A **comparative study of approaches towards energy efficiency and renewable energy use at Higher Education Institutions**

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Abstract

The potential for energy efficiency and for the deployment of renewable energy at universities is substantial, and they represent promising ways to meet an institution's energy needs on the one hand, without a large climate burden on the other. However, in order to achieve successful investment and results, it is imperative to understand the level of current commitment to energy actions. Therefore, this paper investigates the level of engagement in energy efficiency measures of a sample of 50 higher education institutions from round the world, and identifies which types of renewable energy are being used to date. Results show that in more than half of the universities only a small portion of energy consumption comes from renewable sources (1% to 20%) and solar/photovoltaics is the most used source (70%). Investment in energy efficiency is more common in the sample, with 54% of the universities reporting higher levels of engagement, mainly in buildings (78%) and equipment/machineries (56%). Departing from the assumption that sustainable energy use is a pre-condition for campuses to pursue sustainability, the paper identifies current deficiencies and discusses improvements in this key area, with experiences which may be replicable elsewhere.

Keywords: energy sustainability, energy efficiency, renewable energy, sustainable university, sustainable campus.

1. Introduction: energy use at universities

Universities are often likened to towns or cities, because of their size, the fact that may accommodate and serve the needs of large students' populations, the many activities taking place on campus, and a large number of diverse buildings such as laboratories, classrooms, offices, residential accommodation, catering facilities, sports, and recreation centres. By taking American colleges and universities as examples, Pusser and Loss (2003) highlight that a university organisational structure varies depending on institutional type, culture, history, among others.

All these differences have implications for energy demand (Wadud et al., 2019) and exemplify their energy needs. Their significant overall energy consumption requires proper targeting and monitoring, so as to allow universities to reduce their carbon emissions, and improve financial performance by decreasing the costs of managing their utilities (Sapri and Muhammad, 2010; Su et al., 2012).

As a whole, there are large differences in respect of the energy consumption in university campuses, both between countries and within them (Ma et al., 2015). A comparative study of the average energy consumption per unit area shows that in the United States, this value is ranging from 250kWh/m^2 to 800kWh/m^2, where for instance, Yale University's energy consumption reaches 739kWh/m^2, where Cornell University's is about 265kWh/m^2. In South Korea, Finland, and China the energy consumption at universities range between 210kWh/m^2, 229kWh/m^2, and 204 kWh/m^2, respectively. The average campus energy consumption in Japanese universities is in the range of 450-465 kWh/m^2 to 582-600 kWh/m^2 (Ma et al., 2015; Khoshbakht et al., 2018).

Universities use energy for various purposes including lighting, heating, cooling, transportation and for running equipment. Throughout Europe there is a high number of university buildings which in general have high consumptions for electricity, but often also for heating and cooling (Erhorn-Kluttig, 2017). An analysis of six-year energy uses of electricity and heating of buildings in one university campus in Norway demonstrates that electricity use is greater than heating (Guan et al., 2015).

According to the UK-based Carbon Trust, two thirds of the total energy used by colleges and universities in the UK is made up of fossil fuels (Carbon Trust, 2012). In the United States, space heating accounts for the vast majority of natural gas use (E Source Business Energy Advisor, 2015). In Australia, the Victoria University of Wellington uses about 40% of the total energy, which is natural gas, for space heating and hot water (Victoria University of Wellington, 2018). By incorporating renewable energy and energy efficiency, new campus buildings can significantly reduce their energy consumption. A ground source heat pump at the American University of Central Asia (AUCA) in Kyrgyzstan is contributing to an 87% reduction in energy consumption compared to similar existing buildings (AUCA, 2018).

The total electricity consumption structure could be categorized into three parts:

a) non-building electricity consumption,
b) equipment with little electricity consumption, and
c) building electricity consumption, which in turn, may be divided into electric motor system (e.g. elevators, water supply and discharge system), air-conditioning system, lighting, electric socket (e.g. electrical outlets), and special function equipment (e.g. information center, kitchen equipment, etc.) (Su et al., 2012).

The pattern of energy use is defined by various factors such as seasonality, events and teaching schedules, occupancy, building size and type, and the equipment used. There is a significant difference between the summer and winter seasons for both, heating and electricity. The influence of seasonal factors on heating (or cooling) is much higher than on overall electricity usage (Guan et al., 2015; Kim et al., 2010; Rewthong et al., 2015).

Various studies show that student activities significantly contribute to the electricity consumption of a campus. Energy demand tends to be lower during a vacation period, when there are fewer staff and faculty/students present on campus, and increases during term times (Jafary et al., 2016; Kim et al., 2010; Tang, 2012).

Another important factor influencing the amount of energy used is the building type. Buildings serving multiple functions consume more electricity as more types of appliances are used for different purposes (Tang, 2012). University research buildings use significantly more energy compared with other building types, such as those for teaching, academic offices, administration offices, libraries, and residence blocks (Ma, 2013; Khoshbakht et al., 2018).

Energy demands and needs also vary according to different academic disciplines. The large-scale equipment and experimental facilities being used by the faculties of natural science, engineering and human life science, is considered as the reason why power consumption in these areas is among the largest within universities (Zhou et al., 2013; Yuan et al., 2014).

Electrical appliances, especially IT equipment, also require high power to operate, posing a significant impact to the total electricity consumption of buildings (Tang, 2012). An equipment inventory performed on Stanford University's campus estimates that the plug loads, electricity being drawn from any piece of equipment that is plugged into an outlet, from the buildings comprise 32% of the electricity consumption. Lab equipment comprises 50% and computers and monitors 36% of the total plug load electricity consumption, respectively (Hafer, 2017).

In addition, among the major electricity consumers are lighting, ventilation, and cooling (E Source Business Energy Advisor, 2015; Carbon Trust, 2012). For instance, about 60% of the total energy used by Victoria University in Wellington, Australia is used for air conditioning, lifts, lighting, electronics, and lab equipment (Victoria University of Wellington, 2018). At the Curtin University Sarawak Campus, Malaysia, 50% of the total electricity is used for air-conditioning, 30% is consumed by major electrical appliances such as computers, printers, fax machines and photocopy machines, and 19% by lighting (Tang, 2012). At the Suan Sunandha Rajabhat University, Thailand, 75% of electricity is used for air conditioner systems and 14% for lighting (Rewthong et al., 2015).

During the last decades, universities have been actively undertaking measures to reduce emissions from campus operations, and some works have focused on the nexus “energy and climate change” (e.g. Leal Filho, Surroopp 2018). Most of institutional measures aim to improve energy efficiency, minimize energy use, and/or implement energy conservation initiatives. It is well known that more detailed (and exact) data on the energy being consumed at any given moment allows universities to identify further energy conservation and energy efficiency opportunities.

There is a perceived need to better understand and study the connections between energy use and energy efficiency at universities, since this may lead to improvements not only in respect of maximising the use of their energy resources, but also in terms of reducing their carbon footprint.

University campuses are considered as crucial places for learning about the opportunities of adopting sustainable and renewable energy. On the other hand, there are barriers for such initiatives among universities in the world. Prior studies have looked into a variety of approaches to improving the adoption, which are influenced by a number of factors involving both the internal and external stakeholders. However, a comprehensive study is much desired to examine the salient factors that are common to universities around the world and yet to be addressed thoroughly by these stakeholders. Therefore, the novelty of this research is based on exploring approaches used by higher education institutions globally for sustainable energy use on campus, bringing quantitative numbers on energy efficiency measures and renewable energy sources used. Therefore, by proposing a way of measuring the extent to which universities have been investing in energy sustainability, this study aims to:

i. explore the various approaches utilized by higher education institutions in developing sustainable energy on campus
ii. evaluate the extent of adopting energy efficiency measures
iii. evaluate the extent of adopting renewable energy facilities
iv. Identify other administrative measures adopted to support sustainable energy development on campus

2. Energy efficiency and renewable energy at universities

The proper comprehension of the way universities use energy is very important in a scenario of sustainable development (Guan et al., 2016). As presented by Salvia and Schneider (2019), energy efficiency practices can range from simple actions aiming to reduce energy waste, to more elaborated ones, such as setting up research centers, developing technologies, and making buildings more efficient.

There are many benefits accrued by the increase on energy efficiency, such as reduction in pollution and costs (Chang et al., 2018), carbon footprint (Chen et al., 2018), and increased energy security (de la Rue du Can et al., 2018) especially through the optimization of power supply. Maistry and Annegarn (2016) and Bayoumi (2018) highlight the great potential in energy efficiency programs, but emphasize that there are still many universities in which these programs are not performed. It is worth highlighting that implementation of energy efficiency initiatives in universities campuses can contribute to achieve mainly the fourth and seventh Sustainable Development Goals (SDGs) of the United Nations (UN).

The fourth SDG highlights, among other issues, the importance of preparing students to consider sustainable development impacts in their actions as citizens and professionals. For Bull et al. (2018), students need to be involved in initiatives performed by university in order to reduce energy consumption; they need to understand that changes in small habits can generate interesting gains. Therefore, it is directly related to the role of universities when it is considered their importance in the training of future professionals (Allen and Marquart-Pyatt, 2018; Soares et al. 2015).

The seventh goal, in its turn, is associated with the generation of affordable, reliable, sustainable and modern energy for all (UN, 2017). In this sense, the energy efficiency initiatives in universities may contribute a lot to this goal, since universities have an important role in society to create and encourage habits and attitudes to support sustainable development. Therefore, increasing energy efficiency is not only financially attractive, but it is also ethically valuable (Allen and Marquart-Pyatt, 2018). Additionally, due to their features such as size and population, universities campuses can be compared to small cities. Thus, the planning and implementation efforts to increase the energy efficiency in campuses are similar to cities, but on smaller scales (Kolokotsa et al., 2016; Leon et al., 2018). However, many challenges/difficulties will be faced by universities during the implementation of sustainability improvements programs, such as energy efficiency programs.

Some of these challenges/difficulties can be mentioned: lack of resources to performed the initiatives, lack of prior planning of actions and lack of support from top management (Ávila et al., 2017), lack of interest of students, employees and educators or dependence on their behavior (Boulton et al., 2017), unknowledge about new technologies or even about the real meaning of a culture for sustainability (Adams et al., 2018), among others. When analyzing the success cases presented in the literature regarding to energy efficiency programs, it is possible to note that full support of top management in university is essential. The reason for this is the characteristic of continuous improvement of energy efficiency programs. In this sense, they require planning and constancy of purpose to achieve the goals. Many challenges/difficulties will arise and the top management need to keep staff and students engaged in achieving the goals. In many cases, good results may be due to small changes in habit (Allen and Marquart-Pyatt, 2018; Boulton et al., 2017; Bull et al., 2018).

In addition to the small changes, there are many options to increase universities' energy performance (de la Rue du Can et al., 2018). Some examples can be mentioned. Buildings and their equipment for temperature control are essential for the energy efficiency in universities (Chen et al., 2018). Participatory thermal sensing (PTS) is also used to increase the energy efficiency in universities. According to this approach, through people's feedback, the environmental conditions of a place is adjusted in a Heating, Ventilation, and Air Conditioning management system (Sanguinetti et al., 2017). Another methodology is presented by Song et al. (2017). The mentioned authors stand out the necessity to properly manage the spaces in universities to optimize the use of energy. They also point out the importance of allocate classrooms according to the space necessities, since the bigger the classroom the greater the amount of energy required for heating or cooling it.

The literature still presents some interesting examples of energy performance in universities, which can be used as examples for other institutions (Allen and Marquart-Pyatt, 2018; Boulton et al., 2017). Ge et al. (2018) present a study regarding regions in China that have high thermal amplitude problems, with hot summers and cold winters. To address this problem, the authors performed strategies of energy efficiency optimization. Among their conclusions, it may be highlighted the installation of sun shading components and the modification in cooling/heating setpoint temperature generated satisfactory results in summer, but not in winter. They also reached increased energy conservation through optimization in thermal performance during both summer and winter.

Soares et al. (2015), in their turn, propose an energy efficiency plan for a Portuguese university. After analyzing the university conditions, the authors purpose a project to increase the energy efficiency of the institution. This project was based in three actions: change light bulbs, change ballasts from ferromagnetic to electronics, and use of presence sensors in the toilets of the institution. Additionally, the authors highlight the importance of engaging the people from the university to increase their consciousness regarding this issue.

Besides increasing energy efficiency, the use of renewable energy sources is important to reduce the negative impact of human activities in the planet. Currently, the most important energy sources are: hydroelectric, biomass, geothermal, wind and solar photovoltaics (Mohammadi and Mehrpooya, 2018; Zerrahn et al., 2018). The use of these energy sources in higher education institutions are important for two main reasons: universities use a lot of energy and are responsible for developing the awareness of future professionals regarding environmental protection (Freidenfelds et al., 2018; Worsham and Brecha, 2017).

Husein and Chung (2018) analyse the implementation of a microgrid in a university campus in South Korea. Microgrids using renewable energy resources are being adopted by universities worldwide due to their reliability and cost-benefit ratio. The authors highlight the importance of investment-based incentives from government to increase microgrid implementation viability. Kolokotsa et al. (2016) present an analysis of a web-based energy management system to be implemented in universities campuses. Through the optimization of energy systems and the consequent decrease in energy consumption, the management system presented is able to improve the energy efficiency in 30%.

These examples are useful for universities to follow them or even to improve them, adapting for their reality. However, the literature focuses mostly on case studies and fails in providing broader analysis, with a reasonable sample of universities from different countries and realities, together. As described in the next section, this is the gap this research intends to address.

3. Study methods

In order to reach the objectives proposed in this research, a survey involving several universities around the world was conducted, and the data was analysed through the software SPSS (Version 25) to perform descriptive and correlation analysis. The following sections detail better the methodological procedures used.

3.1 Research instrument and sampling

A questionnaire survey was conducted utilizing the online application called Google Forms. The online survey contained a set of questions to examine the research objectives of this exploratory study and measure the extent to which universities have been investing in energy sustainability. Prior studies have examined issues related to sustainable energy developments in various individual countries and institutions through case study and/or in-depth analysis (Soares et al., 2015; Guan et al., 2016; Chen et al., 2018). However, there have been rather few international studies that were performed to collect views across countries in different continents. As such, this study explores various approaches used by institutions around these countries and reveals similarities and differences in their current status. The significance of administrative measures taken to facilitate sustainable energy on campus is examined as well.

The online survey was sent out to higher education institutions which are international members of the Inter-University Sustainable Development Research Programme (IUSDRP). There are currently over 120 members in this network, which is considered as a designated sample of higher education institutions. The participants of this survey are members of management in these institutions possessing adequate knowledge about the pertinent campus sustainability policy and related implementation.

The survey instrument was prepared in English and included two main sections. Section I collected information about the characteristics of the responding higher education institutions. In this Section, the questions were about country base, nature, year of foundation and number of students. Section II contained specific questions to reveal perceived commitments to various sustainable and renewable energy (RE) approaches on campus, such as percentage of energy used from renewable sources, university engagement in energy efficiency (EE) initiatives and in implementing renewable energy on campus, besides administration support and challenges for that. Table 1 presents an overview of the survey instrument.

1. Your Country:	
2. Nature of the university:	Private Public
3. Year of foundation:	
4. Number of students:	
5. What percentage (%) of current energy use at your university each year comes from renewable sources?	1% to 20% 21% to 40% 41% to 60% 61% to 80% 81% to 100%
6. Is your university engaged in the implementation of energy efficiency measures?	yes, very much so yes, a lot yes, a little yes, very little not at all
6.1 If so, since when?	
6.2 If so, please list them (multiple answers possible)	in buildings in specific offices in equipment/ machineries in open spaces (gardens or sport fields) Other:

7. Is renewable energy being deployed at your university?	Yes No
7.1 If so, since when?	
7.2 If so, which categories are being used? (multiple answers possible)	solar energy/photovoltaic geo-thermal energy wind energy energy from biomass Other:
8. Is your university administration supportive of efforts to use energy more efficiently?	yes, very much so yes, a lot yes, a little yes, very little not at all
8.1. If so, at which level? (multiple answers possible)	Rector/President Dear/Vice-Dean Head of Department Other:
9. Which elements pose a challenge to your efforts on energy efficiency? (multiple answers possible)	lack of funding lack of interest from staff lack of interest from student lack of expertise lack of materials/resources Other:

Table 1. Overview of the survey instrument

3.2 Data collection and analysis

Data collection was conducted by research assistants. They distributed the questionnaire via email to the respondents after being provided with detailed instructions for data collection procedure to minimize bias on collecting data. Reminders were sent to the participants in order to maximize the response rate. Access to the completed research study was utilized as an incentive offered to respondents for them to complete the survey.

The data collected from the survey was exported from the Google Forms platform and then imported into SPSS in order to proceed to the statistical analysis. First, descriptive analysis explored the responding institutions' characteristics with respect to country base, nature, number of students and investments in energy efficiency and renewable energy. Administration support and challenges are also discussed, and then a correlation analysis was performed in order to examine any underlying relation among the characteristics of the higher education institutions and their approach to campus sustainable energy.

There are two correlation tests: Pearson and Spearman. The first one is for normal distributions (parametric data) and the second for non-normal distributions (non-parametric data) (Hair et al., 2009; SPSS, 2003). The correlation analysis is used to verify the relationship between two variables. It ranges from -1 (strongly negative) to +1 (strongly positive) and when it is zero, it means that the variables are totally independent from each other. In the correlation analysis, the test of normality should be performed in the first step. There are two tests that are most cited in the literature: Shapiro-Wilks test (for a sample less than or equal to 50) and Kolmogorov-Smirnov test (for a sample higher than 50). In these tests, α is a parameter that the researcher chooses to evaluate the results regarding p-value (Hair et al., 2009; SPSS, 2003).

4. Results and Discussion

The 50 participant universities come from diverse regions around the globe. They are based in the following countries: USA, Brazil, Italy, Portugal, Malta, UK, Finland, Poland, Slovakia, Denmark, Sweden, Germany, Ukraine, Ethiopia, Kenya, Ghana, Egypt, India, Malaysia, Saudi Arabia, Iran, Philippines, Liberia, Indonesia, Hong Kong and Australia. Most part of the institutions are public universities, and in terms of time of operation and number of students the sample is quite balanced, as shown in Table 2.

Nature		**Number of students**		**Year of foundation**		
Public	Private	<10,000 students	>10,000 students	Before 1850	1850-1950	After 1950
35	15	26	24	8	21	21

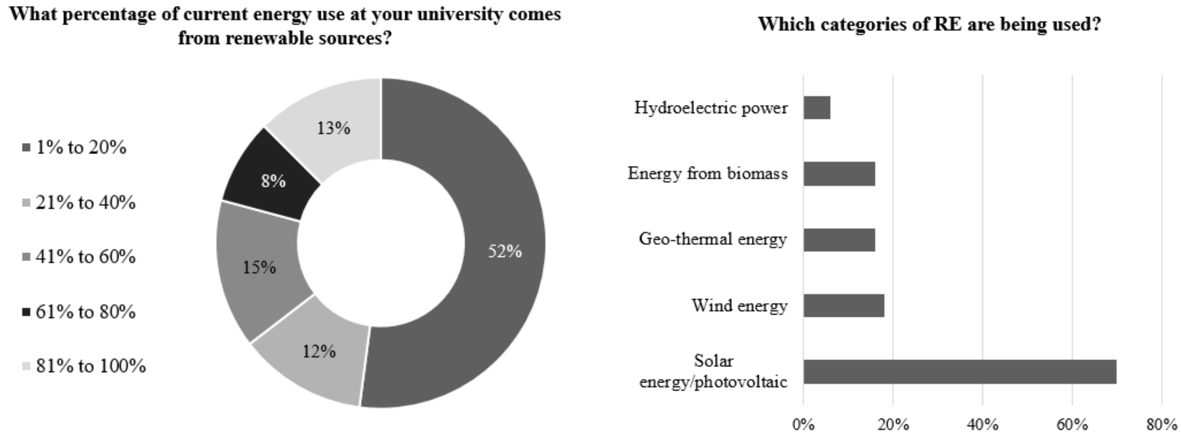
Table 2. Number of universities according to each classification

When it comes to **Renewable Energy**, only a small portion of the energy consumption is reported to come from renewable sources in most universities (52%), as shown in Figure 1.

The best situation, with renewables accounting from 81% to 100% of energy consumption, is reported by only 13% of the respondents, which come from Sweden, Germany, Brazil and Egypt. When asked if renewable energy is deployed at their universities, 72% of universities answered positively. Of these, the vast majority (80%) has been investing in RE more recently, after 2010. Regarding the categories of RE used, solar/photovoltaic energy was the most cited, being developed by 70% of the universities. Biomass, wind and geo-thermal energy present similar shares of use among themselves (around 18%). Hydroelectric power was indicated by only 6% of the respondents. Some institutions have already adopted some measures to increase the use of renewable energy as is the case of the implementation of a microgrids mentioned by Husein and Chung (2018). Some authors (e.g. Freidenfelds et al., 2018; Worsham and Brecha, 2017) point to the importance of the use of these energy sources since the Universities are responsible for a great amount of energy and should help developing consciousness regarding environmental protection in future professionals.

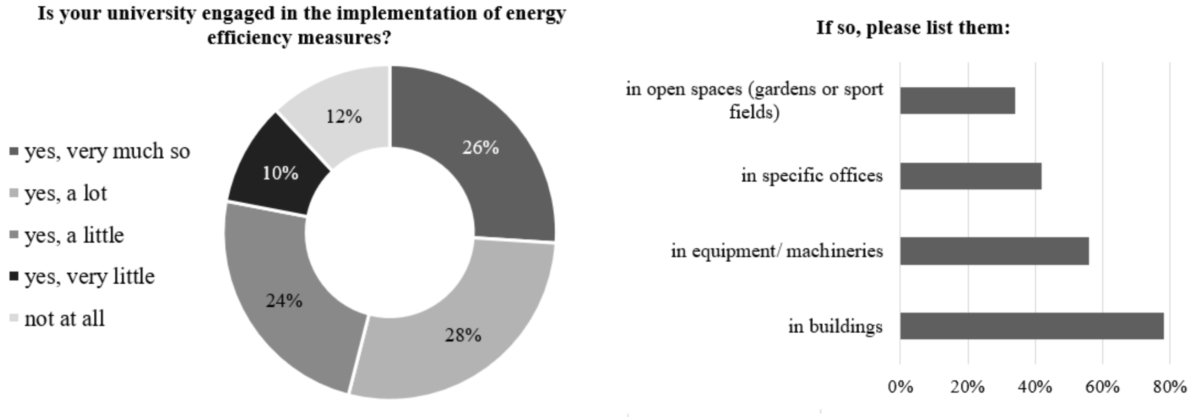
The implications from these results are threefold. First, they provided confirmation of the need for further studies and investments in the context of renewable energy at universities. There is a dearth of them at present. The high percentage of universities using less than 20% of RE reinforced the argument that there is a demand for better options to allow the spread use of such climate friendly technologies. Secondly, the results offered some insights on the potential areas for technology or pilot studies deployment. Finally, the study showed that as the deployment of renewable energy increases, there is a need to consider ways to diversify energy generation at HEIs, not only for energy security reasons, but also for educational purposes.

Figure 1. Results from the Renewable Energy section



When asked about **Engagement in Energy Efficiency** measures (Figure 2), almost 90% of the universities indicated to have some level of engagement, which is very positive. This engagement is recent for almost half of the sample (since 2010), and more spread among the two previous decades for the other share. Most actions are applied in buildings and equipment/machineries, but investments in specific offices and in open spaces (gardens or sport fields) were also mentioned. This is in line with Chen et al. (2018) findings that mention the buildings and equipment as crucial for the energy efficiency in universities. In addition, some universities described incorporation of efficiency practices in Energy Performance Contracting, Sustainable Procurement, Eco-Management and Audit Scheme and Behaviour Improvement. de la Rue du Can et al. (2018) consider that energy efficiency allows a cost-effective energy, and, in fact, universities have a plenty of options to increase their energy performance, as suggested by Soares et al. (2015) (e.g. change light bulbs, change ballasts from ferromagnetic to electronics, and use of presence sensors).

Figure 2. Results from the Energy Efficiency section

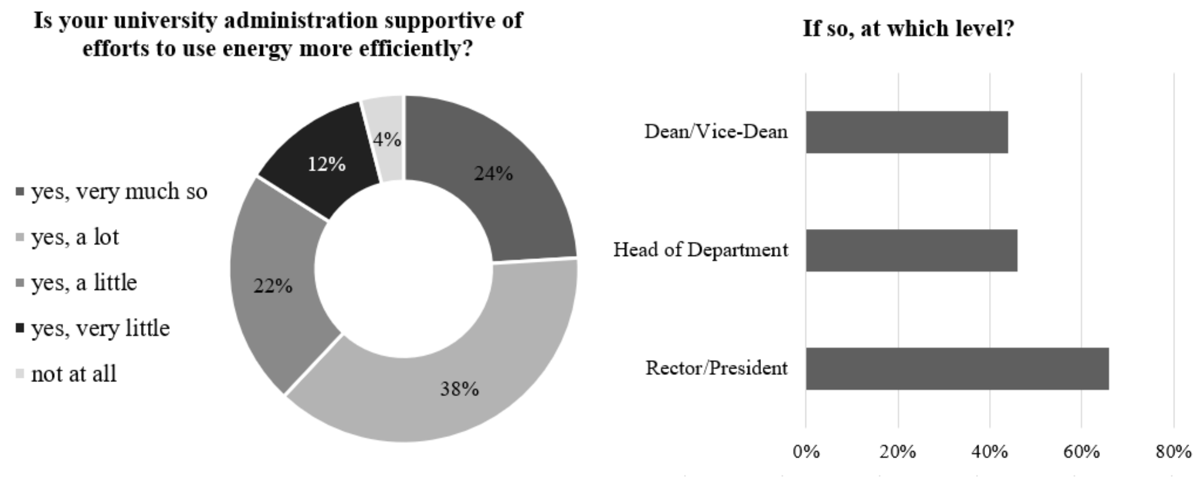


The above results mean that pursuing energy efficiency in HEIs is still more common than investing in renewable energy, probably due to the fact that it encompasses a larger spectrum of actions, from the simplest to the most technological ones (Salvia and Schneider, 2019). On the other hand, considering the good results provided by energy efficiency practices and the available evidence on that, especially from the economic point of view (Maiorano and Savan, 2015), having 12% of universities not investing in energy efficiency is unfortunate. More can be explored in areas such as energy contracting, which would facilitate the implementation of energy efficiency in buildings, for example (Huimin et al., 2019). At this point, government policies incentivizing the implementation of energy efficiency measures would be crucial in order to engage the universities follow this way.

Regarding **Administration Support**, only 4% of universities (as shown in Figure 3) reported not to have support from the administrative sector, which is indeed a very important factor for sustainability measures to succeed. In contrast, Maistry and Annegarn (2016) and Bayoumi (2018) refer that there are still many universities in which the energy efficiency programs are not performed. The other 96% of universities do have some kind of support, which usually comes from Rector/President, or Dean/Vice-Dean and Head of Departments. Some respondents also mentioned support from Researchers/Professors and Estates/Works Directorate. The literature is also clear when mention that the support of top management and planning in university is essential for the success of efficiency programs (Boulton et al., 2017; Bull et al., 2018).

This result suggested that even with declared support, much more could be achieved. Future studies may identify exactly how the administration support is working towards sustainability, and potential differences in experiences in which the support comes more directly from rectory or departments. It is worth mentioning that support should imply in including (energy) sustainability among the top administration priorities, otherwise it is common to observe only intermittent positive results. At this point, it would be useful analyzing the type of organizational culture implemented and how it can influence the implementation of energy efficiency measures.

Figure 3. Results from the Administration Support section

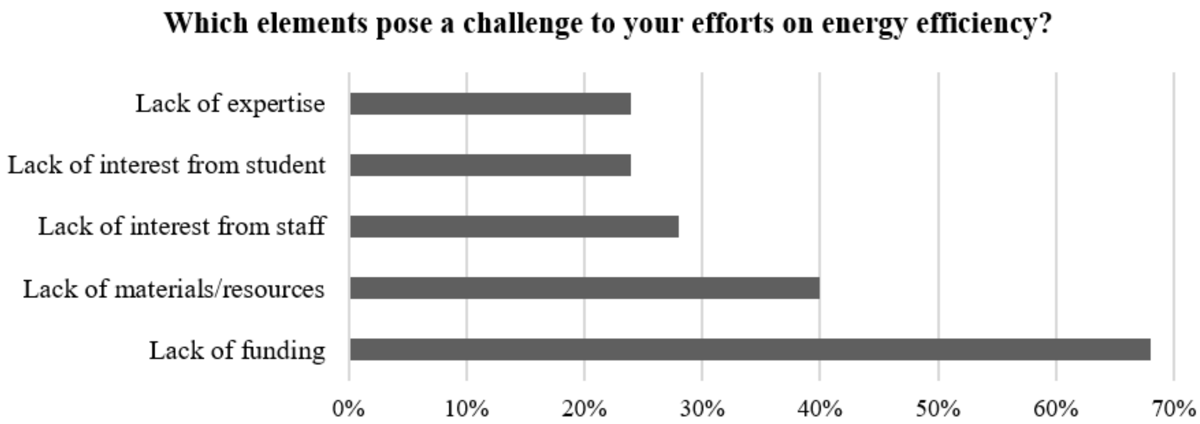


Finally, regarding **Challenges** to the implementation of energy efficiency measures, lack of funding was the most mentioned aspect (68%), followed by lack of materials/resources (40%), as presented in Figure 3. The lack of funding is precisely the barrier referred by

Maiorano and Savan (2015) in their study about Canadian Universities. Some respondents also mentioned lack of policies or geographical scope, limited technology to invest in renewable energy, lack of support from the administration and difficulties to maintain the practices. This is in line with other studies (e.g. Adams et al., 2018; Boulton et al., 2017) that mention the lack of resources to carry on some initiatives, lack of interest of students and employees, and lack of knowledge, among other factors. As far as students are concerned, it is crucial that the university could involve them in activities to reduce energy consumption (Bull et al., 2018).

The results pointed to the fact that as many other sustainability initiatives, energy issues also rely greatly on funding for succeeding. Although one respondent mentioned the limited technology, in general technology tends not to be the main barrier against energy sustainability, but the same cannot be said about public perceptions (Boudet, 2019). How society (or academic community, in the HEIs' context) perceive the efforts towards energy efficiency and use of renewables is a fundamental part of the process, since their interest and participation can ensure a long-term process of change and evolution.

Figure 4. Results from the Challenges section



Regarding the correlation analysis, Spearman test was used since the variables are not normally distributed, as verified through Shapiro-Wilks test (sample N = 50). The results are presented in Table 3.

	1	2	3	4
1. Percentage of energy use coming from renewable sources	1			
2. Investment in renewable energy	0.219	1		
3. Support from university administration	0.162	0.291*	1	
4. Engagement in the implementation of energy efficiency measures	0.402**	0.427**	0.603**	1

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

Table 3. Correlations among categories (N = 50)

These four aspects (percentage of energy use coming from renewable sources, investment in RE, support from university administration and engagement in the implementation of EE) were the ones with more interesting results to be discussed. Higher correlation was observed between engagement in EE and administration support, followed by investment in RE and then percentage of energy use coming from renewable sources.

For Ávila et al. (2017), without the support of senior management in a university, sustainable initiatives seem destined to fail in the longer term. The results from the correlation analysis confirmed that it applies also for energy practices, since the administration support is indeed fundamental for the implementation of EE initiatives in universities.

5. Conclusions

Energy is used in universities for various purposes such as lighting, heating, ventilation, cooling, transport, and running equipment, and significant variations exist in the energy consumption in university campuses, both among countries and within them. Some universities consume around 250kWh/m^2 of energy while the consumption in other universities is as high as 700kWh/m^2. Seasonality, events and teaching schedules, occupancy, building size and type, and the type of equipment used are some of the factors influencing energy needs, demand and consumption pattern in different universities. Understanding the nexus between energy use and energy efficiency at universities can help to maximise the use of campus' energy resources and reduction of carbon footprint. A comprehensive study was conducted to explore the various approaches used by higher education institutions globally for sustainable energy use on campus. The extent of adopting energy efficiency measures and renewable energy facilities was also assessed together with administrative measures and other similar initiatives being adopted to strengthen sustainable energy development on campus. Based on SPSS analysis of survey feedback from 50 participating universities across different regions, it was observed that renewable energy contributes to the energy consumption in a small portion in most universities. Our findings suggested that among the broad range of renewable energy technologies supported by the participating universities, solar/photovoltaic energy applications are the most common. Buildings and equipment/machinery have been identified as the primary focus of energy efficiency improvements of the surveyed universities.

Among the major factors that pose challenges to energy efficiency improvements and renewable energy projects on campus, mention can be made to the commitment and support from management and administration. The availability of funding, resources and materials, as well as interest from staff and students, have also been identified as important for the implementation of energy efficiency projects.

In view of the emergence of international initiatives like the Sustainable Development Goals (SDGs) and the programme "Sustainable Energy for All", universities' engagement in energy efficiency and renewable energy is expected to increase. The research results provided a good basis to further explore possibilities for strengthening efforts on monitoring and reporting energy use and the advancement of sustainable energy projects on campuses. These findings can offer a foundation for establishing benchmarks on sustainability related issues. Similar efforts are undertaken as part of the Sustainability Tracking, Assessment and Rating System (STARS) programme of the US based Association for the Advancement of Sustainability in Higher Education (AASHE) whose members are mainly universities based in North America. In terms of recommendations, in order to advance energy efficiency and renewable energy, universities would have to work at three main levels:

- Level 1- Macro: produce policies specific to energy use, energy efficiency and renewable energy which guide the way the institution deploy and conserve its energy resources.
- Level 2- Meso: to work with individual Faculties, so that university-wide plans are also complemented at the level of Faculties, since some of them (e.g. Science and Engineering) can be quite energy intensive, whereas others (e.g. Design and Law) may not be so.
- Level 3- Micro: initiatives at Department level, with the direct engagement of members of Departments and by means of joint initiatives at this level (e.g. installing timers so energy supply to office equipment may be automatically switched off during late night or weekends).

Moreover, apart from investments in specific to energy-related projects, universities can also introduce teaching programmes (also field-based) and courses on energy topics, engaging students and possibly the general public. Furthermore, a greater involvement in energy-related research could help advance technology development, accelerate deployment and lead to additional reductions in level of energy consumption. Overall, universities are in a good position to reduce their carbon footprint by means of energy conservation and efficiency.

These actions, in combination with investments in renewable energy, have great potential to contribute to cleaner production aspects in higher education, especially through reduction of energy waste, energy consumption and carbon emissions. In fact, energy sustainability is among the main concerns of universities which have been investing in low-carbon campuses due to the potential reduction of carbon emissions as a result of energy efficiency practices and use of renewable energy sources. What is needed is more concerted action, so as to maximise the many financial and ecological benefits a more sustainable energy use may bring to the whole organisation.

As to future research work, it could be interesting to enlarge the sample of higher education institutions involved and expand the topic by exploring and highlighting best practices applied. Planned research also involves the evaluation of energy sustainability in HEIs in broader, such as their connection with teaching, research and outreach.

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