A benchmarking approach to the progress of green materials and systems' use in the UAE construction industry

Aly Elgayar
University of Ottawa, Ottawa, Canada
Salwa Mamoun Beheiry
College of Engineering, American University of Sharjah, Sharjah, United Arab Emirates
Alaa Jabbar
Department of Procurement, Bawabat Al Rumaila General Contracts, Sharjah, United Arab Emirates, and
Hamad Al Ansari
Masdar Institute of Science and Technology, Dubai, United Arab Emirates

Abstract

Purpose – Over the past decade, the United Arab Emirates (UAE) introduced several green regulatory guidelines, federal decrees, and a considerable number of environmentally friendly initiatives. Hence, the purpose of this paper is to investigate the top green materials and systems used currently in the UAE construction industry as per the new laws dictate as well as see if professionals are switching over to incorporate more green materials, systems, and/or designs.

Design/methodology/approach – The work involved reviewing internationally popular green materials and systems for construction, developing a questionnaire based on the literature review, surveying professionals in the seven UAE emirates, and ranking the findings based on the relative importance index.

Findings – Findings found the top used green materials and system in the UAE's construction industry. As well as identified that there is a communication gap between the design and implementation phases that is possibly hindering the use of more green materials and systems.

Originality/value – This study sets a baseline to measure the UAE's progress over the coming years in terms of integrating more green construction materials, systems, methodologies, and trends.

Keywords United Arab Emirates, Sustainability, Construction industry, UAE, Energy and resource efficiency, Green materials and systems

Paper type Research paper

1. Literature review

1.1 Introduction

Preserving Earth's resources has become a pressing matter over recent years. The main concern is preserving the environment for the future generations. The notion of sustainable development (SD) is one of the key answers to the environmental issues faced today. Moreover, global technological advancements and the sophistication of construction techniques helped facilitate the shift to constructing green buildings (Wu and Low, 2010; Lu *et al.*, 2013). Robichaud and Anantatmula (2011) define the term green building as "The process of building that incorporates environmental considerations into every phase of the homebuilding process. That means that

World Journal of Science, Technology and Sustainable Development
Vol. 13 No. 4, 2016
pp. 315-327

2042-5945
DOI 10.1108/WJSTSD-01-2016-0008

during the design, construction, and operation of a home, energy and water efficiency, lot development, resource-efficient building design and materials, indoor environmental quality, homeowner maintenance, and the home's overall impact on the environment are all taken into account". The world, however, relies on the consumption of natural resources, such as oil and natural gas, to continue carrying out its daily functions. Natural resources are finite and will eventually run out. The World Watch Institute conducted a study in the USA and found that a building's construction consumes approximately 17 per cent of available fresh water flow, 40 per cent of energy produced, and 25 per cent of the available harvested timber (Thovichit, 2007). Additionally, the techniques used today have many harmful by-products that are accumulating over time, for example, during the construction of a project, carbon dioxide is produced in large quantities and is assumed to contribute up to 33 per cent of the total carbon dioxide emissions in the USA.

Many green aspiring construction projects follow the criteria set up by the organization of Leadership in Energy and Environmental Design (LEED). In addition to the published design criteria, LEEDs also provides guidelines on construction material based on harm to the environment. This alerts owners, designers, and constructors to the use of specific materials in green building construction (Castro-Lacouture *et al.*, 2009; Baharetha *et al.*, 2012).

For project stakeholders, cost is typically the first factor considered before deciding to proceed with a project investment. As they are familiar to suppliers, clients, designers and constructors, conventional construction materials, and systems are typically priced lower than green-labelled materials and systems. This is one of the main reasons why sustainable materials are avoided. Parties' fear the "presumed" unnecessary increase in the total cost of the project. This preconceived idea is a major hindrance to the construction industry's shift to sustainable construction. However, green materials and systems are not always more expensive as a capital investment and more often than not they tend to reduce the life cycle operational and maintenance costs of the project. On the other hand, designers and contractors can be motivated towards the green shift if they are aware that waste prevention can be ultimately beneficial to all parties. Waste is a representation of lost profit in the long run because it is something that is bought; it cannot be utilized nor sold for salvage at obsolescence (Spiegel and Meadows, 2006).

The world does not rely on sources of renewable energy as much as it should. In 2006, 1.5 per cent of the world's energy demand was provided by renewable energy sources. It is estimated to reach 1.8 per cent by the year 2030. This estimated gradual rise is too slow for the world's need to reduce reliance on fossil fuels and shift to green resources. Similarly, Mekhilef *et al.* (2011) compiled data of the "global industrial sector energy consumptions" between 2006 and 2010. This data were used to develop a model to predict the trend of the energy consumption by the industrial sector until the year 2030 (Figure 1).

1.2 The United Arab Emirates (UAE) efforts

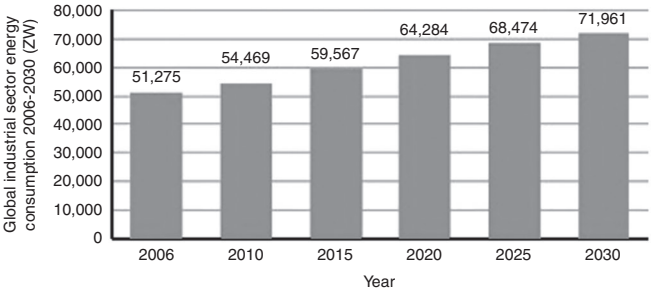
Pollution of the air quality and water sources, depletion of natural resources and raw materials, and the destruction of ecosystems are the three main reasons for the shift towards green construction (Spiegel and Meadows, 2006). In the UAE, the public sector is exhibiting clear signs that it is attempting to restrict dependence on oil generated revenue and investing in research and development of renewable energy sources, technologies and applications.

Various governmental entities have been established in the UAE concerned with safeguarding the implementation of green concepts in new developments' design and construction. Such entities include Estidama, an initiative that falls under the Abu Dhabi Urban Planning Council (UPC). This governmental entity focuses on promoting responsible and SD. Estidama's objectives and goals align with the master plan that the UPC has set: the Abu Dhabi Vision 2030. The main purpose of Estidama is "to preserve and enrich Abu Dhabi's physical and cultural identity, while creating an always improving quality of life for its residents on four equal pillars of sustainability: environmental, economical, social, and cultural" (Estidama.org, 2014). Estidama recognizes that the main two things needed for change are people's conceptions towards sustainability and the design approach. Project owners, designers, developers, constructors, and even residents need to incorporate sustainable concepts into their design and planning processes. With these points underlined, this governmental entity established the Pearl Rating System, a LEED equivalent with the UAE's geographical and social characteristics incorporated. In addition, the rating system is applied during the design, construction, and/or the operational phase of a project's life cycle; thus, the Estidama Pearl Rating System works concurrently with the various project stages (Estidama.org, 2014).

1.3 Green materials and systems

Many green-labelled materials and systems became visible in the construction industry lately. These include occupancy sensors, solar and photovoltaic technology, heating, ventilation, and air conditioning (HVAC) regulators, etc. Occupancy sensors and light reduction controls are usually installed in green buildings together to maximize energy conservation. This allows the regulation of individual rooms for efficient heating, cooling, and lighting to save energy. Occupancy sensors are crucial since buildings typically consume up to 40 per cent of the total energy usage in an economy (Zidek *et al.*, 2011). "The saving potential by occupancy sensors may amount to 61 per cent of the annual power consumption" (Roisin *et al.*, 2008).

The use of solar power for thermal water heating in domestic and industrial sectors has been rising with an estimated 30 per cent annual growth rate. The benefits of integrating solar thermal water generators in domestic and commercial buildings include the reduction of costs and energy consumption. A case study conducted in Nepal claims that by installing solar water heaters in a school of 850 students, its monthly electricity bill was reduced by the equivalent of 1,200 Euros (Mekhilef *et al.*, 2011). Similarly, photovoltaic systems are also gaining momentum in the construction industry for their



Source: Mekhilef *et al.* (2011)

Figure 1.
Global industrial sector energy consumption

significance in supplying green energy. As for costs, the price for photovoltaic systems and panels has been falling over the past few years by up to 86 per cent, making the system a viable and affordable alternative to integrate in projects. For instance, photovoltaic systems reached an installation capacity of 300 KW in the year 2005 in China, and the total photovoltaic installations throughout the country is estimated to be 1 MW, which is still a small amount but is an improvement (Mekhilef *et al.*, 2011).

HVAC systems are usually installed as a single unit to control the temperature of a building. Economizer controls are a budding green technology used to control energy loss from HVAC systems. This is implemented by controlling the amount of fresh air being supplied to the system from the outside. The results of several simulations using this system show that an estimated 66 per cent or 1,951 MWh of energy is saved annually (Mathews *et al.*, 2001).

Insulating materials are used in different capacities in building construction to reduce energy loss. From cavity wall insulation to tarpaulin roof insulation to cork, which is a material that is commonly known to be a traditional insulator is used in construction as filler or in boards form. Additionally, paper insulation is recycled paper that goes through a chemical process to make it fire resistant. However, unlike cork insulation, paper insulation can only be used as a filler material (Jelle, 2011). Furthermore, other techniques such as window glazing provide more insulation than single layered conventional windows. This is the main advantage for using double or triple glazed windows. Insulation may reduce cooling and heating costs by approximately 5-10 per cent. According to a study conducted in Australia, installing double glazed windows saves about 7.31 per cent energy while installing triple glazed windows saves 4.04 per cent energy (Rahman *et al.*, 2010).

Alternatively, reclaiming, reusing, and recycling construction materials saves resources and preserves raw materials. Yet, the major effects that should be taken into consideration when reclaiming materials are the indirect financial and environmental costs of reworking, refinishing, and installation (Calkins, 2009). A prime example of a reclaimed and recycled material is concrete. Concrete can be reclaimed from the remains of demolished buildings and can undergo a recycling process to make it reusable as a coarse aggregate. The process is similar to that of natural aggregates, which includes: crushing, removal of contaminants, washing, etc. There are various applications for recycled concrete and the process presents a safe and economical opportunity (Aïtcin and Mindess, 2011).

Water management systems are also very important, as water is gradually becoming a very vital and scarce resource. There are several examples of systems, implemented in hotels, and large buildings that capitalize on using alternative source of water to reduce dependence on fresh water. These examples include designated collectors and transportation pipes that are placed on roofs for rain water collection. The accumulated rain water is then stored in tanks for further usage in watering plants (Kirk, 1996).

2. Research methodology

The methodology for this research encompassed extensive literature review to find any previous studies conducted or published papers regarding sustainable construction materials and systems. The literature review is the premise for which the questionnaire development was based upon. A cross-reference between compiled sources established a list of ten commonly used sustainable construction materials and systems used worldwide. The list was based upon the advantages each material or system had and how much it contributes to SD. Ease of installation, economical feasibility, and

availability were taken into consideration, because materials and systems selection has to be based upon average construction companies' abilities to obtain and install them. Many of the materials and systems on the survey are also a part of the Estidama's Pearl Rating System, acknowledging that these items can and are being used in the UAE as well as worldwide. After the literature review, the questionnaire was created based upon the research followed by data collection. Collected data were processed using the statistics programme SPSS and then materials and systems ranking was determined by manual calculation of the relative importance index (RII). Questionnaire creation, data collection, and results analysis are discussed thoroughly in Section 3.

3. Questionnaire development and data collection

Upon finalizing the initial list of green materials and systems, further research was conducted to investigate the degree of use of these materials and systems in the UAE construction industry. The list of green materials and systems that was finalized and used for the purpose of this study, and included in the survey, is the following (Table I):

(1) occupancy sensors;

(2) solar thermal water generation systems;

(3) recycled materials;

(4) cork insulation;

(5) triple/double glazed windows;

(6) paper insulation;

(7) light reduction controls;

(8) HVACe;

(9) indoor water management; and

(10) solar photovoltaic (Table I).

The purpose of the survey was to obtain the experiences of various engineers in construction companies in the UAE in terms of their usage of green construction materials and systems. The selected measuring scale implemented on the survey creation is the Likert-type scale. Likert-type scale is one of the most popular methods to measure attitudes by the use of summated rating. This type of attitude scale is very reliable and is a valid instrument for the measurement of people's attitude as it is used to conduct various forms of research. The scale usually consists of five options where the typical responses range between the extremes of "strongly agree" to "strongly disagree", with three more intermediate options. This type of scaling system makes it possible to quantify the responses on various items and can be summed separately to give a total score for an individual item (Arnold *et al.*, 1967).

The survey was created to measure four things: frequency of green construction materials and systems use in construction today in the UAE, frequency of consideration to use green materials and systems in the design phase of a project, frequency of seeing green materials and systems being installed in projects across the UAE, and whether or not there is a significant rise in use of green materials and systems in the UAE construction industry over the past five years. An additional question was asked to check what ideas engineers in the field had to help encourage the use of green materials and systems. The questions were phrased simplistically and the

Material/system name	Definition	References
Occupancy sensor	A device that detects the occupancy of space and turns the lights on or off automatically depending on the presence of people in that area	Krarti (2000), Thumann and Mehta (2008) and Estidama – Pearl Rating System
Solar thermal water generation systems	A system that harvests solar energy to heat up water for buildings rather than utilizing electricity like with typical water heaters	Muguti *et al.* (1999), Mendler *et al.* (2006), Thumann and Mehta (2008), Spence and Kultermann (2010) and Estidama – Pearl Rating System (n.d.)
Recycled materials	Salvaged materials from previously built buildings where they are gone through a recycling process to become reusable	Mendler *et al.* (2006), Calkins (2009) and Spence and Kultermann (2010)
Cork insulation	A type of insulation that is made entirely of corks	Mendler *et al.* (2006) and Spence and Kultermann (2010)
Triple or double glazed windows	Window panels that are separated by air or gas to reduce the heat transfer between the atmosphere outside and that in the building in order to save energy	Krarti (2000), Thumann and Mehta (2008), Spence and Kultermann (2010)
Paper insulation	Insulation that is made of recycled paper and has gone through chemical processes to make it fire retarding and insect repellent	Spence and Kultermann (2010)
Light reduction controls	A system that optimizes the usage of energy by automating the usage of lights through an entire facility	Krarti (2000), Frej and Browning (2005), Thumann and Mehta (2008) and Estidama – Pearl Rating System (n.d.)
HVACe	Technology to regulate indoor environmental comfort. This includes heating, ventilating, and air-conditioning	Muguti *et al.* (1999), Krarti (2000) and Thumann and Mehta (2008)
Indoor water management systems	Systems installed in buildings to regulate and reduce water wastage which includes sensor faucets	Krarti (2000) and Thumann and Mehta (2008)
Solar photovoltaic	Photovoltaic materials, found in solar cells, which convert energy from sunlight directly into electricity	Muguti *et al.* (1999)

Table I.
Defined list of materials and systems with corresponding references

survey was designed to take about five minutes. Two methods were used to distribute the survey: First of all, an online version was created to collect data via e-mail. Second, a hard copy of the survey was created and printed for company and construction sites visits to administer the survey on the spot.

After the creation of the survey, collecting data form various construction companies across the UAE was the next step. To ensure that the survey would be answered by an adequate sample that represents the majority, specific criteria was set to determine which companies to give the questionnaire to and collect data from. The criteria included that the company must have been established in the UAE for at least six years and must have worked on at least ten projects ranging from medium to large-scale projects. The list of companies was obtained from the UAE's online database for contracting companies. Selection of a company was verified to satisfy the set criteria from the companies' website (date established, number of past projects, and types of past projects). A total of 38 project manager engineers were interviewed from 38 different companies across the UAE. Each individual interviewed had served a number of years with the company and has supervised multiple various sized projects with their respective company.

3.1 Analysis and results

The compiled data were inputted in the statistics programme SPSS and used to generate a descriptive statistics table and frequency tables for each material/system for each question. SPSS codes were created to stand for every material due to SPSS inability to accept long names for categories. The code that was developed is merely the first letters of the material or system followed by the number of question to separate data points. Table II displays the codes, as SPSS understood them, and the descriptive statistics associated with every material for every question. Moreover, the data were analysed using the RII to determine the rankings of the green materials and systems. The RII is a technique commonly used for data analysis that indicates which options on a survey are given high importance and which get low importance, thus, determining the ranking of the options listed in a survey. The technique uses the weight that is specified during the survey design via the Likert-type scale and the frequencies of each result to compute the relative importance of the material or system based on the responses.

The formula for computing the RII is as follows.

RII (Al Jurf and Beheiry, 2012):

$$\mathrm{RII} = \frac{\sum_{i=1}^{5} Wi \cdot Xi}{\sum_{i=1}^{5} Xi} \tag{1}$$

	n	Median	Mean	SD
OS1	38	3	2.82	1.205
SWGS1	38	2	2.18	1.036
RM1	38	3	2.74	1.223
CI1	38	3	2.79	1.417
TDGW1	38	5	4.21	1.143
PI1	38	2	2.50	1.371
LRC1	38	3	2.84	1.285
HVACe1	38	5	4.47	1.006
IWMS1	38	3	3.16	1.220
SP1	38	1	1.82	1.159
OS2	38	3	2.47	1.606
SWGS2	38	2	2.11	1.448
RM2	38	2	2.26	1.465
CI2	38	2	2.21	1.545
TDGW2	38	4	3.32	1.919
PI2	38	2	1.97	1.365
LRC2	38	3	2.71	1.707
HVACe2	38	5	3.55	1.955
IWMS2	38	3	2.66	1.760
SP2	38	1	1.89	1.539
OS3	38	3	3.16	1.386
SWGS3	38	3	2.82	1.249
RM3	38	3	2.95	1.314
CI3	38	3	2.84	1.424
TDGW3	38	4.5	3.79	1.473
PI3	38	3	2.58	1.426
LRC3	38	3	3.08	1.514
HVACe3	38	5	4.21	1.277
IWMS3	38	3.5	3.32	1.454
SP3	38	1	2.55	1.446

Table II. Descriptive statistics of total survey sample results

where:

- W_i is the response weight;
- i is the response index that ranges from 1 to 5 and represents very low influence, low influence, medium influence, high influence, and very high influence; and
- X_i is the frequency of the ith response (Al Jurf and Beheiry, 2012).

4. Results

4.1 Descriptive statistics

4.2 Frequency tables

Tables III-VI.

4.3 RII

For each question in the survey, a corresponding RII was computed to rank the green materials and systems. For the first question, the RII ranked the green materials and systems based on the frequency of their use in recent projects, depending on responses by contractors. The RII for the second question indicates the ranking of how often the

Table III. Frequencies of materials and systems commonly used by companies from survey question no. 1

	Scale					
Materials	0 = no answer	1 = never	2 = rarely	3 = sometimes	4 = often	5 = always
OS	0	6	10	10	9	3
SWGS	0	11	14	9	3	1
RM	0	5	13	13	1	6
CI	0	9	8	10	4	7
TDGW	0	1	3	6	5	23
PI	2	7	12	8	5	4
LRC	0	9	4	12	10	3
HVACe	0	1	2	2	6	27
IWMS	0	5	5	12	11	5
SP	0	20	11	4	0	3

Table IV. Frequencies of consideration of materials and systems by companies from survey question no. 2

	Scale					
Materials	0 = no answer	1 = never	2 = rarely	3 = sometimes	4 = often	5 = always
OS	6	5	7	10	5	5
SWGS	6	8	8	11	2	3
RM	6	3	15	7	3	4
CI	6	6	12	7	2	5
TDGW	6	2	4	6	2	18
PI	6	8	13	4	6	1
LRC	6	5	3	11	6	7
HVACe	6	2	3	2	4	21
IWMS	7	4	5	8	7	7
SP	7	13	4	8	3	3

green materials and systems are considered in the design phase of the project. The third question RII ranks the green materials and systems on the basis of how frequent contractors' views other companies using these materials and systems in projects across the UAE (Figures 2-4).

5. Discussion

As shown in Table VII, it is evident and logical that HVACe would be the top used system in the UAE given the climate conditions of the region. Air conditioning is very costly due to high-energy consumption levels, but integrating an economizing system optimizes air-cooling, reduces energy consumption, and ultimately reduces costs. In the long run, installing HVACe is an investment and many contractors have recognized this. Typically coupled with the HVACe system are triple and double glazed windows as they optimize air-cooling by preventing heat transfer between the outside

	Scale					
Materials	0 = no answer	1 = never	2 = rarely	3 = sometimes	4 = often	5 = always
OS	1	4	8	7	11	7
SWGS	1	4	11	11	7	4
RM	1	5	8	9	11	4
CI	1	7	9	6	10	5
TDGW	1	3	3	8	4	19
PI	1	11	6	9	7	4
LRC	2	6	4	8	11	7
HVACe	1	1	3	2	8	23
IWMS	1	5	4	9	9	10
SP	1	10	10	6	6	5

Table V. Frequencies of witnessing use of materials and systems across the UAE from survey question no. 3

		Frequency	%	Valid %	Cumulative %
Valid	n/a	3	7.9	7.9	7.9
	No	4	10.5	10.5	18.4
	Yes	31	81.6	81.6	100.0
	Total	38	100.0	100.0	

Note: Frequencies of witnessing a rise of green construction across the UAE from survey question no. 4

Table VI. Green construction proliferation in the UAE noticed by interviewees

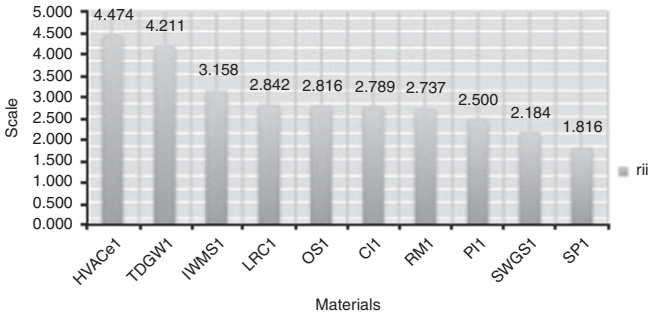


Figure 2. Question no. 1 rankings

and inside environments. This preserves the cold air inside buildings and reduces the amount of cooling an air conditioner has to do and, in turn, reduces energy consumptions and costs. Indoor water management systems such as sensor faucets help reduce water wastage, which is a scarce resource in the UAE. Desalination is an expensive process; thus, optimizing water use and reducing wastage can conserve valuable water and cut desalination expenditures.

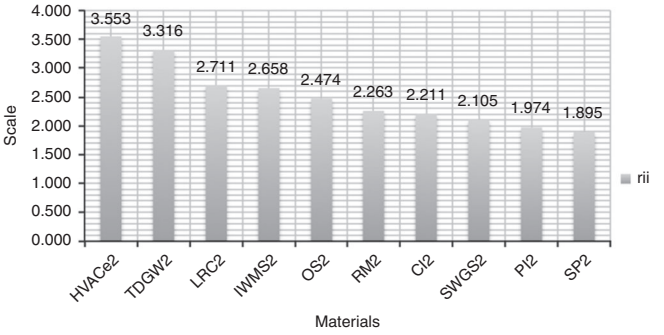


Figure 3.
Question no. 2 rankings

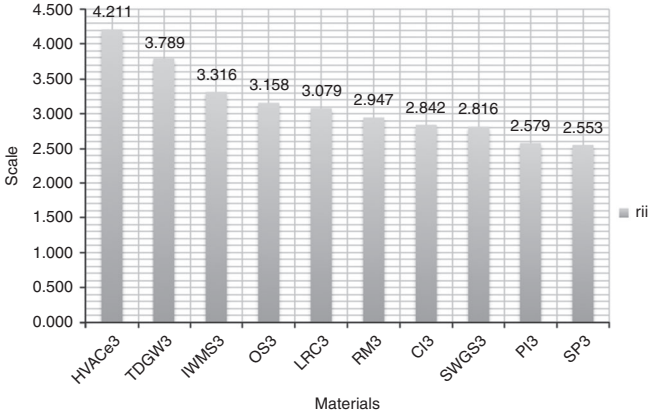


Figure 4.
Question no. 3 averages

Material/system	RII	Material/system	RII	Material/system	RII
HVACe1	4.47	HVACe2	3.55	HVACe3	4.21
TDGW1	4.21	TDGW2	3.31	TDGW3	3.78
IWMS1	3.15	LRC2	2.71	IWMS3	3.31
LRC1	2.84	IWMS2	2.65	OS3	3.15
OS1	2.81	OS2	2.47	LRC3	3.07
CI1	2.78	RM2	2.26	RM3	2.94
RM1	2.73	CI2	2.21	CI3	2.84
PI1	2.50	SWGS2	2.10	SWGS3	2.81
SWGS1	2.18	PI2	1.97	PI3	2.57
SP1	1.81	SP2	1.89	SP3	2.55

Table VII.
Relative importance index results in descending order

Furthermore, Light reduction controls and occupancy sensors are two systems that compliment each other and work well together in reducing electricity consumptions. Dubai is a business hub and, as such, many of the commercial buildings consume a lot of electricity. Light reduction controls and occupancy sensors optimize the intensity of the light emitted by the bulb depending on the surrounding environment and switch off any lights with the absence of people from rooms, corridors, and/or hallways. Cork insulation is used in the UAE in foundations to prevent vibrations; even though cork insulation is used to prevent heat or cool loss, it is not applicable in the UAE as walls are made of concrete. The least used on the list is recycled materials and this could be due to many reasons. The processes to recycle and salvage concrete do exist, but might be unfamiliar to many contractors. Ironically, the systems that utilize the most abundant renewable resource readily available, solar energy, do not make it on the list of the top 7 and, in fact, are the lowest two materials used. Solar thermal water generation system and solar photovoltaic were ranked 9th and 10th, respectively.

Moreover, there is a discrepancy between the results of question nos 1, 3 and 2. Question nos 1 and 3 display a similar pattern of frequency and rankings; however, the frequencies of question no. 2 were significantly lower. The reason for this discrepancy is due to the fact that while the construction managers were answering the survey some of them skipped the second question and did not answer it. In this study, a "No Answer" had a weight of zero and when the RII was computed, this lowered the results relative to the sample of 38. When asked why they skipped the question, some construction managers stated that they could not answer it as they were not involved in the design phase of the project and thus did not know which materials and systems were considered and which were not. As for UAE's progress in shifting to green construction, Figure 5 indicates that most of the engineers in the UAE have seen significant progress in the green movement through the construction industry over the past five years and are hopeful for further rapid improvement.

6. Recommendations

From the results of this study, it is recommended that UAE construction projects place more emphasis on integrating green materials and systems in the early design phase. This warrants the early involvement of contractors or constructors. As the results indicated, some of the construction managers did not answer the second question related to the design phase of the project because they were unaware of what was done in that phase. Further studies are suggested to look into which green materials and

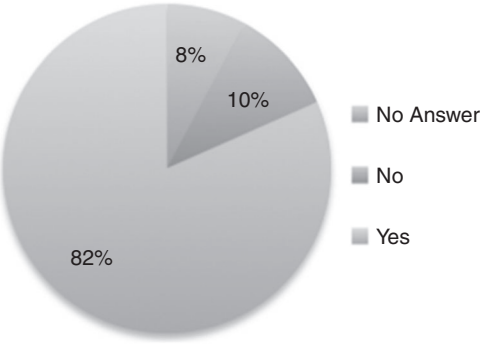


Figure 5.
Question no. 4 percentages

systems are regarded in the design phase. Additionally, the UAE should target more solar energy powered systems, as solar energy is abundant during daytime in the summer and winter and should be harnessed to generate electricity for the various needs of buildings to reduce energy consumption and therefore electricity costs.

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Corresponding author
Aly Elgayar can be contacted at: alyelgayar@gmail.com