Energy for Sustainability International Conference 2019
Designing a Sustainable Future
Turin, 24-26 July 2019

A SURVEY ON THE IMPACT OF ENERGY AND BUILDINGS SUSTAINABILITY INITIATIVES IN UNIVERSITY CAMPUSES

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Keywords: Sustainable campus, sustainable university, campus operations, energy initiatives, buildings initiatives

Abstract *University campuses are complex structures, generally consisting in large amounts of built-up area and of users involved in a diversity of activities, resulting in a substantial consumption of resources, waste generation and greenhouse gases emissions, similarly to an urban community. Acting on the use phase, the so-called operations, offers the possibility of improving the environmental performance of buildings, facilities and outdoor spaces, resulting in higher savings rates at a short and medium term.*

Sustainability initiatives on campus operations may be arranged in several key areas, such as Energy, Buildings, Waste, Water, Transportation, Air and Climate and Food. This work focus on Energy and Buildings initiatives, by reviewing those studied or effectively implemented in university campuses with reported results in scientific publications. Literature shows a wide range and diversity of results. This work intends, thus, to understand those results, by exploring the extent to which the success of initiatives is related to campuses characteristics, particularly to the campuses dimension.

The results of this work show a tendency for smaller campuses to present better results on the feasibility of actions, through higher rates of energy consumption decrease; larger ones present diverse impacts, being their probability of success dependent on the addition of supporting measures to the energy generation, as the implementation of energy storage or microgrids. These findings, even recognizing the need of more research to produce more robust conclusions, can help to identify key points for actions to optimize the adoption of sustainable strategies according to each campus specificities, and to succeed in the accomplishment of the sustainable campus principle.

1. INTRODUCTION

Assuming the commitment to respond to climate change concerns, Higher Education Institutions (HEI) are increasingly involved in incorporating environmental concerns in the core of their activities, due either to the social responsibility of training future leaders and citizens, as to the recognition that campuses structures are large consumers of energy and other resources, with negative consequences on the environment and on the universities' bills.
Universities' campuses comprise large and complex structures, embracing a significant number of users and activities that may occur at almost twenty-four hours a day. They involve not only the greenhouse gases (GHG) emissions and the consumption of energy, water, materials or food, but also the management of transportation and of the waste produced. Acting on the use phase, generally known as the *operations* phase, provides the opportunity to improve the environmental performance of campuses physical structures and infrastructures at a short and medium term, which may justify the attention that literature has been giving to this field, when compared to other aspects of sustainability in HEI such as Education or Governance [1].
Although relevant work has been done on the diverse approaches that HEI may adopt to be involved in sustainability principles [1]–[8], the knowledge on existing sustainable campus practices is still limited, as there is few scientific literature that may help to stimulate an in-depth discussion on the theoretical and practical outlines of sustainable campus operations.
This work intends, thus, to better understand the implementation of initiatives in universities campuses in the area of operations, regarding the accomplishment of the sustainable campus philosophy. For this purpose, a review on the scientific literature regarding the effective implementation of sustainability measures or the studies evaluating their feasibility in university campuses is proposed. The main objective is to understand the extent to which the success of initiatives – translated on the increase of renewable energy supply or on the decrease of energy demand or of GHG emissions – is related to campuses physical characteristics, such as the size of the campus. Knowing that universities have their own specificities, it is hypothesized that sustainability measures do not have the same impact in all campuses equally, and the evaluation of the most appropriate to each campus becomes crucial to increase their potential for success.

2. MATERIAL AND METHODS

The undertaken work resulted from a literature review based on scientific publications only, by searching on Science Direct (https://www.sciencedirect.com) and Google Scholar (http://scholar.google.com) websites, through the keywords "sustainab", "university", and "campus". The collected publications were filtered by considering those published from 2010 onwards, and categorized according to STARS [9] definitions – Energy, Buildings, Waste, Water, Transportation, Grounds, Air and Climate, and Food. This work focuses on the area of Energy and Buildings – the ones most addressed in literature – and only those who present results were considered. A total of 68 publications were retrieved for this survey – 43 journal articles, 15 book chapters and 10 conference proceedings. The articles were organized according to the type of initiatives implemented or studied.

From each study, the HEI referred to was determined and classified according to the size, based on the QS classification (http://www.iu.qs.com/university-rankings/qs-classifications/), a simplified approach of Carnegie Classification of Institutions of Higher Education that proposes a categorization of size according to the total number of students.
Given the wide diversity of the results presentation in each study – rates of reduction on energy consumption, on electricity demand, savings, tons of CO_2 emissions reduction, or even payback time for the feasibility studies – the interpretation of results was based on a qualitative approach – being considered that all the initiatives that provide reductions or savings have a positive impact.

3. RESULTS AND DISCUSSION

Figure 1 synthesizes the type of initiatives and case studies in Energy and Buildings areas, according to HEI dimensions. These are classified as S (institution with less than 5000 students), M (greater or equal to 5000 and lower or equal to 12 000 students), L (greater or equal to 12 000 and lower or equal to 30 000 students) and XL (greater than 30 000 students). The number of initiatives with positive results against the total number of initiatives for each type – x/x – is presented as well.

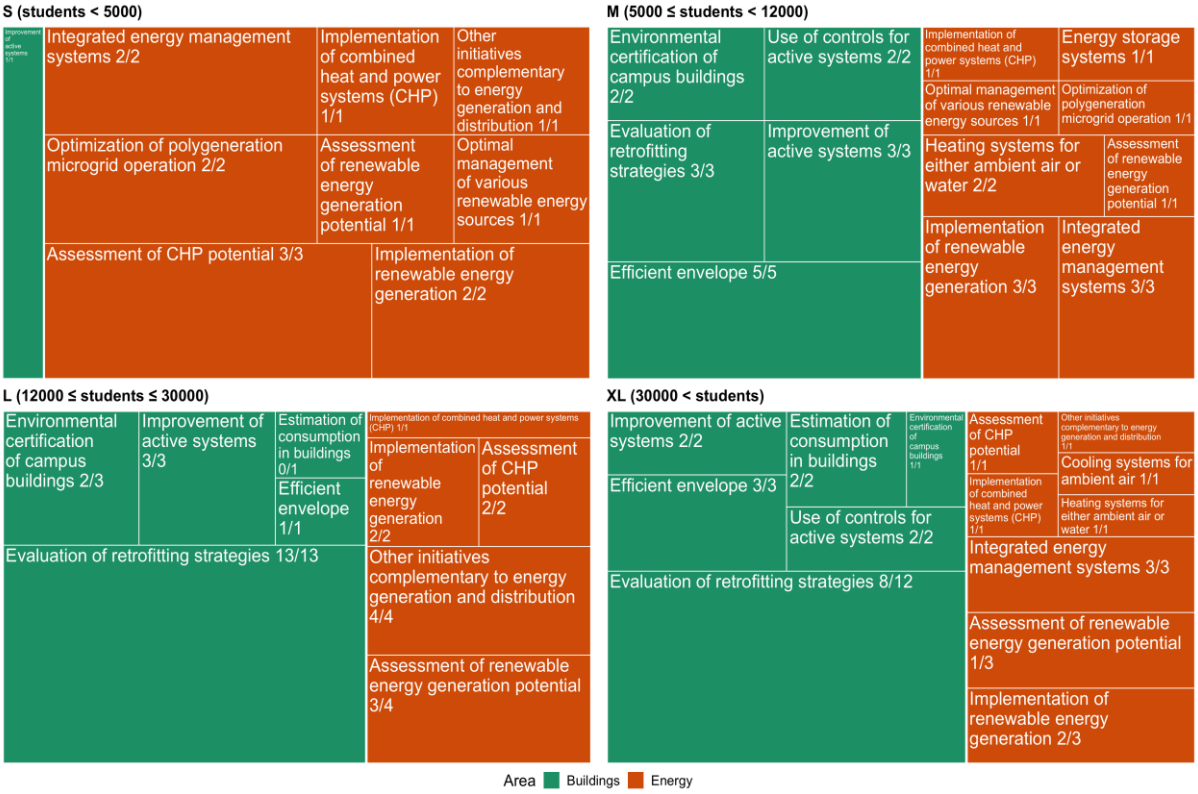

Figure 1. Initiatives in Energy and Buildings areas on small (S), medium (M), large (L) and extra-large (XL) sized universities.

An overview of the initiatives on Energy found on literature highlights the penetration of renewable sources for energy production as the most substantial, as well as its application to combined heat and power (CHP) plants or to heating/cooling systems. The addition of microgrids, batteries for energy storage or energy management systems are found as well. Regarding Buildings, the efficiency of the envelope, through the thermal insulation of opaque areas and the control of heat gains on glazing areas, is the most addressed initiative; in the case studies, it is reflected on the evaluation of retrofitting strategies for existing buildings.

In what concerns to the share of initiatives per HEI size, the implementation of energy generation, distribution and management systems dominates the smaller universities (S). The remaining universities show a relatively balanced distribution between Energy and Buildings initiatives, although with differences in the most implemented. Medium-sized universities (M) present more actions on the improvement of buildings envelope, and the larger ones (L and XL) on the evaluation of retrofitting strategies. These initiatives generally comprise a combination of passive measures (thermal insulation of opaque envelope and upgrading of glazing areas) and improvement of active systems, as the increasing of lighting and/or HVAC systems efficiency.

Analysing the impact of the initiatives itself, literature shows that the smaller universities have a greater potential for successful implementation of renewable energy systems, through higher percentages of energy supplied by renewable sources – more than 100 % [10], [11], against 80 % on M [12] and about 34 % on L [13], [14]. It is in such a way that the Environmental Campus Birkenfeld reported by [15], one of the smaller campus of this work's body of literature, is considered the first Europe's Zero-Emission Campus. For the case of larger universities (XL), various studies show that renewable energy generation do not supply substantially the campus energy consumption and, thus, has a minimal contribution [16]–[18]. The largest universities that present a major supply by renewable sources tend to implement a combination of initiatives to increase the energy system efficiency, such as hybrid systems [19], CHP [20], [21], microgrids [20], [22] or energy storage [23]. The energy management systems seem to help all the participating universities in decreasing energy consumption, regardless of their size or location. The same is noted in the deployment of smart meter displays, since the effectiveness of these measures are mostly dependent of the users' behaviour and predisposition to be involved on the decrease of energy consumption.

In what concerns to Buildings, passive measures present significant reductions on the decrease of energy demand, namely the thermal insulation of opaque envelope that seem to have a positive effect in all sizes, even with slightly prominent reductions on energy demand in smaller universities [24], [25]. The evaluation of retrofitting strategies present positive impacts in all sizes as well, with percentages of reduction on energy demand of about 40 % for M universities [26], between 6 % and 50 % for L universities [21], [27], [28] and between 25 % (if only windows are replaced) and 93 % (combination of passive and active strategies) in XL universities [29]. Active systems, as the upgrading of artificial lighting to LED technologies and of HVAC systems, provide significant reductions on energy demand, being the smaller university the one with higher savings [30]. Again, the use of supporting

measures, as the automated controls for lighting, temperature setpoints or gas use, help the largest universities to perform better [31].

4. CONCLUSIONS

The undertaken work revealed trends and some relationship between the impact of the initiatives and the size of universities, especially concerning renewables penetration measures. Thus, smaller universities tend to show better results through higher percentages of energy savings and of coverage by renewable energy generation. The larger ones seem to be dependent on the additional measures to support power generation, such as hybrid systems, CHP or microgrids. This conclusion may lead to the suggestion that there are types of initiatives more appropriate to each campus, according to its characteristics, namely the size.

This study identifies some limitations. On one hand, the results found on literature and used in this work are presented on such a diversity of means that it would be of great importance to establish common metrics, performance parameters, calculation methods or even common measure units for results presentation, in order to be able to better discuss and compare initiatives and impacts among themselves.

On the other hand, even recognizing the lack of comprehensive information on the literature and the few studies based on empirical data, the results achieved with this study raise a line of research, paving the way for future work.

Hence, more research is needed, in order to draw robust conclusions that can help HEI to design action plans appropriate to the characteristics of each campus within a priority order framework, optimizing investments, resources and succeeding in the accomplishment of the sustainable university campuses.

ACKNOWLEDGEMENTS

The presented work is framed under the Energy for Sustainability Initiative of the University of Coimbra (UC).

Funding: This work was supported by the Portuguese Foundation for Science and Technology (FCT) and European Regional Development Fund (FEDER) through COMPETE 2020 – Operational Program for Competitiveness and Internationalization (POCI), under the project Ren4EEnIEQ (PTDC/EMS-ENE/3238/2014 and POCI-01-0145-FEDER-016760, respectively) and by project UID/Multi/00308/2019 supported by FCT. Ana R. Amaral acknowledges the support provided by FCT under Doctoral grant PD/BD/113718/2015.

REFERENCES

[1] M. Yarime and Y. Tanaka, "The Issues and Methodologies in Sustainability Assessment Tools for Higher Education Institutions: A Review of Recent Trends and Future Challenges," *J. Educ. Sustain. Dev.*, vol. 6, no. 1, pp. 63–77, 2012.

[2] R. Lozano *et al.*, "A review of commitment and implementation of sustainable development in higher education: Results from a worldwide survey," *J. Clean. Prod.*, vol. 108, pp. 1–18, 2015.

[3] R. Lozano, R. Lukman, F. J. Lozano, D. Huisingh, and W. Lambrechts, "Declarations for sustainability in higher education: Becoming better leaders, through addressing the university

system," *J. Clean. Prod.*, vol. 48, pp. 10–19, 2013.
[4] L. P. Amaral, N. Martins, and J. B. Gouveia, "Quest for a sustainable university: a review," *Int. J. Sustain. High. Educ.*, vol. 16, no. 2, pp. 155–172, 2015.
[5] D. Fischer, S. Jenssen, and V. Tappeser, "Getting an empirical hold of the sustainable university: a comparative analysis of evaluation frameworks across 12 contemporary sustainability assessment tools," *Assess. Eval. High. Educ.*, vol. 40, no. 6, pp. 785–800, 2015.
[6] K. Ceulemans, I. Molderez, and L. Van Liedekerke, "Sustainability reporting in higher education: A comprehensive review of the recent literature and paths for further research," *J. Clean. Prod.*, vol. 106, pp. 127–143, 2015.
[7] L. Lidstone, T. Wright, and K. Sherren, "An analysis of Canadian STARS-rated higher education sustainability policies," *Environ. Dev. Sustain.*, vol. 17, no. 2, pp. 259–278, 2015.
[8] A. Lauder, R. F. Sari, N. Suwartha, and G. Tjahjono, "Critical review of a global campus sustainability ranking: GreenMetric," *J. Clean. Prod.*, vol. 108, pp. 852–863, 2015.
[9] AASHE, "STARS Technical Manual," Philadelphia, USA, 2017.
[10] J. U. Junior, F. S. Tonin, J. D. Mariano, and G. M. Tiepolo, "Analysis of the Operation of Photovoltaic Systems Installed at Federal University of Technology - Paraná in Curitiba," *Brazilian Arch. Biol. Technol.*, vol. 61, 2018.
[11] L. B. Krasnhak, E. A. M. de Mello, G. R. Moura, F. da R. Santos, and J. U. Junior, "Analysis of Production and Consumption of Electric Energy in the Green Office of UTFPR in Curitiba," *Brazilian Arch. Biol. Technol.*, vol. 61, 2018.
[12] B. V Kobiski, E. F. Casagrande, and G. Pendleton, "Carbon Stored in a Sustainable University Building: Bringing Education to Practice," in *Integrative Approaches to Sustainable Development at University Level*, W. L. Filho, L. Brandli, O. Kuznetsova, and A. M. F. do Paço, Eds. 2015, pp. 185–195.
[13] B. D. Radhakrishnan and S. Viswanathan, "National University's Integrated Approach Towards Sustainable-Green Campus: Leadership, Curriculum, and Outreach," in *Implementing Campus Greening Initiatives*, W. L. Filho, N. Muthu, G. Edwin, and M. Sima, Eds. Springer International Publishing, 2015, pp. 75–91.
[14] A. Pinto, F. Rodrigues, and A. Mota, "Geothermal contribution on southern Europe climate for energy efficiency of university buildings. Winter season," *Energy Procedia*, vol. 134, pp. 181–191, 2017.
[15] K. Helling, "Environmental Campus Birkenfeld - A Role Model for Universities on How to Contribute to the Implementation Process of the Sustainable Development Goals," in *Handbook of Sustainability Science and Research*, W. L. Filho, Ed. Springer International Publishing, 2018, pp. 539–551.
[16] N. Kalkan *et al.*, "A renewable energy solution for Highfield Campus of University of Southampton," *Renew. Sustain. Energy Rev.*, vol. 15, no. 6, pp. 2940–2959, Aug. 2011.
[17] C. L. Kwan and T. J. Kwan, "The financials of constructing a solar PV for net-zero energy operations on college campuses," *Util. Policy*, vol. 19, no. 4, pp. 226–234, 2011.
[18] S. Pusat and M. T. Akkoyunlu, "Evaluation of Wind Energy Potential in a University Campus," *Int. J. Glob. Warm.*, vol. 14, no. 1, pp. 118–130, 2018.
[19] T. Forman *et al.*, "Improving Building Energy Performance in Universities: The Case Study of the University of Cambridge," in *Handbook of Theory and Practice of Sustainable Development in Higher Education Volume 1*, W. L. Filho, L. Brandli, P. Castro, and J. Newman, Eds. Springer International Publishing, 2017, pp. 245–266.
[20] B. Washom *et al.*, "Ivory tower of power: Microgrid implementation at the University of California, San Diego," *IEEE Power Energy Mag.*, vol. 11, no. 4, pp. 28–32, 2013.

[21] C. K. Mytafides, A. Dimoudia, and S. Zorasa, "Transformation of a university building into a zero energy building in Mediterranean climate," *Energy Build.*, 2017.

[22] V. Machamint, K. Oureilidis, V. Venizelou, V. Efthymiou, and G. E. Georghiou, "Optimal Energy Storage Sizing of a Microgrid under Different Pricing Schemes," in *12th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG 2018)*, 2018.

[23] O. Opel, N. Strodel, K. F. Werner, J. Geffken, A. Tribel, and W. K. L. Ruck, "Climate-neutral and sustainable campus Leuphana University of Lueneburg," *Energy*, 2017.

[24] F. Mancini, C. Clemente, E. Carbonara, and S. Fraioli, "Energy and environmental retrofitting of the university building of Orthopaedic and Traumatological Clinic within Sapienza Città Universitaria," *Energy Procedia*, vol. 126, pp. 195–202, 2017.

[25] P. Fonseca, P. Moura, H. Jorge, and A. de Almeida, "Sustainability in university campus: options for achieving nearly zero energy goals," *Int. J. Sustain. High. Educ.*, vol. 19, no. 4, pp. 790–816, 2018.

[26] L. Bellia, M. Borrelli, R. F. De Masi, S. Ruggiero, and G. P. Vanoli, "University building: Energy diagnosis and refurbishment design with cost-optimal approach. Discussion about the effect of numerical modelling assumptions," *J. Build. Eng.*, vol. 18, no. September 2017, pp. 1–18, 2018.

[27] M. H. Chung and E. K. Rhee, "Potential opportunities for energy conservation in existing buildings on university campus: A field survey in Korea," *Energy Build.*, vol. 78, pp. 176–182, 2014.

[28] S. Nagpal and C. F. Reinhart, "A comparison of two modeling approaches for establishing and implementing energy use reduction targets for a university campus," *Energy Build.*, vol. 173, pp. 103–116, 2018.

[29] M. M. Sesana, M. Grecchi, G. Salvalai, and C. Rasica, "Methodology of energy efficient building refurbishment: Application on two university campus-building case studies in Italy with engineering students," *J. Build. Eng.*, vol. 6, pp. 54–64, 2016.

[30] S. Jain and P. Pant, "Environmental management systems for educational institutions: A case study of TERI University, New Delhi," *Int. J. Sustain. High. Educ.*, vol. 11, no. 3, pp. 236–249, 2010.

[31] J. Granderson, M. A. Piette, and G. Ghatikar, "Building energy information systems: User case studies," *Energy Effic.*, vol. 4, no. 1, pp. 17–30, 2011.