will be computed and multiplied by the total number of students in the region (neighborhood or municipality). For residents with access close to the metro, the same consideration will be made. For the group that is not served by these two modes, travel by bus will be considered. Traveling by car will not be considered.
- To build this scenario, expenses for teachers and employees travel will not be considered.
- 254 school days per year will be considered

Based on the work of Júnior *et al* (2018), the water consumption was estimated at 33 liters of water per person during the day. The study considers toilets, excluding consumption in canteens for teachers and employees. (read the Water footprint calculation manual, mainly that resulting from indirect consumption, namely consumption for paper production, etc.

Annual consumption/buildings = 33 (liters/person.day)*254(days/year)*18,606 students = 155955.5 $m^3$/year

Annual canteen consumption =19 (liters/meal,day)*1860(ref.day)*254(days/year) = 9.97$m^3$/year

| Item Water | Estimated annual consumption $m^3$/ year | Total people / day |
|---|---|---|
| Average consumption of the buildings | 155955.5 | 18606 |
| Consumption in the canteen | 8976 | 1860 |

Energy consumption

| Type of Fuel (by HEI) (*) | Consumption / month | Total $m^3$ (year) |
|---|---|---|
| Gasoline | 3000 (liters) | 36 |
| Diesel | 1000 (liters) | 12 |

| | | |
|---|---|---|
| Gas | 0.00243 kg/meal*day | 691 |
| Electric energy canteen | | 604.723 MWh/year |
| Electric energy Campus | | 27853 MWh/year |

(*) used in the calculation of the carbon footprint

Food consumption

| Food (*) | Individual consumption/year kg | Total kg |
|---|---|---|
| Cereals and vegetables | 39 | 72540 |
| Fruits | 28.9 | 53754 |
| Milk | 163 | 303180 |
| Meat | 47.5 | 88350 |

(*)(estimation in the calculation of the ecological footprint)

Paper Consumption

| Amount per capita (*) | Annual consumption | Total in mass |
|---|---|---|
| 2.5 sheets / student*day | 36290 reams / year | 54.32 (t/year) |

(*) estimated in the carbon footprint

***Calculation of the Water Footprint***

| Items | Annual consumption | Coefficient of Equivalence | Equivalent in $m^3$ water |
|---|---|---|---|
| Energy | | | |
| Gasoline (*) | 36 $m^3$ (year) | 0.105 Gal / mile | 13.18 |
| Diesel (*) | 12 $m^3$ (year) | 0.08 Gal / mile | 5.8 |
| Gas | 691 $m^3$ (year) | 2.51 L/kg LPG (**) | 4.35 |
| Electric energy canteen | 604.723 MWh/year | 0.106 $m^3$/ kwh | 64,100.63 |
| Electric energy Campus | 16313.22 MWh/year | 0.106 | 1,729,201.32 |
| Food | | | |
| Cereals and vegetables | 72540 (kg/year) | 1644 l/kg | 119,255.76 |
| Fruits | 53754 (kg/year) | 962 l/kg | 51,711.34 |
| Milk | 303180 (kg/year) | 1020 l/kg | 309,243.6 |
| Meat | 88350 (kg/year) | 15415 l/kg | 1,361,915.25 |
| Paper | 54.32 (t/year) | 300 to 2600 $m^3$/ton (using average value 1450) | 78,764 |
| Water canteen ($m^3$) | | | 8976.36 |
| Water university ($m^3$) | | | 155,955.5 |
| Total ($m^3$/year) | | | 3,879,143.0 |
| Footprint / built campus area | | | 22.86 ($m^3/m^2$.year) |
| Daily footprint per | | | 0.82 $m^3$/student.day |

| | | | |
|---|---|---|---|
| capita | | | 820 ( l/student.day) |

(*) not considering the spent upon the students´ access to the university

a) Equivalence for gasoline: 0.07 – 0.14 gal $H_2O$/mile. = using average value = 0.105 / Average consumption of one car 14 km/liter

Total traveled = 36000 L *14km/L = 504000 km = 33171 miles

b) Equivalence for diesel: 0.05-0.11 gal $H_2O$/mile (using mean = 0.08 gal water / mile) / Average consumption of an urban bus 2.57 km / L

Total traveled = 12000l*2.57 = 30840 km = 19163 miles

c) Equivalence for gas consumption (Density 2.5 kg/m$^3$) considering factor 2.51 l/kg lpg (Kandananond, 2018)

***Ecological footprint***

The ecological footprint of HEI will be estimated using the methodology described by Ortegos and Acosta (2019). The global ecological footprint and the footprint by students will be estimated for first comparison of the results with the values reported in the considered work. As the studied HEI does not have a series of necessary controls, several considerations will be made (and identified) and referenced for their subsequent implementation.

The seven items will be considered, namely: Energy (electric), water, waste, fuel from mobile sources, paper, food and building.

Considerations regarding the items included in the calculation

d) **Energy consumption:** In this case, only the electric energy consumption already calculated in the carbon footprint estimate will be considered)

e) **Water footprint:** The work associates the total water consumed in the campus and compares it with the volume of Olympic swimming pool

f) **Waste footprint** (kg or ton) The work considers non-hazardous waste (i.e., organic, recyclable, common and inert waste) and toxic waste (biological and chemical). The result is expressed in the number of trees necessary to absorb the generated emissions (species Samanea saman). In this case, there is no control in the studied HEI, so the internet search which has already been made will be used both for the generation from UC and in the campus.

g) **Energetic footprint of mobile sources.** The estimation considered in the calculation of the carbon footprint will be used. The result is expressed in the number of trees necessary to absorb the generated emissions (species Samanea saman)

h) **Paper footprint:** This footprint, measured in reams, includes virgin fiber paper, recycled fiber and ecological paper (e.g. bagasse fiber). The results are expressed in terms of the number of trees (i.e. Samanea saman) necessary to produce this quantity of paper. As there is no control of this type of material in HEI, an estimate based on means verified in studies identified on the internet will be used, already elaborated in the carbon footprint

i) **Food footprint:** A typical menu of a traditional meal (vegetables, proteins, etc.) within a normal diet will be considered. These results will be compared with the calories necessary per day (in a single meal). An internet search indicates that the annual consumption of a person is 39 kg cereals and vegetables; 28.9 kg fruits; 27.1 kg greenery; and 25.4 kg meat[1].

j) Land occupation (or building) footprint. Finally, the built land footprint measures the area used for buildings and infrastructure. This footprint (measured in m$^2$) includes buildings, parking lots, roads, forest and planted vegetation. The results are expressed in units equal to a standard football pitch. In this case, the available data shows that the non-built area of the campus is 120 thousand m$^2$ and the total built area is 160,629 m$^2$,

***Calculation of the Ecological Footprint***

Parameters for determination of ecological footprint Source: Ortegon, K. & Acosta, P.(2019).

| Parameter | Emission Factor (EmF) | Equivalence Factor (EQF) | SRL (*) | Consumption (C) | Footprint (gha/year) |
|---|---|---|---|---|---|
| Electric kwh RU | 0.2 kg ($CO_2$/ kWh) | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 604,723 (kWh) | 29.55 |
| Electric (IES) | 0.2 kg ($CO_2$/ kWh | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 16,313,220 (kWh) | 808 |

| | | | | | |
|---|---|---|---|---|---|
| Water (IES) | 0.5 ($KCO_2/m^3$) | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 155,955.5 ($m^3$/year) | 19.31 |
| Water (Water (RU) | 0.5 ($KCO_2/m^3$) | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 8976.36 ($m^3$/year) | 1.11 |
| Waste (RU) (**) | 0.557 kg /$CO_2$ kg non-toxic | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 23.62 t/year | 3.25 |
| Waste (IES) (***) | 0.557 kg /$CO_2$ kg non-toxic | 1.29 (gha/ha) | (0.000192 ha-year/ kg $CO_2$) | 361 t/year | 49.8 |
| Paper | | 2.10 (gha/t.paper) | | 23629 reams / year | 114 |
| Cereals and vegetables | 0.0017 ha-year/ kg.grains | | | 72540 (kg/year) | 123.3 |
| Fruits | 0.0005(ha –year/ kgfruits) | | | 53754 (kg/year) | 26.8 |
| Milk | 0.0011 ha yr kgmilk) | 0.46 (gha/ha) | | 303180 (kg/year) | 153.40 |
| Meat | 0.0069(ha- year/ kgmeat) | 2.53 (gha/ha) | | 88350 (kg/year) | 1542 |
| Built area | | 2.53 (gha/ha) | | 16.9629 (ha) | 42.91 |
| Total | | | | | 2913.42 |

(*) land sequestration rate, which is the average forest area required to sequester 1 kg of $CO^2$ per year; BL = built land, P; Productivity = 1 t paper/435 reams

(**) base: 1860 (user students), (***) base: students/teachers/servants (total 24397 people)

Equations used

a) Footprint related energy: $PE_{energ.} = C\ (Kwh)*Emf*SRL*EQF$

b) Footprint related to water: $PE_{water} = C(m^3/year) * EmF * SRL * EQF$

c) Solid waste: $PE_{re.sol.} = C\ (kg) * EmF * SRL * EQF$

d) Paper footprint: $PE_{paper} = C\ ream * P * EQF$

e) Footprint related to food: $PE_{food} = C\ kg * EmF * EQF$

f) Footprint related to travel: it will not be considered in this work

g) Footprint related to the built area $PE_{built\ area} = BL_{(ha)} * EQF$

Preliminary analysis of the results

The estimated data show that

| Environmental footprint | Global | Per capita | |
|---|---|---|---|
| Carbon footprint | 6886.68 $tCO_2$eq/year | 0.45 $tCO_2$eq/student.year | |
| Water footprint | 3,879,143.0 $m^3$/year | 22.86 ($m^3/m^2$*year) | 0.82 $m^3$/student.year |
| Ecological footprint | 2913.42 (gha/y) | 0.156 (gha/student.year) | |

a) Water footprint: source:Nunes *et al* (2013) apud ortegon K and Acosta P (2019)

| HEI | Country | Year | Population | Area (ha) | PE global (gha) | PE Per capita |
|---|---|---|---|---|---|---|
| University of Algarve | Portugal | 2013 | 4.950 | 20 | 5.049 | 1.02 |
| Ohio State University | USA | 2006 | 77.120 | 711 | 650.666 | 2.4 |
| Studied HEI | Brazil | 2019 | 18606 | 42.91 | 2913.42 | 0.156 |

b) Carbon footprint Source: R. MENDOZA-FLORES *et al* (2019)

| HEI | Country | Year | Total $tCO_2eq$/year | Per capita |
|---|---|---|---|---|
| Polytechnic University of Cartagena | Spain | 2013 | 9,088.4 | 1.07 |
| University of Cambridge | UK | 2016 | 102,049.9 | 3.50 |
| PUC (RJ) | Brazil | 2011 | 5.782 | 0.29 |
| Studied HEI | Brazil | 2019 | 6886.68 | 0.45 |

c) Water footprint

| HEI | Country | Year | Population | Area (ha) | Water footprint | |
|---|---|---|---|---|---|---|
| | | | | | Total | Per capita |
| Studied HEI | BR | 2019 | 28.575 | 28.96 | 3,879,143.0 $m^3$/year | 0.45 $m^3$/student.year |
| Keele Univ[1] (*)190 days teaching | Eng. | 16/20 15 | 11.328 | 250 | 532.415 (*) | 0.247 |
| Kathmandu Univ[2] | Nepal | | 3655 | 18.11 | 628,375.55 | 0.513 |

1, Yifan Gu et all (2019), 2 Vaidya, B., Shrestha, S. & Ghimire, A.,(2021).

## IV. CONCLUSIONS

As it is a central HEI, served by different modes of public transport, the contribution of student travel was not considered. It will be object of more detailed study, depending on the area of activity of the university.

Although HEI in question does not present an implemented, documented environmental policy broadly spread to its community and the external community, the environmental issue is consolidated in the Campus. Different graduate and postgraduate courses develop important projects on the subject, with potential to be applied in the university itself.

For effective inclusion of the environmental management in the analyzed HEI, the organizational chart of HEI shall be reviewed. There, it is recommended to include a formal unit responsible for the environmental management, composed of different representatives from the different segments of the university, which shall prepare a plan responsible for the logistics of the sustainability management.

It is indispensable for the university management to position in relation to sustainability, initially implementing a policy that involves the social issue as well.

For the analyzed HEI to move towards a sustainable movement, monitoring parameters shall be adopted, such as electric energy and water consumption in the respective buildings of the campus. It is also recommended to monitor the consumption of the facilities (electric energy, water and gas) in the university canteen, and establish partnership with the UC operator for the food waste to be measured.

Although not much data about the analyzed HEI is available, an estimate of its sustainable potential was possible thanks to the adoption of parameters found in the specialized literature. The results serve as a base for analysis and future implementation by the organizational structure of HEI, for environmental policies to be systematically practiced.

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