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Energy Efficiency Initiatives in a Campus Building

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Higher Learning Institution (HLI) is a place for academicians, students and its administration staff in a campus. HLI is among the favoured targeted locations to embrace for sustainability and energy conservation solutions due to the campus operations and activities that have significant energy consumption depending on the size of the campus including its buildings and infrastructures. There are several alternatives for which HLI is able to offer huge opportunities in retrofitting initiatives to concern on energy efficiency. This paper presents a study leads to the identification of possible retrofit initiatives and the criteria affecting the retrofitting of M50 building in Faculty of Civil Engineering towards zero energy. A questionnaire survey was distributed to occupants of M50 building in order to identify the preferred energy efficiency technologies to be implemented. The result was analysed with Relative Importance Index (RII) and it shows that solar photovoltaic, green roof and variable air volume were among the most preferable technologies. The relevant criteria for each energy efficiency initiatives being prioritised and ranked based on Factor Analysis (FA). The purpose of using the selected approach and ranking is to investigate the significance of each criteria. The performing result assists as a step for energy efficiency initiatives in a campus building, thus minimizing the energy impact to environment from its operations and activities. The study outcome is also indirectly fulfilling an example case for sustainable teaching, learning and research process.

1. Introduction

The university campus is the commercial building type for which the issue of energy efficiency has been the main topic discussed due to the increase of building energy usage annually (Jomoah et al., 2013). The energy efficiency issue should become the main focus on campus because it has high energy consumers, high energy cost, contribute to climate changes and easily affected by the lack of resource of non-renewable energy (Lo, 2013). Campus universities are considered as small towns due to their large number of users, sizes and are involved with complex activities and operations. The wastage of energy tends to occur by various space types such as lecture auditorium, offices, computer rooms and laboratories. The increasing number of population and expansion of the existing campus also contribute to the increase of ecosystem degradation. It has become a major concern, especially for the policy makers and planners in university with regards to the sustainability issue. There are an increasing number of universities that have voluntarily signed the declaration related to environmental protection in order to show their sustainability commitments (Alshuwaikat and Abubakar, 2008). The building's energy usage contributes for about 33 % of the final total energy consumption and become the main source for worldwide CO_2 emissions. One of the effective improvements in energy and ensuring for sustainability is through the increase of energy efficiency usage in existing buildings. This could be conducted through the replacement of existing building technology with more energy efficient, which consequently enables for a better reduction in energy expenditure (Tan et al., 2016). The energy efficiency principle is basically to ensure that the energy operations are reduced such as cooling, heating, lighting and other appliances without giving an impact to occupants comfort and health. Improvement of energy efficiency entails not only the environmental benefits, but also economic benefits especially in operational cost savings (Ruparathna et al., 2016).

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This includes lowering the levels of heat by turning down the levels of thermostat, set standards for appliances, set limits to the appliances consumption and capacity. It is basically concerned with the consumer behavior, regulation and changes with the lifestyle. It involves with technical processes for which old equipment can be replaced with an energy efficient system (Herring, 2006).
Table 1 show the critical summary research of energy efficiency initiatives which has been implemented on campuses. The critical gap is to identify current green technology that is common implemented and effective to apply in campuses

Table 1: Summary of Energy Efficiency Initiatives taken in campuses

Retrofit Initiatives									
a) Indiana State University (Appleby,2013)							√		
b) University of Malaya (Mahlia, 2011)	√								
c) U.S colleges (National Grid, 2003)	√					√	√		
d) College of Desert (College of Desert, 2011)	√	√							
e) Boston University (Gevelbar , 2007)	√					√		√	
f) Rome Italy University Building (Citterio et al., 2003).	√				√		√	√	
h) University of Mexico (Escobedo et al., 2014)	√		√						√
i) Melbourne University (Di Stefano, 2000)	√								
j) University of Seoul Korea (Chung, 2014)	√	√		√	√		√		
m) Kingsville Texas University (Ayala et al., 2011)	√	√							
n) University of Malaya (Saidur et al., 2011)		√							

Legend:

Lighting	Solar	Window	Refrigeration	Daylight
Ventilation	Roof/atrium	Occupancy sensor	Wall	

2. Energy Efficiency in Campus

The overall energy performance in institutional buildings is mostly influenced by its existing systems and components, especially mechanical system, lighting system and building envelope. For mechanical components which mainly consist of heating, ventilation and air-conditioning (HVAC) system known as the most building energy consuming equipment. Appropriate selections and operations of HVAC systems are able to achieve 25 % savings and also offer for indoor comfort. There are two possible methods for HVAC energy reduction namely as passive and active. Passive method includes window replacement, natural ventilation and air tightness improvement. For active measure, it includes improvement and upgrade of the boilers, installation of variable frequency drives and thermostat with programmable system. For the lighting system, The methods for improvement in lighting system efficiency includes the lamp installation with high luminous efficacy, conversion to higher energy performance lighting, task lighting design, integration of daylight and lighting systems and installation of occupancy sensor at workspace. For building envelope, it concerns the improvements of insulation, painting, using phase change material to improve the thermal performance such as heat gain and heat loss. In addition, building envelope is also involved with the installation of ventilated double skin façade, glazing and shading system (Ruparathna et al., 2016).

3. Methods

This paper employed two phases of data collection. The first phase is to conduct questionnaire surveys to determine the user's preferable energy efficient technology that needs to be installed in M50 building to reduce the energy usage. The establishment of preferable energy efficient technology is based on the building energy condition which has the potential to achieve for zero energy balance. The questionnaire survey was distributed directly to the respondents which basically comprises of occupants in the building to allocate a rank to each of listed retrofitting technologies. The data obtained were analyzed through the Relative Importance Index (RII). The formula of RII as presented in Eq(1) (Sambasivan, 2007). The result obtained was ranked based on the classification of RII as tabulated in Table 2.

$$RII = \frac{\Sigma\, \mathrm{w}}{A\ \times N} \qquad (1)$$

where,
w = Weighting given to each retrofit technology range from 1 to 14, (1= lowest mark and 14= highest mark.
A = Highest weight (i.e. 14 in this case) N = Total number of respondents

Table 2: Classification of Relative Importance Index

Scale	Level of Preferences	Relative Importance Index (RII)
1	Not preferred at all	0.0 < RII ≤ 0.2
2	Slightly preferred	0.2 < RII ≤ 0.4
3	Moderately preferred	0.4 < RII ≤ 0.6
4	Preferred	0.6 < RII ≤ 0.8
5	Most preferred	0.8 < RII ≤ 1.0

The second phase of data collection concerns about the importance criteria affecting the decision of energy efficient technology based on the identification of top two preferred retrofitting technologies which are solar PVs and green roof. The purpose is to further justify the findings obtained through the level of preferences in energy efficient technology. Each of the energy efficient technologies has its own criteria which questioned to the construction industry stakeholders comprise of architects, mechanical engineer and green building experts. It requires respondents in giving a rate of importance of each criteria according to the scale given. The relevant criteria was prioritized and ranked by using the Factor Analysis method. The development of the criteria is based on the secondary data which obtained from academic publication such as from published journals, books, thesis and online articles.

Factor Analysis is a data reduction method from a large set of variables and allows interpreting the criteria based on its importance (Pallant, 2014). The statistical analysis was performed by using Statistical Package for Social Sciences (SPSS). There are several protocols adopted in conducting Factor Analysis. Firstly is to determine the sampling adequacy through the Kaiser-Meyer-Olkin (KMO) and Barlett's Test of Sphericity.

The minimum value for KMO that should be achieved is 0.50, while the Barlett's Test of Sphericity is $P < 0.5$ (William et al., 2012). Secondly is concern on the factor extraction. The factor extraction use is based on the default setting which is Principal Component Analysis. Thirdly is the rotational method and the Varimax with orthogonal rotation was selected. Lastly is to determine the factor loading for which the prime goal of this study is to retain the factor 0.50 and above.

4. Findings

4.1 Identification of Preferable Energy Efficiency Technology

The energy result of M50 building has proven that it has the potential to achieve for energy efficiency because it consume for optimum energy utilization which is about 40 % at 6.23 kWh/m^2. Therefore, the energy efficient technology that needs to be installed in the building is part of the initiative to reduce the building electricity bill and its energy usage. This section is to analyse the building user perspective on technology, which is suited to be implemented in M50 building. The total number of M50 building occupants is 36 people. Thus, Sekaran (2000) has established the determination of sample size distribution from a given population and stated that the number of questionnaire that should be distributed is 32 people. From the 32 questionnaires distributed, only 20 have returned and completed the survey. The respondent's opinion is listed in Table 3.

Table 2 shows that PVs represents the "most preferred" technology, ranked by respondents with the RII 0.90 in a range of (0.8 < RII ≤ 1.0). PVs are currently being widely accepted as part of important technology for power generation because it offers reliability, silent operation, no pollution to the atmosphere and has low operation and maintenance costs (Syed Fadzil and Byrd, 2012).

A green roof is at the second highest ranking representatives as "preferred" with the RII 0.77. Apart from green roof, respondents also have ranked VAV, replace window with low emissivity glass, blind control and presence sensor with lux control as "preferred" technology with the RII in a range of (0.6 < RII ≤ 0.8). All of these technologies offer users the comfortability with their surrounding temperature and at the same time reducing the air-conditioning and lighting usage.

The classification of RII revealed that computerized automation system and reflective roofing ranked as "moderately preferred" with the RII 0.59 and 0.55 respectively. The least preferable technology is achieved by an electronic ballast lighting device, demand limiting controller, radiant floor system, push button with thermostat and control cabling conduit. It was ranked as "slightly preferred" with the RII in a range of (0.2 < RII ≤ 0.4). The reason might be due to the users' non awareness to the existence of the technology or a lack of knowledge with the technology details in comparison to other technologies listed.

Table 3: Respondents Preferable Energy Efficiency Technology

Retrofitting Technology	Score	Relative Importance Index (RII)	Ranks
Solar Photovoltaic (PVs)	252	0.90	1
Green Roof	215	0.77	2
Variable Air Volume (VAV)	213	0.76	3
Replace Window with Low Emissivity Glass	195	0.70	4
Blind Control	178	0.64	5
Presence Sensor with Lux Control	173	0.62	6
Computerized Automation System	166	0.59	7
Reflective Roofing	153	0.55	8
Peak Load Warning Technology	109	0.39	9
Electronic Ballast Lighting Device	80	0.29	10
Demand Limiting Controller	75	0.27	11
Radiant Floor System	74	0.26	12
Push Button with Thermostat	67	0.24	13
Control Cabling in UPVC Conduit	65	0.23	14

4.2 The Criteria Ranking

In this section, questionnaire surveys were conducted to elicit the importance of criteria which developed for two of energy efficient technologies preferred by respondents which are solar PVs and Green Roof. A total of 330 questionnaires distributed, 169 were successfully returned. The Factor Analysis allows revealing the criteria from very important to less important.

4.2.1 Criteria Ranking for Solar Photovoltaic

For solar PV, the Principal Component Analysis with Varimax (orthogonal) rotation of 39 Likert scale questions was conducted. The KMO achieved is 0.681 with the Barlett's Test of Sphericity Sig = 0.00 which shows the sampling adequacy and its statistical significance. Based on the rotation, from 39 variables loaded, 3 of the variables have been eliminated due to factor loading less than 0.50. The summary of strong factor loading from the most to least importance that is categorized in accordance with its main criteria and sub-criteria is tabulated in Table 4.

Table 4: Factor Analysis Result for Solar Photovoltaic

Criteria	Sub-criteria	Factor loading	Sub-criteria	Factor loading
Management Criteria	Certification and rebates	0.781	Permits and covenants	0.648
	Funds and investment	0.753	Insurance coverage	0.592
	Land and space	0.729	Feed in tariff scheme	0.564
	Regulatory compliance	0.677		
Economic Criteria	Maintenance cost	0.818	Significant potential cost and savings	0.718
	Capital investment	0.798	Return on investment	0.535
	Payback period	0.785	Cost to purchase material	0.535
	Construction cost	0.770		
Environmental Criteria	Visual impact	0.833	Hazardous waste	0.729
	Cultural landscape	0.768	Greenhouse gas emission	0.565
	Native vegetation and wildlife impact	0.755	Land degradation	0.503
	Safety implication to fire hazard	0.745		
PV Features Criteria	Life expectancy of PV module	0.757	Array frames type	0.687
	Manufacturability	0.746	Warranty	0.678
	Mounting system	0.723	Durability and longevity	0.674
	PV system size	0.722	Grid-connected or stand alone	0.621
	Type of panel module	0.698		
Design Criteria	Solar irradiation	0.688	Reliability	0.586
	Site solar resource	0.673	Time use and session	0.522
	Orientation	0.612	Withstand with structural wind load	0.522

4.2.2 Criteria Ranking for Green Roof

For green roof, there are 37 variables loaded subjected to Principal Component Analysis. The Kaiser-Meyer-Olkin result is 0.913 which exceeds the recommended value of 0.50. The Bartlett's Test of Sphericity also shows the statistical significance with Sig= 0.000.

In order to determine the factor to be retained and to interpret the components into a simple structure, the Varimax rotation was performed as a method of rotation. Based on the rotation, from 37 variables loaded subjected to 6 criteria, there are 5 variables were eliminated as the factor loading less than 0.50. The summary result for strong factor loading of criteria developed in green roof is tabulated in Table 5.

Table 5: Factor Analysis Result for Green Roof

Criteria	Sub-criteria	Factor loading	Sub-criteria	Factor loading
Economic Assessment	Construction costs	0.761	Estimation of energy and cost reduction	0.675
	Return on investment	0.729	Payback Period	0.578
	Maintenance costs	0.705		
Plant Characteristic	Appropriate plant selection of geographic region	0.686	The plant full range growth	0.622
Occupants Comfort Criteria	Achieve indoor air quality	0.591		
	Reduce the heat transfer/thermal satisfaction	0.544		
Site Assessment Criteria	Available roof space for plants to be grown)	0.775	Determine the longevity of the structure	0.634
	Estimated wind forces	0.774	Determine the sun, wind varies on the site	0.613
	Determine the existing roof structure	0.733	Orientation of the building	0.589
	Assess any opportunities or risks	0.674	Quality of existing materials	0.566
	Expected rainfall volume and distribution	0.670	Access to site for cranes and other machinery	0.534
	Size of usable roof area	0.667	Access for maintenance	0.533
	Condition of roof slope and pitch	0.652	Expected maximum and minimum temperatures	0.529
Design Criteria	Appropriate waterproofing	0.711	Consider the structural capacity	0.649
	Appropriate drainage	0.699	Comply with the regulations and local laws	0.562
	Ensure access for passers-by is not impeded	0.691	Determine the type of green roof required	0.515
	Appropriate irrigation system	0.658	Water collection and storage opportunities	0.509
Environmental Criteria	Greenhouse gas emission	0.605		

5. Conclusion

The rise in global energy demands has made the HLI to adopt the energy efficiency measures which are able to significantly contribute to campus energy conservation. HLI also known as the targeted location and centers of transformation in order to address the global energy issue as well as to employ progressive actions for the benefits of current and future generations. The efforts in energy efficiency in HLI have started to increase as there are many initiatives taken to promote towards sustainability environment on campus. Based on the findings, it shows that solar PVs are the most preferred energy efficiency technologies selected by respondents to adopt in M50 building. Green roof were also selected as the preferable technology and to have significant contribution to the improvement of the current energy condition. The criteria developed for each of the energy efficient technologies also have shown its significance based on the factor loading value. The identification of ranking criteria assists in the decision making process which developed as a guide to priorities the criteria that should be taken into account in energy efficiency approaches selected.

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References

Alshuwaikhat H.M., Abubakar I., 2008, An Integrated Approach to Achieving Campus Sustainability: Assessment of the Current Campus Environmental Management Practices, Journal of Cleaner Production, 16, 1777-1785.

Appleby P., 2013, Sustainable Retrofit and Facilities Management. 1st edition. Oxford, United Kingdom. Routledge.

Ayala E., Kocurek J., Wright J., Sijansky L., Chang J., Jr Contreras R.C, 2011, Energy Efficient Method Identification for an Education Building, Architectural Engineering Conference 2011, California United States. 235–243.

Chung M.H., Rhee E.K., 2014, Potential Opportunities for Energy Conservation in Existing Buildings on University Campus: A field survey in Korea, Energy and Buildings, 78, 176–182.

Citterio M., Romeo C., 2003, Retrofit of a University Building in Rome Italy. Energy Conservation in Buildings and Community System Case Study Overview. Rome Italy: International Energy Agency.

College of Desert., 2011, College of the Desert Campus-wide Lighting Retrofit. Southern California: Edison International.

Di Stefano J., 2000, Energy Efficiency and The Environment: The Potential for Energy Efficient Lighting to Save Energy and Reduce Carbon Dioxide Emissions at Melbourne University, Energy, 25(9), 823–839.

Escobedo A., Briceño S., Juárez H., Castillo D., Imaz M.,Sheinbaum C., 2014, Energy Consumption and GHG Emission Scenarios of A University Campus in Mexico, Energy for Sustainable Development, 18(1), 49–57.

Gevelber M., Choate R., Sheehan K., Vitolo T., Ercolino E., Ricci L., Mchale M., 2007, Opportunities for Achieving Significant Energy Reduction in Existing University Buildings: Developing efficient HVAC operations. Boston United States: Boston University.

Herring H., 2006, Energy Efficiency - A Critical view. Energy and Buildings, 31, 10–20.

Jomoah I.M., Al-Abdulaziz A.U., Sreerama K., 2013, Energy Management in the Building of a University Campus in Saudi Arabia-A Case Study, International Conference on Power Engineering, Energy and Electrical Drives, Istanbul, Turkey. 659-663.

Lo K., 2013, Energy Conservation in China's Higher Education Institutions, Energy Policy, 56, 703–710.

Mahlia T.M.I., Razak H.A., Nursahida M.A., 2011, Life cycle Cost Analysis and Payback Period of Lighting Retrofit at the University of Malaya, Renewable and Sustainable Energy Reviews, 15(2), 1125–113.

National Grid., 2003, Managing Energy Costs in Colleges and Universities. Street Boulder Colorodo, E Source Companies LLC.

Pallant J., 2014, Spss Survival Manual. A step by Step Guide to Data Analysis Using SPSS for Windows (Version 12),1st edition, Allen and Unwin, New South Wales, USA.

Ruparathna R., Hewage K., Sadiq R., 2016, Improving the Energy Efficiency of the Existing Building

Stock: A Critical Review of Commercial and Institutional Buildings, Renewable and Sustainable Energy Reviews, 53, 1032–1045.

Saidur R., Hasanuzzaman M., Mahlia T.M.I., Rahim N.A., Mohammed H.A., 2011, Chillers Energy Consumption, Energy Savings and Emission Analysis in an Institutional Buildings, Energy, 36(8), 5233–5238.

Sambasivan M.,Soon Y.W., 2007, Causes and Effects of Delay in Malaysian Construction Industry, Journal of Project Management, 25, 517- 526.

Sekaran, U. (2000). Research Method for Business: A Skill Building Approach, 3rd Edition, John Wiley & Sons, United States of America.

Syed Fadzil S.F., Byrd H., 2012, Energy and Building Control Systems in the Tropics, 1st edition, Universiti Sains Malaysia Pulau Pinang, Malaysia.

Tan B., Yavuz Y., Otay E.N., Çamlıbel E., 2016, Optimal Selection of Energy Efficiency Measures for Energy Sustainability of Existing Buildings, Computers & Operations Research, 66, 258–271.

Williams B., Brown T., Onsman., 2012, Exploratory Factor Analysis: A five-step guide for novices, Australasian Journal of Paramedicine, 8(3), 1-13.