Comparative Analysis of Sustainable Development Environmental Indicators Between Worldwide, Portugal and Brazil and Between Two Universities within these Countries

F Rosa¹, A Kern¹, L Bragança²

¹Universidade do Vale do Rio dos Sinos – UNISINOS
²Universidade do Minho - UMinho

E-mail: fabianaros@unisinos.br, apkern@unisinos.br

Abstract. Measuring the environmental performances by indicators is considered as a crucial step to keep track of progress towards sustainability. This study compares trends in environmental sustainability indicators worldwide, Portugal, Brazil and two universities in these countries. The data collection is done based on findings from the Organisation for Economic Co-operation and Development (OECD) between 2007 and 2017, and reports from both universities between 2010 and 2018. As a result, it can be seen that global Carbon Dioxide (CO2) emissions decreased (10.6 to 9 ton/capita). Portugal also reduced its CO2 till 2014 (5.2 to 4.6 ton/capita) but experienced a raise in its rates in the following years. Brazil experienced a growth in its CO2 (1.7 to 2 ton/capita), as did the Portuguese university (0.85 to 0.87 ton/alumnus). World municipal waste decreased (541.8 to 524.4 kg/capita), as well as in Portugal until 2013 (513.7 to 436.7 kg/capita), but in the following years increased. Similarly, Brazil reduced the indexes until 2011 (271.9 to 266.8 kg/capita) and increased in 2012. In the Portuguese university, the rates increased until 2014 (4.02 to 9.02 kg/student) and reduced in 2015, as in the Brazilian university that increased until 2018 (19.53 to 25.08 kg/student). Portugal, Brazil, and the two universities pointed out a trend of increasing emissions and waste while the world data a reduction. The Brazilian university had higher municipal waste rates than Portugal. The consumption of water and energy in the Portuguese university decreased while it increased the Brazilian university. Actions have already been undertaken at universities to lower the environmental burden by improving the energy efficiency of buildings through the use of cleaner energy, setting up mobility studies, and campaigns to reduce consumption and cut down waste generation.

1. Introduction

Reflection on economic development has led to increased awareness of environmental problems that have occurred due to living standards, which are incompatible with environmental regeneration. This resulted, from the 1970s, to the emergence of the concept of sustainable development, which: “advocates a type of development that ensures the quality of life for current and future generations without destroying the support base that is the environment.” [1]

From this perspective, to achieve sustainable development, it is required changes in business practices through a lean, efficient and green organization (green business practice means “formally mindful of environmental issues”). This implies applying some principles in every step of an
organization's work, such as doing more with less, waste-free design, carbon-friendly power supply, and more. [2]

The approach to sustainable development has become more globalized and less localized. In the global context, it seems that the dependence of human societies on natural resources has been decreasing. This fact that can be confirmed from the decrease of production and consumption of energy intensive resources, increase of non-intensive energy products and the service sector. [1]

For effective actions to take place concerning existing and potential social/environmental challenges, society needs to base its development scientifically based on: appropriate policies; education that raises collective awareness and leads to action; investment to build new or improved existing technologies; and changes in economic and social structures. [3] Thus, sustainable development can be defined and operationalized through the development and application of indicator systems or assessment tools that can measure sustainability. Some methods seek to assess sustainability from the assumption of some characteristics and goals of society, while others seek to observe the goals and emerging principles of society itself. Both are considered important for a more elaborate picture of what sustainable development is. [1]

Indicator systems and assessment tools can be targeted at buildings or organizations. Thus, a campus, as an organization that often has a robust building infrastructure, can benefit from the existing different systems and tools. [4] A university is made up of a community of individuals in which its operations involve a wide range of facilities and activities, including all waste generated, chemical consumptions, energy used and other demands. [5]

A campus can be compared to small urban centers. Higher education institutions carry out a series of core activities related to teaching, research, extension, and others related to the operation including food, lodging, convenience. Campus activities, therefore, require a complex of buildings and basic infrastructure, consisting of water and energy supply networks, sewage and rainwater collection networks, and access and waste collection routes. [4]

In building analysis, sustainability assessment systems aim to collect and report information and indicators for decision making during the different phases of building construction, design and use. From the use of indicators, phenomena are identified, analyzed and valued. [6] These systems aim to assess the environmental impact of buildings and construction projects, and may include urban scale projects, community projects and infrastructure. They involve issues related to reducing the use of non-renewable materials, water use, emissions, waste and pollutants. [7] It can also point out the optimization of local potential, preservation of regional and cultural identity, minimization of energy consumption, protection and conservation of water resources, use of environmentally friendly materials and products. [6]

These systems are based on the evolution of categories and indicators, in which a building's sustainability index is expressed by a score derived from weights assigned to system categories and indicators. The sustainable performance of the building is then evaluated by a certificate issued by the adopted system. [8]

Some environmental assessment systems are used by organizations in the search for of environmental impacts parameters and control, aligned with the concept of sustainability. We highlight the environmental management system (EMS) according to ISO 14001 and the management system by the Global Reporting Initiative (GRI), since both are the systems used by the universities studied in this work.

The application of ISO 14001 helps organization to achieve results that add value to the environment, to the organization itself and to stakeholders by considering environmental aspects of its activities, products and services, with a perspective of life cycle. [9]

GRI is an independent, non-profit, international, partner-supported international organization that has pioneered sustainability reporting since 1997. GRI has helped companies and governments to understand and communicate their impact on sustainability, climate change, human rights. human rights, governance and social welfare, enabling social, environmental and economic benefits to those involved, created from real actions. [10]
According to the Global Sustainability Standards Board (GSSB) [11], sustainability reports make it possible to publicly report economic, environmental and/or social impacts and contributions to the goal of sustainable development. From these reports, an organization can identify impacts on the economy, the environment and/or society, and disseminate the results in a globally accepted standard.

The objective of this study is to compare the trends of environmental sustainability indicators regarding CO$_2$ emissions, waste generated, water and energy consumption, from global values, considering Portugal and Brazil and from two universities in these countries.

As specific objectives it is intended:
- to point out the collected environmental indicators.
- to analyze the values obtained.
- to identify the actions taken from the universities to reduce indicators.

2. Research Method

The main steps of the research method are shown in Figure 1.

![Figure 1. Research main steps](source: Prepared by the author)

The survey of environmental indicators was made from data released by the Organization for Economic Cooperation and Development (OECD), considering the global values, the indices of Portugal and Brazil. The choice of the OECD was based on the worldwide representativeness and participation of several countries.

The OECD data were presented from a global view in the last year collected, the evolution of indicators from graphs and tables, considering the number of inhabitants.

For universities, the sustainability and environmental management reports generated by them were used. University indicators were analyzed considering the number of students enrolled. The analysis period varied according to the availability of information.

2.1. Universidade do Minho (UMinho) - Portugal

It was founded in 1973 and is recognized as an important national reference in the European and global panorama. [12] It has three poles, the campus of Gualtar, Braga, Azurém (photo 1) and Couros, Guimarães.

![Photo 1. Campus Gualtar](source: https://www.uminho.pt/PT/uminho/Paginas/default.aspx# [13])
It has a range of student and educational support facilities and services, which include libraries, laboratories, print shops, banks, bookstores, bars, canteens, restaurants, sports halls and residential apartments. [14]

The university followed the GRI guidelines to develop sustainability reports. UMinho is the first Portuguese university to make this report according to the GRI, the second European and the sixth worldwide. [15]

2.2. Universidade do Vale do Rio dos Sinos (UNISINOS) – Brazil
UNISINOS (photo 2) has 50 years of history, seeking development, continuing education and the capacity for innovation. [16]. It was the first university in Latin America to achieve ISO 14001 environmental certification, which shows its commitment to issues related to the environmental impacts of its activities. The implementation and maintenance of ISO 14001 certification is carried out by the Environmental Management System (EMS), based on continuous improvement. [18].

Photo 2. Campus São Leopoldo

Source: http://www.unisinos.br/noticias/sobre [17]

It has one of the largest libraries in Latin America, a multifunctional complex, research institutes, technology and reflection, and a technological complex. [19] The institution is among the largest private universities in Brazil and, besides the campuses in São Leopoldo, and Porto Alegre, is present in eight states of the country. [20]

There are several actions concerning the environment such as the program “Positive Energy”, Comitesinos, in which the EMS develops activities for the integration of the entire academic community. Results are presented through reports available on the institution's website. [21] [22] [23] [24].

3. Results and discussion
The results are presented in terms of carbon dioxide (CO$_2$) emissions, urban waste, water and energy consumption. Table 1 shows which indicators were analyzed.

Table 1. Analyzed indicators

| Indicator             | OECD Total | OECD Portugal | OECD Brasil | UMinho UNISINOS |
|-----------------------|------------|---------------|-------------|-----------------|
| CO$_2$ emission       | X          | X             | X           | X               |
| Waste                 | X          | X             | X           | X               |
| Water consumption     |            |               | X           | X               |
| Energy consumption    | X          | X             | X           | X               |

Source: Prepared by the author
3.1. CO$_2$ Emission

3.1.1. OECD

Figure 2, Graph 1 and Table 2 show the dimensions of CO$_2$ emissions in the countries with focus in Portugal and Brazil.

**Figure 2.** Worldwide CO$_2$ emission in 2016 (Tons/capita)

![Worldwide CO$_2$ emission in 2016 (Tons/capita)](source: OECD [25])

**Graph 1.** CO$_2$ Emission (ton/capita)

![CO$_2$ Emission (ton/capita)](source: Prepared by the author, based on OECD [25])

| Year | OECD total | Portugal | Brasil |
|------|------------|----------|--------|
| 2007 | 10.6       | 5.2      | 1.7    |
| 2008 | 10.3       | 5        | 1.8    |
| 2009 | 9.6        | 5        | 1.7    |
| 2010 | 9.9        | 4.5      | 1.9    |
| 2011 | 9.7        | 4.5      | 2      |
| 2012 | 9.5        | 4.3      | 2.1    |
| 2013 | 9.5        | 4.2      | 2.2    |
| 2014 | 9.2        | 4.1      | 2.3    |
| 2015 | 9.1        | 4.5      | 2.2    |
| 2016 | 9          | 4.6      | 2      |

**Table 2.** CO$_2$ Emission (ton/capita)

Source: Prepared by the author, based on OECD [25]
According to OECD, in 2016, the total CO$_2$ emission index is 9.0 ton/capita. Portugal and Brazil emit lower index, which is equivalent to 4.6 ton/capita (-48.89%) and 2.0 ton/capita (-77.78%), respectively.

Total OECD tends to reduce CO$_2$ emissions, as does Portugal. However, Portugal has shown a slight increase in recent years. Brazil has an increase in emissions over the years, but in 2016, reduced its index.

3.1.2. UMinho
UMinho controls CO$_2$ emissions from natural gas used for heating, electricity and from other sources, considering the consumption of goods and services, waste generated from operations and mobility. Table 3 and Graph 2 show a slight increase in total emissions. The indicator for student emission reflects this slight increase.

**Table 3. CO$_2$ Emission (ton/student), UMinho**

| Indicator                                                                 | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  |
|---------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|
| CO$_2$ Emission (ton CO$_2$eq) - total                                    | 15131 | 14982 | 15499 | 14726 | 14580 | 16038 |
| CO$_2$ Emission (ton CO$_2$eq) - direct emissions                         | 1247  | 1060  | 891   | 1060  | 874   | 716   |
| CO$_2$ Emission (ton CO$_2$eq) - indirect emissions (GEE)                 | 4142  | 4115  | 4539  | 3839  | 3970  | 6672  |
| CO$_2$ Emission (ton CO$_2$eq) - other indirect emissions                 | 9742  | 9807  | 10069 | 9827  | 9736  | 8650  |
| Number of students                                                        | 17828 | 17957 | 18729 | 18522 | 18332 | 18331 |
| CO$_2$ /student (ton CO$_2$eq/student)                                    | 0.85  | 0.83  | 0.83  | 0.80  | 0.80  | 0.87  |

Source: Prepared by the author, based on UMinho [15][26][27][28][29]

However, according to chart 2, the total emission in 2015 was higher than 2014 making a 10% increase from one year to another, and from 2010 to 2015 an increase of 5.99%. This fact can be observed due to the high energy consumption in this period and consequently an increase of gas emissions. Indirect emissions and other indirect emissions depend on third parties. [15] In 2015 indirect emissions were marked by unfavorable weather conditions recorded in 2015.

**Graph 2. CO$_2$ Emission (ton. CO$_2$ eq)**

Source: Prepared by the author, based on UMinho [15]
The main source responsible for total emissions is represented by other emissions, where the item mobility is the one that most influences this index (99.32%). This rate has been declining over the years due to studies on the use of cars by the academic community.

3.2. Urban Waste

3.2.1. OECD

Figure 3 shows the generation of municipal waste (2017). This map can be analyzed in conjunction with graph 3 and table 4.

**Figure 3.** Urban Waste worldwide in 2017 (kg)

![Figure 3](image)

Source: OECD [30]

**Graph 3.** Urban Waste (kg/capita)

![Graph 3](image)

Source: Prepared by the author, based on OECD [30]
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Table 4. Urban Waste (kg/capita)

|            | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| OECD total | 541.8 | 530   | 530.3 | 527.4 | 522.2 | 519.7 | 520.6 | 523.2 | 526.8 | 524.4 |
| Portugal   | 513.7 | 515.6 | 512.3 | 487.3 | 450.4 | 436.7 | 449.9 | 457.7 | 472.2 | 485.2 |
| Brazil     | -     | 271.9 | 269.3 | 266.8 | 288.7 | -     | -     | -     | -     | -     |

Fonte: Prepared by the author, based on OECD [30]

In accordance with Table 4, in 2017 the total OECD index is 524.4 kg / capita. Portugal emits 485.2 kg/capita, which is equivalent to -7.48% of the total OECD. According to the last year of collection in Brazil, the index collected was 288.7 kg/capita, equivalent to -44.71% of the total OECD. Portugal and Brazil generate indices lower than total OECD. Both the total OECD index and Portugal show a downward trend considering the years 2008 to 2017. It is noteworthy that in Portugal, their indexes have been increasing, from 436.7 kg/capita in 2013 to 485.2 kg/capita in 2017. In Brazil, considering the years from 2009 to 2012, an increase in trend is indicated.

3.2.2. UMinho e UNISINOS

Both studied universities have indicators of total weight of waste concerning the number of students (table 5).

Table 5. Waste Indicators

| Indicator            | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|----------------------|------|------|------|------|------|------|------|------|------|
|                      | UMinho (Portugal) | UNISINOS (Brasil) |
| Waste (kg)           | 71680 | 71650 | 117270 | 122210 | 165380 | 63410 | 543083 | 617000 | 601485 |
| Number of students   | 17828 | 17957 | 18729 | 18522 | 18332 | 18331 | 27811 | 26381 | 23982 |
| Waste/student (kg/student) | 4.02 | 3.99 | 6.26 | 6.60 | 9.02 | 3.46 | 19.53 | 23.39 | 25.08 |

Source: Prepared by the author, based on UMinho [15] [26][27][28][29], UNISINOS [22][23][24]

For UMinho, regarding the global indicator, there is an upward trend over the years (graph 4). It is possible to observe a high increase from 2011 to 2012 (45.62ton), which is not due to an increase in production, but due to new processes and methodologies that have been changed, allowing accurate quantification for publication of results. [28]. In the years 2013 and 2014 there was a significant increase of 43.17 ton.

However, from 2014 to 2015, there is a significant reduction of this indicator from 101.97 tons in which the rate of tons of waste generated decreased from 9.02 kg / student to 3.46 kg / student.
In relation to the waste/student of UNISINOS, there is an upward trend in this indicator (chart 5). It is possible to observe an increase in 2017 of 73.92 ton compared to 2016, as well as an increase of 2.47 kg/student. In 2018, there is a reduction concerning the previous year of 15.52 ton, which is equivalent to a reduction of 0.52 kg/student.

3.3. Water Consumption

3.3.1. UMinho e UNISINOS

The indicators are presented in terms of water consumption (m³) in relation to the number of students (table 6).

| Indicator        | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------------------|------|------|------|------|------|------|------|------|------|
| UMinho (Portugal)|      |      |      |      |      |      |      |      |      |
| UNISINOS (Brazil)|      |      |      |      |      |      |      |      |      |
According to graph 6, it is possible to verify that there is a tendency to reduce the water consumption in UMinho. It can be seen that consumption has been reducing since 2013, from 73.39mil m³ to 65mil m³ in 2015. If we consider the consumption difference of 2010 and 2015, there is a reduction of 8.287m³, equivalent to -11.29%, as well as the rate of consumption per student that has also been decreasing over the years. There is concern about both economic and laboratory activities regarding the level of water quality that is sent to the municipality system. To this aim, training actions were carried out for staff and students.

In relation to UNISINOS, it is observed (graph 7) a tendency of increase of this index, as well as the index per student. In 2016, an index of 2.36m³/student was found, while in 2018 this index increased to 2.94. In addition to awareness campaigns, constant corrective and preventive monitoring and maintenance are performed to avoid potential leaks in underground networks. Even so, some leaks occur in the secondary networks (near the buildings), due to pipe rupture that becomes difficult to detect.

**Graph 6.** Water consumption (m³) – UMinho

| Water consumption (m³) | Number of students | Water /student (m³/student) |
|------------------------|-------------------|-----------------------------|
| 73390                  | 17828             | 4.12                        |
| 74287                  | 17957             | 4.14                        |
| 75780                  | 18729             | 4.05                        |
| 66462                  | 18522             | 3.59                        |
| 64851                  | 18332             | 3.54                        |
| 65103                  | 18331             | 3.55                        |
| 65558                  | 27811             | 2.36                        |
| 71151                  | 26381             | 2.70                        |
| 70454                  | 23982             | 2.94                        |

Source: Prepared by the author, based on UMinho [15][26][27][28][29], UNISINOS [22][23][24]
3.4. Energy Consumption

**UMinho e UNISINOS**

The indicators refer to the energy consumption in relation to the number of students (table 7).

| Indicator | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|-----------|------|------|------|------|------|------|------|------|------|
| Energy Consumption (GJ) | 84359 | 70871 | 66941 | 68245 | 66620 | 74359 | 32599 | 32461 | 32751 |
| Propane gas (GJ) | 2.5 | 7.0 | 13.0 | 0.0 | 0.0 | 0.0 | 32599 | 32461 | 32751 |
| Natural gas (GJ) | 22227 | 18888 | 15861 | 18892 | 15572 | 12771 | 27811 | 26381 | 23982 |
| Electricity (GJ) | 62129 | 51976 | 51067 | 49353 | 51048 | 61588 | 32599 | 32461 | 32751 |
| Number of students | 17828 | 17957 | 18729 | 18522 | 18332 | 18331 | 27811 | 26381 | 23982 |
| Energy/Students (GJ/student) | 4.73 | 3.95 | 3.57 | 3.68 | 3.63 | 4.06 | 1.17 | 1.23 | 1.37 |

Source: Prepared by the author, based on UMinho [15][26][27][28][29], UNISINOS [22][23][24]

At UMinho [26][27], direct energy consumption by primary energy source accounts for the institution's energy consumption and distributes according to the main primary energy sources, considering the consumption of electricity, natural gas and propane in GJ/year. According to Graph 8, it can be observed a reduction in the consumption trend, where the difference between 2010 and 2015 was 9,999.51 GJ, corresponding to a reduction of -11.85%. However, there is an increase in consumption from 2014 to 2015 of 7,739 GJ, which corresponds to an increase of 11.62% from one year to the next, which is also seen in the increase in the consumption rate per student.
Some actions are being taken as a guide to good practices, infrastructure rehabilitation at UMinho facilities; execution of the medium voltage ring, connecting three sectioning and transformation stations; installation of automatic power factor correction equipment at transformer stations; adequacy of HVAC systems; installations for energy metering and management systems; structural measures to improve the energy efficiency of buildings; awareness-raising campaign on the rational use of energy; training given to the academy.

UMinho has been seeking to increase the energy efficiency of buildings through the use of cleaner energies, for example by using around 47% of electricity supplied from renewable sources such as wind. One of the actions regarding facilities was the inclusion of the electric car charging system on the campus in 2015. [15]

Graph 9 shows UNISINOS indexes of energy consumption, which presents a slight upward trend: 2016 presented consumption of 32,599, while 2018, 32,751 GJ. Consumption per student increased from 1.17 to 1.37 GJ student.

Electricity consumption varies according to some external interference at Unisinos, such as the number of students, government fees, and summer temperatures that result in higher consumption of
air conditioners by the academic community, which requires constant action by investment. The University has been buying electricity from the free market since 2017, which makes the rate lower. In addition, it maintains permanent maintenance actions such as replacement of air conditioning systems with more efficient and modern equipment; reduction of lighting systems of buildings and parking lots between 23h and 6h; replacement of conventional fluorescent lamps with LED’s.

4. Conclusions

In this study one can compare the trends of environmental sustainability indicators regarding CO₂ emissions, waste generated, water and energy consumption, from global values, from Portugal, Brazil and two universities in these countries. For countries and worldwide, data obtained from OECD indicators between 2007 and 2017 were used. For universities, the sustainability and environmental management reports of the institutions from 2010 to 2018 were surveyed.

Worldwide CO₂ emission rates are decreasing (10.6 to 9ton/capita) as well as Portugal (5.2 to 4.6 ton/capita). Brazil showed an upward trend (1.7 to 2ton/capita), as did the University of Portugal (0.85 to 0.87ton/student). At UMinho this fact can be observed due to the high energy consumption and mobility issues related to the use of cars by the academic community.

For the waste generated, both the total OECD index (541.8 to 524.4 kg/capita) and Portugal (513.7 to 485.2kg/capita) indicate a downward trend considering the years 2008 to 2017. It points out that in Portugal the rates have been increasing (from 436.7kg/capita in 2013 to 485.2kg/capita in 2017). In Brazil, considering the years from 2009 to 2012, there is an increase in trend (271.9 to 288.7 kg/capita), as well as in UMinho (4.02 to 9.02 kg/student by 2014 and a reduction in 2015) and at UNISINOS (19.53 to 25.08 kg/student).

Water consumption (4.12 to 3.55 m³/student) and energy (4.73 to 4.06 GJ/student) at UMinho decreased over the years, while UNISINOS water indices (2.36 to 2 94 m³/student) and energy (1.17 to 1.37 GJ/student) increased. UNISINOS had higher urban waste rates than Portugal and lower rates in terms of water and energy consumption. Actions were taken to reduce the environmental burden, improving the energy efficiency of buildings through the use of cleaner energy, establishing mobility studies and campaigns to reduce consumption and reduce waste generation.

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