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Evaluating Heat Island Effect at University Campus with Reference to LEED v4.

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Abstract

The growing complexity in environmental degradation requires a serious action for adopting sustainable initiatives in the different institutions design and operation. Leadership in Energy and Environmental Design (LEED), is the most widely used green building rating system in the world that helps institutions to evaluate their current sustainable performance, and provides a concise guidance for identifying and implementing practical and measurable solutions. One of the important challenges to achieve sustainability, especially in hot dry climate region, such as Jeddah city, KSA, is the urban heat island effect that contributes to energy consumption. Effat University, Jeddah is striving towards convoying the sustainable trends in developing and designing its campus, in the light of Saudi 2030 vision, which targets reducing energy consumption. This research contributes to the knowledge of rating sustainability through measuring the level of sustainability at Effat University Campus with reference to the LEED v4 rating system (Operation and Maintenance). The research focuses on site selection category, Heat Island Reduction Credit, Option 1 Non-roof Surfaces. This was carried on through quantitative methodology that based on surveying the university campus landscape elements and materials, and interviewing maintenance key persons. The results of this research would potentially help Effat University to improve the campus environmental and energy performance through recommending a set of evidence-driven actions that can help in reducing heat island effect and enhance the efficiency of the university landscape sitting and material. This would also help in moving Effat University one-step forward to develop a green campus and being LEED Certified.

Keywords

Heat Island Effect; Rating Sustainability; Sustainable Site; Rating System; LEED; operation and maintenance; Green Campus

1. Introduction

The growing complexity in environmental degradation require a serious action for adopting sustainable initiatives in the different institutions design and operation. Green Campus is an emerging trend for higher education institutions launched by the U.S. Green Building Council (USGBC) to integrate the role of campus in accelerating the sustainability movement **[1]** by improving energy efficiency, conserving resources and enhancing environmental quality by educating for sustainability **[2].**

To support universities in meeting their sustainability goals, USGBC offered a strategy for using the LEED rating system to evaluate current campuses sustainable performance as an initial step for achieving their goals. It is the most widely used green building rating system in the world, which provides a concise guidance for identifying and implementing practical and measurable solutions **[3].**

LEED for Existing Buildings: Operations & Maintenance was designed to certify the sustainability of ongoing operations of institutional buildings. It assigns a section for measuring the site properties performance toward sustainability, which is Sustainable Sites or "SS" category. This category addresses the environmental concerns related to buildings' surrounding areas, its landscape, hardscape, and exterior management practices. This section promotes responsible, innovative, and practical site design strategies that are sensitive to plants, wildlife, water and air quality. In the line of promoting sustainable practices, the Site Sustainable credits are designed to measure and mitigate the negative effects the buildings have on the local and regional environment. **[4].**

One of the negative effects of modern performances is the urban heat island phenomena that happens where the urban air temperature in a specific area is higher than the surrounding areas **[5].** The heat Island Effect is considered one of the green campus operations that represents important concern to be addressed to achieve sustainability especially in hot dry climate region, such as Jeddah city.

As part of Effat University striving towards convoying the sustainable trends in developing and designing its campus and in the light of Saudi 2030 vision, which targets reducing energy consumption, the research objective is to develop recommendations that can help in reducing heat island effect. This can be achieved through choosing the appropriate materials and creating alternatives to increase the shaded areas at the outdoor spaces of Effat campus. This research contributes as well to the knowledge of rating sustainability through measuring the level of sustainability at Effat University Campus using the LEED rating system.

2. Literature review

a.Green Campus

In the light of the serious impacts of climate change, and the growing complexity in environment, due to the excessive dependence on natural resources and development processes, the necessity of sustainability has gained the attention of various institutions [6]. The governments and international organizations expanded their efforts to reduce the negative impacts of development practices on the environment [7].

The Realization of the universities' positive contribution in reducing the degradation of environment through their operations has resulted in the emergence of sustainable campus initiatives since three decades [8]. Nowadays, Green campus initiatives are becoming an integral part of university systems, which can contribute in the process of environmental sustainability not only at the level of the campus itself but also at the level of the wider community [2]. Green campus has a crucial role in helping students to understand the complex relations between the environment, energy and the economy [9], it links the Curriculum to real life enabling the students to apply what they learn. [10]. In addition, it helps in changing generations behavior toward more sustainable attitudes in daily lives [11] besides their role in spreading the awareness of sustainability among communities as it represents a forum where academic staff, students and community members can meet, discuss and share experience to create innovative change. A green campus can be defined as a place where environmental friendly practices and education go hand in hand to promote sustainability in the campus [12]. It is one of the fields that can be identified most promising in achieving sustainability [13]. The bottom line is green campus can considered as a live model of sustainability [14], which behaves responsibly regarding the environment in the management of energy and human resources.

Its practices can help in improving overall environmental performance through the divergent operations such as reducing heat island effect, management of green buildings and sustainable landscaping, adopting waste management, decreasing resource use, reducing carbon footprint and many other operations [15].

b.Heat Island Reduction

The Heat Island Reduction as one of green campus operations represents important concern to be addressed to achieve sustainability especially, in hot dry climate region, such as KSA, and main cities, such as Jeddah city, [16].

This becomes more evident for KSA cities when considering the expected climate changes. According to [17], the temperature will rise by 2.0 – 2.75 C inland and by 1.5C in coastal areas by 2050. The result is increasing in the cooling loads, and requiring larger ventilating and air conditioning and greater electricity consumption, which generate greenhouse gases and a substantial cost in the operating budget [18]. In this sense, there is a vital need to reduce the urban heat stress.

Reducing heat island effect is considerably challengeable [19] because it's affected by many factors, [20] [21] [22]. Thus, in hot climate regions, shading, or spatial arrangement, plays a significant role in reducing the heat island effect in outdoor spaces [19]. In order to achieve heat island reduction and other sustainability practices the use of a measurable rating system is an essential method to assess the sustainability level. In the assessment process, the development performance is compared against a standard for a number of criteria [23]. The following part handels in details the LEED rating system, or Leadership in Energy and Environmental Design, which will be used in assessing the sustainability in the research case study.

c.The LEED Rating System

There are many examples of international rating systems all over the world [3]. They are all set on the same fundamental principles and play a great role in developing sustainable practices to mitigate the environmental risks and problems [24]. LEED rating system is the most widely used green building rating system in the world and increasingly recognized as exemplary tool among scholars and practitioners [3]. Since it was launched in U.S. at 1993 by the authority of US Green Building Council, it has been investigated by many scholars, to examine its efficiency. It has been approved that there is about 25-30% more energy efficient of the LEED certified buildings. A LEED rating system is a reliable indicator of a sustainable built environment; that demonstrate a building's ability to provide significant benefits [24].

This system covers five sectors of building industry: (1) Building Design and Construction, (2) Interior Design and Construction, (3) Building Operations and Maintenance, (4) Neighborhood Development, and (5) Homes Design and Construction (USGBC, 2018). This research depends on LEED operation and maintenance (O+M) version 4, as it is designed to measure the existing projects including schools and campuses; it consists of six categories: (1) Location and Transportation (LT), (2) Sustainable Sites (SS), (3) Water Efficiency (WE), (4) Energy and Atmosphere (EA), (5) Material and Resources (MR), and (6) Indoor Environmental Quality (EQ), in addition to Innovation and Regional Priority [4].

For the research purpose of evaluating the heat island reduction in the case study, the sustainable site SS will be considered. The sustainable sites category focuses on the site design for a building or a group of buildings and its impact on the surrounding environment. In the line of the study purpose, the study will focus on the Heat Island Reduction credit option 1 "Non-roof Surfaces" that addresses the outdoor spaces landscaping properties that take about 33.5 % of Effat Campus area "the research case study".

U.S. Green Building Council awards LEED credits for reducing the urban heat island by establishing a high reflectance paving surfaces with Solar Reflectance Index SRI of at least 28, an open grid system, vegetated materials with high albedos and shading, to minimize the effects on microclimates and human and wildlife habitats [4].

The U.S. Green Building Council (USGBC) uses the SRI to indicate to the impact on a surface temperature due to the amount of heat that a surface would gain when exposed to the sun. This amount of heat depends on the reflectance and emittance of the surface of solar radiation. The SRI varies from 100-0 for white and black surface, respectively [25]. The higher the SRI the lower absorption of solar radiation, the higher infrared emission, the cooler the material, and the better selection for mitigating the heat island effect. However, the solar reflectance is also affected by the finishing techniques and drying time [26].

3. Research method

This research follows quantitative methods in data collecting and analysis. It is designed to assess a campus non-roof spaces in reference to the LEED standards. A single case study is conducted on a small scale, in order to obtain an in-depth analysis of the campus landscape sitting and materials contribution to heat island reduction.

The selected case study is Effat University Campus, Jeddah, the first private university for women in Kingdom of Saudi Arabia. In the line of the research purposes, Effat University is committed to sustainability values and Saudi Vision 2030 that are stressed the importance of preserving the nature and conserving the coming generation rights of natural energy, and applying reasonable strategies to mitigate urban risks such as heat island effect phenomena.

In terms of architecture and urban features, Effat University is a gated campus, where the outdoor spaces are integrated with the closed spaces; the buildings are surrounding outdoor vegetated areas, see Fig.1. A central huge paved plaza is located in the university center surrounded by buildings with different uses; the mosque, restaurant, administration, and Engineering faculty. Some outdoor spaces are abandoned due to extreme exposure to sun, glare, or location away of students and faculty vital movement, see Fig.2.

Figure 1. Effat Campus outdoor space integrated with buildings. Recource: Author, May 2018

Figure 2. Effat paved open Plaza-extreme exposure to sunand glare.Recource: Author, May 2018

In order to investigate the sustainability level in Effat Campus, the researchers start by assessing the heat island effect as a first step, following by assessing multi aspects in the future research. The LEED Operation and maintenance V4 Reference Guide, the most updated version of LEED in 2018, is used as an international benchmark. The LEED credit that is assigned to measure the Heat Island for non-roof surfaces requires to compile quantitative data regarding three outdoor landscape elements: the plantation, shaded structures and paving.

The credit establishment requires using any combination of the following strategies for a minimum of 50% of the site paving; this includes three kinds of treatments:

1. Plantation includes:

a)Shading Plants: the existing plant material provides shade over paving areas (including playgrounds) on the site within 10 years of planting. (S)
b)Vegetated Planters: do not include artificial turf. (P)
2. Structure sitting includes:
c)The shade with structures that covered by energy generation systems, such as solar thermal collectors, photovoltaics, and wind turbines. (E)
d)The shade with architectural devices or structures that have a three-year aged solar reflectance (SR) value of at least 28. (A)
e)Provide shade with vegetated structures. (V)
3. Paving includes:
f)Paving materials with a three-year aged solar reflectance (SR) value of at least 28. (R)
g)An open-grid pavement system. (O)
In order to assess the campus paving and landscape, data is collected by different methods, the site survey, reviewing maps, and interviewing the maintenance key persons. The site survey is conducted during different times of day for shading calculations. Reviewing maps is used for recognizing the areas of vegetation and paving. Interviewing the maintenance key persons were performed to get information about paving materials and structures. Those tools in addition to the literature review.
Regarding the data analysis method, the data collected are benchmarked to the LEED standards to investigate the campus performance in reducing the heat island effect and sustainability, and to put the hands on the weakness that might hinder Effat University from having a green campus. According to LEED S.S credit Option 1 requirements that the combination of previous strategies are used in a minimum of 50% of the site paving. To approve that, two equations are used [4] as following:
1.Equation 1 the cumulative qualified surfaces areas.

$$Q = (S+P+E+A+V+R+O) \tag{1}$$

2.Equation 2 the percent of qualified surfaces areas of the site paving.

$$Q > T/2 \tag{2}$$

Q is the qualified surfaces areas.
T is the total area of site paving within the project site boundary.
(S,P,E,A,V,R,O) are the seven areas that are achieved by selected strategies.

4. Data analysis

a.Campus Non-roof Surfaces
The total area of Effat University campus including the roof and non-roof surfaces is 82703.81m^2. The Non-roof surfaces is 27732.24 m^2 constitutes 33.5% of the total campus area, and is represented by group of gardens, movement pathways and main plaza. The total area of the green elements is 7527.17m^2, which represents 27% of the total area of the non-roof surfaces. The total area of the paved surfaces is 20205.07m2, which represents 73% as shown in table 1, and Fig.3.

Table 1. The classification of the paving non-roof surfaces and its location in the map.

Non roof surfaces no.	Green/m2	Pavement /m2	Pavement Material	No. of Shading Plants
A1	1278.73	779.46	Stamped Concrete tile	6 palms
A2	587.48	879.91	Stamped Concrete tile	6 palms
A3	0	1715.62	Concrete tile with pebble	0
A4	0	2834.82	Concrete tile with pebble	0
A5	1107.8	867.02	Stamped Concrete tile	4 palms
A6	1104.3	1180.57	Stamped Concrete tile	16 palms +1 tree
A7	165.12	3479.59	Concrete tile with pattern	6 palms
A8	481.07	547.95	Stamped Concrete tile + Concrete tile with pebble +Ceramic	12 palms
A9	1141.78	1189.52	Stamped Concrete tile + Asphalt	7 palms +1 tree
A10	832.24	606.11	Stamped Concrete tile	0
A11	638.37	2114.99	Stamped concrete tile + Interlock Concrete tile + Asphalt	0
A12	0	1671.12	Concrete tile with pebble	0
A13	190.28	2338.39	Asphalt	0
Total	7527.17	20205.07		57 palms + 2 trees

Figure 3. Effat Campus google map and the distribution of non-roof surfaces. Recource: Google Earth, 2018

b.Heat Island Reduction Strategies

1.Plantation includes:

a)Shading Plants

Referring to LEED (O&M) V4, 20018, the effective shaded area is identified by plants that provide shade over paving areas within 10 years of planting. The plants in Effat Campus have been surveyed and listed.

Table 2 shows that most planted trees within campus spaces are palms which constitute 96.5% from the total number of shading plants in addition to two shading evergreen trees. In the line of credit requirement for not counting the same area more than once, all shading areas that overlapping the vegetated planters or SRI qualified paving are deducted, see Fig.4. The qualified shaded area of the plants after deducing the non-qualified areas are 594 m2 constitutes only 33% of the total shading areas resulting from plants. The low percent of qualified shading areas due to allocating the palms and trees in the middle of the green areas which causes them to shade only the green grass rather than paved pathways.

Table 2. The qualified shading areas

c	No	Shaded are at 10 a.m.	Shaded are at 12 a. m.	Shaded are at 3 p.m.	Arithmetic mean of shaded area	Qualified shaded area
Palms	57	1875	1140	1875	1630	486
Trees	2	178	108	178	154.5	108
Total						594 m2

Figure 4. Effat Campus google map and the distribution of shading palms over vegetation planters areas. Recource: Google Earth, 2018

Table 1 and Fig.3 also show the unbalanced distribution of trees and palms within the different spaces, as they are existing only in 50% of outdoor spaces. Furthermore, the palms do not give the required amount of shading because of its height and leaves shape and distribution.

b)Vegetated Planters

The site survey shows that the natural vegetated planters occupy 7527.17 m2 which constitutes 27 % of the total non-roof surfaces, distributed within 50% of Campus outdoor spaces. The vegetated rectangular planters are surrounded by the main pathways of the faculties' buildings and the dorms area. The central plaza where the most activities are supposed to happen there and connects the different zones of faculties, admin, restaurant, main hall, and dorms, lacks of vegetation.

2.Structure

According to credit requirements, the heat island reduction can be achieved through establishing structures that are covered by energy generation systems, have a three-year aged solar reflectance (SR) value of at least 28, or vegetated structures.

The campus contains only one structure for outdoor cafeteria “Pergola” that shades an area of 55 m2 constitutes 0.2% of the non-roof surfaces, see Fig. 5. The structure is made of wooden pillars and cross beams, with SRI 38 and not covered by neither any kind of energy generation systems nor vegetation, which means this structure is qualified for the credit requirement.

Figure 5. The outdoor cafeteria with wooden structure “Pergola” Recource: Author, May 2018

3.Paving

The aim of the Sustainable Sites Credit: “Heat Island Reduction, Non-Roof” is to mitigate the heat island effect, which would result in saving energy through reducing the use of air conditioning. This can be met if not less than half of the non-roof impervious surfaces in the site (sidewalks, courtyards and streets) is paved with a cool material that have three-year aged solar reflectance (SR) not less than 28.

With regard to the paving, there are six different materials used all around the campus. The variation of the material is based on the use of the streets and sidewalks, which is classified into two types of use: heavy duty and light duty pavement. There are three types of pavement used for the heavy-duty use: (1) concrete tile with pattern, (2) concrete tile with pebble finish, and (3) asphalt. Those three types are used in the paths/streets where vehicles are allowed, to provide durable surface. The other three types of pavements that are used for light duty in the sidewalks for pedestrians are: (4) stamped concrete tile, (5) interlock concrete tiles, and (6) ceramic tiles. Those six paving materials varies in their solar reflectance, as shown in table 3. The stamped concrete tile is used in the sidewalks connecting colleges together. The stamped concrete tiles are sprayed on a yearly basis to get shiny as the tiles are usually covered with dust all over the year, which maintain its ability to solar reflectance. The interlock concrete tile is used in the courtyards, and the ceramic tiles are used around the dorm, the restaurant, and the nursery buildings. All sidewalks surrounding the buildings were shaded. However, with the expansion of the buildings in the university, those 2 meters sidewalk width became part of the indoor space. Consequently, most of the sidewalks around buildings are not shaded, which resulted in the existence of glare in the sidewalks where ceramic is used). Table 3 shows the solar reflectance index for the paving materials used in the campus.

Under Heat Island Reduction Credit, LEED v4 for Building Operations and Maintenance, certification establishes the SRI threshold values for paving materials with a three year aged not less than 28. Concrete is an ideal material that meets this requirement. Regardless to the components of the concrete mix, concrete is used to reduce the heat island, which contributes to qualifying for LEED Green Building Rating System. According to the ASTM C 1549, material with light colors has high solar reflectance oppositely from dark colored material that has low solar reflectance. And based on the results of testing 45 concrete types, all types of concrete have at least a solar reflectance of 0.3, and the solar reflectance of the ordinary concrete varies between 0.36 to 0.47 [27].

On the other hand, and with the increasing awareness of the environmental needs, there are an elevating demand on the use of opaque ceramic materials including tiles, coating and plates for exterior surfaces not only because of the durability of opaque ceramic materials, but also due to the fact that ceramic materials maintain their color brightness. This means that opaque ceramic materials would maintain their high SRI values over time, which contributes to the score in the heat island requisite [28].

There is another option under the LEED Credit including using at least 50% unbound open-grid pavement system, which is not available on Effat University campus.

Table 3. Solar Reflectance Index of paving materials used in campus

Material surface	Image	Solar Reflectance*	Solar reflectance according to the color	SRI
Concrete tile with pattern	Figure 6	0.30	0.46	51
Concrete tile pebble finish	Figure 7	0.30	0.5	58
Asphalt	Figure 8	0.1		6
Stamped concrete	Figure 9	0.30	0.46	51
Interlock concrete tiles	Figure 10	0.30	0.46	51
Ceramic tiles (light colors)	Figure 11	0.5 to 0.6		59 to 72

Figure 6.

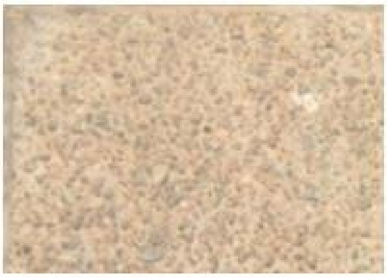

Figure 7.

Figure 8.

Figure 9.

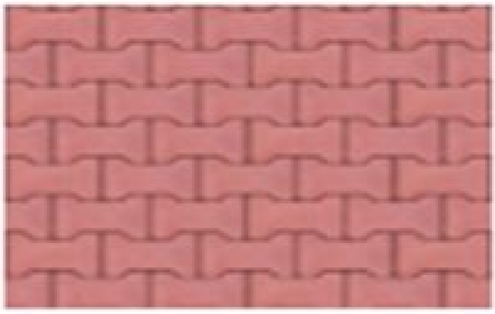

Figure 10.

Figure 11.

5. Results

1.The total area of Effat University campus including the roof and non-roof surfaces is 82703.81m2.
2.The total area of non-roof surfaces within the project site boundary (T) = 27732.24 m2
3.The qualifying surfaces area as shown in table 4, with consideration that each surface should be counted only once.
4.Based on LEED S.S Credit equations:
Q= (S+P+E+A+V+R+O)
Q = (0 + 7527.17 + 0+0+0+ 17169.68+0) m2
Q = 24696.85m2
5.The total qualifying area (Q) must be 50% or more of the total non-roof surfaces (T)
Q=24696.85 > T/2 =27732.24/2= 13866.12 m2

According to previous calculations, the Total Qualified Surface Area =89 % of the Non-roof areas. This means the landscape sitting and paving materials in Effat Campus are qualified to LEED standards and more than required by 39%.

Table 4. The qualified non-roof surfacesareas for leed rating system

Description		Symbol	Area /m2	Qualified ? Y or N
Plantation	Shaded areas by plants	(S)	594	No, for not duplicating the area
	Areas of vegetated planters	(P)	7527.17	Yes
Structure	The area shaded by structures covered by energy generation systems	(E)	0	Not Existing
	The areas shaded by the wooden structures with minimum (SRI) 38	(A)	55	No, for not duplicating the area that is counted once.
	The area shaded with vegetated structures.	(V)	0	Not Existing
Paving	Areas of Paving materials with minimum (SRI) 28	(R)	17169.68	Yes, all paving areas are qualified, excluding only Asphalt.
	An open-grid pavement system.	(O)	0	Not Existing
Total Qualifying Surface Area		(Q)	25393.85 m2	

6. Conclusion and recommendations

This research aims to rate the sustainability at Effat University campus with reference to the international rating system LEED v4 for (Operation and Maintenance). In order to investigate the sustainability, the researchers start by assessing the heat island effect as a first step that will be followed by assessing multi aspects in the future research. The site landscape sitting and material of Effat Campus are assessed for LEED credit equivalency, the Heat Island Reduction credit requires a combination of some strategies to be applied for a minimum of 50% of the site paving areas.

This study approves the ability of university campus to qualify the LEED Credit requirements. The study finds out that the site characteristics contribute to the heat island reduction with the combination of the vegetated planters and the paving material with minimum SRI 28. The two strategies are applied on 89% of the non-roof surfaces area. The area with qualifying paving material constitutes 60 % integrated by the vegetated planters, which is covering 27% of the area. The shading plants is covering only 2% of non-roof surfaces land which almost green, and is totally deducted for not duplicating the area.

Despite the study ends up with promising results, the site survey and interviewing maintenance staff infer to important consideration. The glare that is caused by the high SRI values should be treated by increase the number of shading native trees to cover pedestrian pathways, seating areas, and plaza, this contributes to human thermal comfort in addition to mitigating the glare and heat island reduction. Furthermore, the fair distribution of vegetated planters is recommended for cooling the surrounded areas. The results of this research encourage adopting the holistic approach for Campus design, which potentially would help Effat University to improve the campus environmental and energy performance through recommending a set of evidence-driven actions to enhance the efficiency of the university landscape sitting and material. In addition, Effat University can take a step towards developing a green campus and being LEED Certified.

7. References

[1]USGBC. (2018). US Green Building Council. https://new.usgbc.org/.
[2]Bloom, D. et al. (2006). *Higher education and economic development in Africa.* No. 102. Washington, DC: World Bank.
[3]Shwe, T., et al. (2017). Sustainability assessment of university campus through various rating systems. ISER 48th International Conference. Nagoya, Japan.
[4]LEED(O&M)-V4. (2018). *LEED V4 for building operations and maintenance*. US Green Building Council.
[5]NASA. (2016). Retrieved 2018, http://www.nasa.gov/
[6]Filho, W. (2000). Dealing with misconceptions on the concept of sustainability. *International Journal of Sustainability in Higher Education, 1* (1), 9-19.
[7]Mousaa, R., Farag, A. (2017). The Applicability of LEED of new construction (LEED-NC) in the Middle East. *Procedia Environmental Sciences, 37*, 572 – 583 .
[8]Jain, S., Pant, P. (2010). Environmental management systems for educational institutions. "*International Journal of Sustainability in Higher Education, 11*(3), 236 – 249.
[9]Wright, T. (2010). University presidents' conceptualizations of sustainability in higher education. *Int. Journal Sustainable Higher Education,11*, 61–73.
[10] Green Campus Program. (2017). Smarter sustainable campus communities: *A guide for campuses embarking on the green-campus programme*. Available online: http://www.greencampusireland.org/wp-content/uploads/2016/12/Green-Campus-Guidebook-2016-2017.pdf
[11] Tukker, A., et al., (2008). Fostering change to sustainable consumption and production: An evidence based view. *J. Clean. Prod., 16*, 1218–1225.
[12] Hordijk, I. (2014). Position paper on sustainable universities. *J. Clean. Prod., 14*, 810–819.
[13] Richardson, G., Lynes, J. (2007). Institutional motivations and barriers to the construction of green buildings on campus: A case study of the University of Waterloo, Ontario. "*International Journal of Sustainability in Higher Education Volume", 8*(3), 339-354.
[14] Jackson, T. (2011). Prosperity without growth: Economics for a finite planet, 2nd ed.; Routledge: New York, NY, USA.
[15] Calder, W., Dautremont-Smith, J. (2009). Higher education: more and more laboratories for inventing a sustainable future. In J. Dernbach, (Ed.) "Agenda for a sustainable america". Washington, DC: Environmental Law Institute, 93-107.
[16] Nouri, A. (2015). A framework of thermal sensitive urban design benchmarks: Potentiating the longevity of

Auckland's public realm. Buildings, 5(1), 252-281.
[17] Ragab, R., Prudhomme, C., (2000). Climate change and water resources management in the Southern Mediterranean and Middle East countries. The Second World water forum, 17-22, March 2000.
[18] LEED(O&M). (2009). LEED V4 for building operations and maintenance. US Green Building Council.
[19] Vallati, A., et al. (2016). Influence of street Canyon's microclimate on the energy demand for space cooling and heating of buildings. *Energy Procedia, 101*, 941-947.
[20] Santamouris, M., Asimakopoulos, D. (1996). Passive cooling of buildings. Earthscan.
[21] Galli, G., et al. (2013). Passive cooling design options to improve thermal comfort in an Urban District of Rome, under hot summer conditions. *Int. J. Eng. Technol, 5*(5), 4495-4500.
[22] Zinzi, M., et al. (2014). Preliminary studies of a cool roofs' energy-rating system in Italy. *Advances in Building Energy Research, 8*(1), 84-96.
[23] Poveda, C., Lipsett, M. (2011). A Review of Sustainability Assessment and Sustainability/Environmental Rating Systems and Credit Weighting Tools. *Journal of Sustainable Development, 4*(6).
[24] Shin, M., et al. (2017). LEED, Its efficacy and fallacy in a regional context—An urban heat island case in California. Sustainability.
[25] Standard, A. S. T. M. (2001). Standard practice for calculating solar reflectance index of horizontal and low sloped opaque surfaces. ASTM International, West Conshohocken, PA.
[26] Standard, A. S. T. M. (2006). Standard test method for measuring solar reflectance of horizontal and low-sloped surfaces in the field. ASTM E 1918-16. ASTM International. West Conshohocken.
[27] Marceau, M., & Van Geem, M. G. (2007). Solar reflectance of concretes for LEED sustainable sites credit: heat island effect. Portland Cement Association.
[28] Jacinto, L. I., et al. (2017). Determination of solar reflectance index of ceramic coatings for use in outside surfaces. In *Materials Science Forum* (Vol. 881, pp. 251-256). Trans Tech Publications.