Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 8 (19): 3460-3466, 2008
ISSN 1812-5654

Prevalence and Penetration of Lighting Control Systems in Dubai Buildings: A Pointer to Future Measures

R. Gomathi Bhavani and M.A. Khan
BITS, Pilani-Dubai, Dubai International Academic City, P.O. Box 500022, Dubai, UAE

Abstract: The findings of a research study conducted to analyze the prevalence and penetration of various lighting control systems in the new projects of Dubai is presented in this paper. A sample of 205 new projects in Dubai were classified into three categories namely residential, commercial and hotel projects and the presence of five lighting control technologies in these buildings were analyzed. The study also identifies that meeting the requirements of property developers, not energy saving, is the biggest demand driver of lighting control business in Dubai. From the response of participants, also analyzed are the factors for resistance to adoption of these systems. Looking into the future scenarios, the study identifies the different factors that would make these controls more common in future. The present trends point towards aggressive energy policies of the government in future such as implementation of lighting code regulation which has its own share of difficulties and challenges.

Key words: Automated lighting, intelligent buildings, energy saving, lighting codes, green building, daylighting

INTRODUCTION

Presently, the United Arab Emirates (UAE) is witnessing a construction boom that few countries in the world could have experienced at a particular time. The Government's clear vision of the future of their country, their relaxed policies on trade and investment lead to the development of this country from the beginning of 1980s. The population spread of UAE is very different in the sense that expatriates from other countries outnumber the nationals by a huge margin. Expatriates make up the majority of population and are mainly drawn from the Indian subcontinent, Europe and neighbouring Arab countries (Al Tamimi, 2006). A Dubai policy in the summer of 2002 announced freehold property ownership for people of all nationalities (Al Tamimi, 2006). Since then, buyers have been flocking to the various upscale developments and buying property in record times (Al Tamimi, 2006). The overall strategy of adopting free market principles has brought about an increasing volume of investments in a large variety of projects and joint ventures, manufacturing and service industries; retail and tourism business have increased (Al Tamimi, 2006).

The major boom in the building and construction industries has significantly enhanced the demand for lighting and electrical products. The many sophisticated developments taking shape across the UAE are wooing the customers using the dramatic effects that can be created through architectural lighting to enhance their properties and theatrical lighting, which uses intelligent lighting to improve the quality of the audience experience. Dubai, which is the commercial hub of the Middle East and melting pot of many nationalities, is concerned about its image to preserve and enhance its international brand identity.

In the Gulf States, although there is small amount of research and writing that is relevant to the use of conservation measures, there is a need for such methodologies due to their economic and environmental benefits (Radhi, 2008). In the recent past, the effect of glazing and code compliance on Air-Conditioning systems was presented by Omar and Al-Ragom (2002). Iqbal and Al-Houmoud (2007) have analyzed alternative energy conservation measures for an office building in hot and humid climate, choosing Dammam, Saudi Arabia as their location of study. Very recently, Al-ajmi and Hanby (2008) have reported their work on simulation of energy consumption on Kuwaiti domestic buildings while Radhi (2008) has proposed a systematic methodology for optimizing the energy performance of buildings in Bahrain.

The need for research and documentation on automated lighting systems in the region has assumed much more significance now after His Highness Sheikh Mohammed Bin Rashid Al Maktoum, UAE Vice-president and Prime Minister and the ruler of Dubai issued a

Corresponding Author: R. Gomathi Bhavani, BITS, Pilani-Dubai, Dubai International Academic City, P.O. Box 500022, Dubai, UAE Tel: +9714 4200700 Fax: +9714 4200844

resolution on implementation of green building specifications. The research described in this paper was motivated by the author's observation that all the works mentioned above have concentrated on the energy-efficient air-conditioning systems of buildings in the region and that there is a need to identify how the lighting systems are performing presently which could serve as an indicator for future measures. The objective of this paper therefore is to present the results of the research study conducted to analyze five lighting control technologies employed in the new projects in Dubai which are classified into residential, commercial and hotel projects and to analyze the extent and sophistication of lighting control on the present installations. From the study, we also examine the demand drivers and challenges faced by providers of lighting control business in the region. The aggressive energy policies of the government may mandate lighting code regulations in future. So we also identify the difficulties and challenges associated with implementing such regulations in an expatriate-dominated society like Dubai.

THE RESEARCH STUDY

The concept behind the lighting controls is to operate lighting automatically according to the function of an area, the time of day, ambient light levels or occupancy. The knowledge about the type of visual task that is going to be done in a given space and the electricity rates at various times of the day will help in deciding a particular control mechanism. Energy saving can be the objective of providing lighting control in a typical scenario. The load shedding control can also be used as a strategy in automated lighting. It permits a reduction in lighting load to achieve reduction in power demand at the peak time. Before such a load-shedding technique is applied to the real world, however, it is important to understand occupants' illuminance requirements with respect to dimming (Akashi and Neches, 2005).

The popular control technologies taken in this study are dimming, lighting control panels, occupancy sensors, Building Management Systems (BMS) and daylighting systems. Lighting control panels and BMS contribute to the scheduling technologies for smaller and large buildings (100, 000 ft^2 upwards) respectively. Scheduling systems activate lighting at pre-set time intervals that range from minutes to hours. When properly integrated with electric lighting system, daylighting systems not only save energy by reducing off electric lighting load but also increase user comfort and satisfaction. The combination of the above mentioned strategies provide the highest level of energy savings. It is impossible to assume that there could be a single ideal set of criteria for good lighting (Tregenza, 2003). The association between the nature of lighting and people's expectation and satisfaction is very complex and hence is very challenging and interesting.

Some key projects currently underway that would require lighting solutions and services are: Burj Dubai; the tallest building in the world, Business Bay; a multi billion dollar global commercial and business centre in the heart of Dubai, Dubai Autodrome and Business park; a state-of-the-art motor racing facility containing six different track configurations and motor industry companies, Dubailand; a US$ 7.5 billion mixed-use theme park consisting of stadiums, golf courses, academies and facilities, Dubai International City; 20, 000 apartments in 350 buildings with townships based on China, England, Italy, France, Russia and Morocco, Dubai Metro and Railway projects; a US$ 4 billion project catering to 70 km length underground and elevated train systems, Hydropolis hotel; the world's first underwater hotel etc. (Dubai Explorer, 2007).

The study was conducted between April 2006 and October 2007 on a sample of 205 new projects in Dubai. By data collection through the web and interaction with the construction industry, the buildings were identified as to whether the projects use at least one form of lighting control and were classified as residential, commercial and hotel projects. Table 1 shows this information. It was found that out of 205 projects, 94 projects (45.9%) were using some form of lighting control out of which 53 were residential buildings, 25 were commercial and 16 were hotel projects.

Table 1: Details of new projects

Categories of new projects	No. of projects taken for the study	No. of projects that use lighting control
Residential	129	53
Commercial	60	25
Hotels	16	16
Total	205	94

Table 2: Types of new projects that use lighting control

Categories of new projects	No. of projects that use lighting control
Residential (53)	
Villas	9
Apartment buildings	33
Staff accommodation	11
Commercial (25)	
Banks	4
Offices	8
Educational institutions	3
Recreational facilities and shopping malls	8
Hospitals	2
Hotels (16)	
3 star hotels	4
4 star hotels	3
5 star hotels	5
Service apartments	4

Table 3: Professions of participants

Professions of participants	No. of participants interviewed
Lighting designers	11
Engineers	14
Manufacturers	13
Total	38

Engineers' category also included four energy consultants

It was identified that the projects that use lighting control could be further classified into the categories as shown in Table 2 according to the building use. A total of 38 professionals involved in the lighting control business from among these 94 projects were chosen and interviews were held with them. The professions of participants are indicated in Table 3.

The participants were asked as to whether the project they represent indeed used any form of lighting control and what method of control was specified in the project. Depending on the answers provided on a particular category of lighting control systems, follow-up questions were asked. The results of the study are presented in the next section.

RESULTS

Prevalence and penetration: Given in Table 4 is the result of the research study conducted on the five different forms of lighting control used in each of the three categories of projects.

During the follow-up phase of the study, the participants indicated the following as the most important reason for prevalence of a particular system in a given category. The dimming is most popular in hotels (100%) mainly because of the prevalence of use of architectural control in conference rooms and ballrooms and stand-alone dimmers in hotel rooms. Commercial buildings widely adopt dimming (40%) and some of them for fluorescent lighting using electronic ballasts and DALI (Digital Addressable Lighting Interface) and non-addressable digital control, DSI technology.

Lighting control panels are housed near the distribution boards and they control the lighting circuities. All the relays and dimmers predominantly are controlled by a common protocol such as EIB (European Installation Bus), C-Bus, PROFIBUS (Process field bus) etc. and lighting control panels are widely employed in residential (75.5%) and commercial projects (80%) and could potentially become a standard feature in future, according to 21 participants.

Occupancy sensors are mostly used in corridors and lift lobbies in residential projects (28.3%) and in conference rooms, boardrooms, car parks and reception areas in commercial projects (20%). Twenty four participants felt that this simple technology has the reach to achieve significant energy savings in buildings in Dubai.

BMS has wide acceptability in most of the new projects and lighting control is generally interfaced with BMS thus offering flexible solutions, fast expandability and easy adaptation to customer needs, remote monitoring and greater energy efficiency. In some projects we find that lighting control panels are used as standalone as well.

Daylighting though highlighted by most of the manufacturers in promoting their systems, is being adopted in few projects (12%). This is likely due to heat gain problems associated with it in the desert climate of Dubai since it has a direct impact on the air-conditioning load. There is less work done to assess and evaluate the performance of daylighting systems in the buildings of Dubai. However, Al-Sallal (2006) has done an experimental work recently in universal space studios in Al-Ain, UAE and the research done by Aboulnaga (2006) investigates the problems associated with misuse of glass as a building element in UAE particularly in Dubai. Inadequate design with ill-selected glass/glazing type may lead not only to poor daylighting in building interiors but also contribute significantly to fatigue, insomnia, seasonal affective disorder (SAD) and above all increase CO_2 emission (Aboulnaga, 2006). According to ten participants, with more such research and refinement coming into daylighting systems meant for hot regions, the adoption of these systems in Dubai would become more common in design practice. According to Yannas (2007), 1-2% of the outdoor illuminance in the UAE can be sufficient to provide the illumination levels of 300-500 lux required for typical indoor activities.

Demand drivers: The participants were asked about what they considered as the demand drivers of automated lighting control business in Dubai. Options included meeting the requirements of the property developers, incorporating personal control for increased satisfaction, comfort and productivity, flexibility in controlling the floor area, willingness to embrace new technologies such as DALI and energy savings. Table 5 shows the participants' choices.

From the interaction with the participants, the following emerged as the reason for their choices. Major developers in Dubai see the automation in lighting as a selling feature to promote their properties. This is the biggest driving force (89%). They offer lighting control or create containment for future incorporation. Scene control, occupancy sensors and workstation lighting controls dominate the market due to user satisfaction and

Table 4: Prevalence of lighting control in new projects in Dubai

Categories of new projects	Dimming (%)	Lighting control panels (%)	Occupancy sensors (%)	Building management systems (%)	Daylighting systems (%)
Residential (53)	18.9	75.5	28.3	37.7	0
Commercial (25)	40	80	20	80	12
Hotels (16)	100	62.5	0	100	0

Values given in parentheses are total number of projects in the given category

Table 5: Factors driving the demand of lighting control systems in Dubai

Factors considered as demand drivers	Percentage of participants that choose this option
Meeting the requirements of the property developers	89
Incorporating personal control for increased satisfaction	63
Productivity and comfort	48
Flexibility in controlling the floor area	38
Willingness to embrace new technologies such as DALI	51
Energy savings	41

Table 6: Resistance to adoption

Factors for resistance	Percentage of participants that choose this option
Initial Cost	78
Educating the user in operating the controls and making him feel comfortable	48
Operational issues	32
Perception of clients that system may not function as intended	36
Difficulty in specification	58

Table 7: Factors that would make the controls more common in future

Reason for becoming common in future	Percentage of participants that choose this option
Future Implementation of codes and standards	81
Boom in construction	72
More user awareness and willingness to experiment	70
Integration with BMS and improvisation in design	51
Rise in inflation and energy costs	42

convenience factors. Open office spaces require modification and alteration depending on the client's requirement and adaptation of lighting control makes these tasks easier.

Though energy saving is the ultimate feature of automated control, it is still not a major driving force in decision making in Dubai (41%), due to the fact there are no specific regulation or energy codes in place and also the cost of energy is less because UAE contains 98 billion barrels, the fifth largest proven oil reserves in the region, according to Energy Information Administration, the official energy statistics from the United States. Considering the fact that UAE enjoys the highest per capita income, the consumers are still not feeling the pinch due to cost of energy when compared to their other expenditures.

Resistance to adoption: The participants from the professional group responded as given in Table 6, when asked about the various factors that prevent a project from using lighting control technologies. Participants could choose more than one factor.

The main resistance to adoption comes due to the initial cost, which is the same reason that concerns the providers the world over. The specific reason of educating the user in operating the controls and making him feel comfortable with the expertise is particularly relevant in the case of BMS (48%). With a proper after-sales service network non-existent, the apprehension of clients is not completely unjustified. Operational issues or technical drawbacks (32%) are mainly due to the occupancy sensor category wherein countering the delays and false-offs continue to pose some problem, even though design refinements have injected some confidence with the users.

The designer group expressed that some clients perceive that these systems may not function as intended as they have experienced lights going off at wrong times (36%). They also face challenges while integrating an existing light system with new controls, looking for more creative solutions. The respondents also felt that they faced a unique and difficult situation to specify lighting control systems in a region where energy costs are minimal and value engineering is the norm considering the fact that labour costs form a substantial portion of the overall project costs. When it comes to cost cutting in a project, the lighting control becomes one of the first casualties. With the rental properties forming a major part in residential and commercial sectors in Dubai, some owners have hesitation in going for advanced controls. This explains why a high factor (58%) accounted for resistance due to specification.

Reason for optimism: Overall, the participants agreed that lighting controls are becoming common in all commercial projects and the extent of advancement and sophistication is dependent on project type, scale, client criteria and cost. They also opined that if some new codes mandating lighting controls such as ASHRAE (American Society of Heating, Refrigeration and Air-conditioning Engineers)/IESNA (Illuminating Engineering Society of North America) 90.1-1999 are mandated, the cost for these systems will eventually reduce because of increase in

demand. Table 7 shows the details of the responses when asked about what are the factors that would make these controls common in future.

DISCUSSION

Here, we examine how Dubai buildings will accept and adapt themselves to automated lighting control in future with particular focus on energy perspective. The study conducted indicates that energy saving is not the biggest demand driver for these controls and hence we identify this area as untapped and scrutinize this aspect to interpret the future scenarios. The study also has two other important results that property developers require lighting controls to be installed in their buildings and that the willingness to experiment new ideas cause encouragement among the providers and designers. With these significant findings, we review the role of the government in making the controls popular.

Governmental measures: Presently Dubai Electricity and water authority (DEWA) has an energy conservation cell and it releases advertisements in the local newspapers to raise awareness among the public for efficient use of energy. DEWA recently launched quotes your decision campaign to raise awareness among the community to curb excessive consumption of electricity. It has introduced different slabs to charge tariff for residential, commercial and industrial consumers ranging from 20 fils per kWh to 33 fils per kWh. In an effort to utilize solar energy, Dubai Municipality erected solar-powered parking meters as well as some road signage in and around the city (Kazim, 2007).

The government of Dubai recognizes and encourages people who have adopted energy efficient strategies in their buildings and is committed to achieving sustainable environment protection by encouraging more green buildings to be constructed and Leadership in Energy and Environmental Design (LEED) ratings to be achieved for new buildings. The LEED specialist, Keith (2005) reiterates that lighting controls, as a minimum per local energy code compliance, is required on all LEED projects. In fact, it's a prerequisite (Keith, 2005). In addition, lighting controls can be a major contributing factor to the Energy and Atmosphere category, Credit 1, Maximizing Energy Performance and the Indoor Environmental Quality category, Credit 6, Controllability (Keith, 2005).

Since January 1, 2008 the villas, hotels, mosques and all kinds of buildings planned for future must conform to sustainable development criteria as announced by His Highness Sheikh Mohammed Bin Rashid Al Maktoum, UAE Vice-president and Prime Minister and the ruler of Dubai. There are 70 planned U.A.E. buildings now aiming for green status, according to Hilson Moran, which has a seat on the Emirates Green Building Council (Hughes, 2008). The UAE is picking up on messages from around the world and one of those is sustainability and they have the ability to implement it, says Chris Johnson, a Gensler managing principal (Hughes, 2008). The company Pacific Control Systems' 5-storey headquarters building at the Dubai Techno Park has achieved the platinum rating and Wafi City's District Cooling Plant was also awarded a silver LEED certification. Metito's headquarters at the Dubai Techno Park known for its daylighting design and Tameer's towers, a 72 storey building made of locally produced pre-cast-concrete panels are few of the many examples vying for green status. The developers are responding very positively to the Ruler's new resolution. A regional English daily reported that the developers in the UAE are choosing to build the highest level of green buildings to the surprise of certifying body, Middle East Centre for Sustainable Development (Gulf News, 2008). Our finding that meeting the requirements of the property developer as the primary demand driver underscores this aspect.

In line with the green building resolution, DEWA enforces regulations through various stages. As per this regulation, the control systems such as motion sensors, dimming systems and lighting with timers are required to be used in all buildings and are to be considered by all consultants, consumers, developers etc.

Such market pressures can simulate the need for lighting control technologies. With high economic and population growth rates and a fairly low energy cost, the country's energy consumption has risen tremendously in the past decades (Kazim, 2007). With the cost of energy going up, the government may mandate more energy code practices in future. A similar forethought was earlier expressed by Berkeley Researchers on why so few buildings use advanced lighting control systems. They believed electricity prices would rise in the next five years, creating an incentive to owners and operators to adopt such measures to slash costs (Snoonian and Bowen, 2005).

The population mix of Dubai is predominantly expatriate-oriented, thanks to its tax-free atmosphere and high level of living standards. This aspect poses unique issues concerning labour and expertise in implementing and pursuing energy standards and codes, if the government chooses to do so. We briefly examine the challenges of implementing lighting codes in particular.

Challenges in enforcing lighting code regulations
Design challenges: Building codes and standards have enormous effect on the type of controls designed and implemented into a lighting system. The codes if implemented will make the designers think innovatively to structure a lighting system into a building's network.

Devising of such control strategies to suit a particular requirement needs huge design expertise. When these sustainable design requirements become code, the industry and its products should rise up to the challenge and expect to be refined for the better. The region should equip itself with the design skills to match these technical demands.

Challenges in training: The lighting codes if implemented will set maximum allowable energy consumption levels for various lighting systems and will have its statements of requirements and evaluation methodologies. The assessment of impacts of these codes, its economic analysis and training is a complex and technical task (Chan and Yeung, 2005). The analysis of cost data for lighting products involves difficult calculations because products having variable costs and shapes can offer similar light at similar efficiency and efficacy. This poses challenge in cost analysis and hence requires training at this level too. The training of design professionals, contractors, lighting equipment suppliers, code officials or inspectors is critical for successful implementation of codes and hence the training will have to be implemented by way of seminars, presentations and software to demonstrate lighting design compliance.

Enforcement challenges: Enforcing the codes requires high level of expertise and the government has to hire multiple code officials with specific areas of specialization. Recruitment of skilled code officials and training them could put additional pressure on the government.

Informing the consumers: If codes are mandated, the government has to equip the residential consumers with the accurate and reliable information of products. The government has to insist on printing lamp output in lumens, energy wattage and average lifetime on the packaging of lamps. This will enable the consumers to choose more energy efficient products and help avoid confusion. Bridging the gap between available lighting technology and consumer knowledge is a significant challenge and one that in Japan is jointly met by government and industry initiatives (Sanderson *et al*., 2007). The successful inclusion of a community into environmental policy brings with it a need to develop both environmental awareness within the community and capacity building within a nation's human resources. (O'Brien *et al*., 2007). When awareness and capacity building are attempted without policy participation the results have often been poor (O'Brien *et al*., 2007).

If codes become the norm and are well defined, the most popular control technology will evolve with time. From the study, the sheer amount of construction activities happening in Dubai can be seen as a tremendous opportunity for implementing energy codes and standards.

CONCLUSION

This research study identified that intelligent and automated lighting finds its place in almost all landmark developments in commercial and hotel projects in Dubai mainly for scene control and due to the ability to employ multiple control strategies simultaneously with a centralized intelligence. This is mainly because building owners and property developers see them as a way to promote the image of buildings or properties. The study also highlighted that the feasibility of these systems in all types of buildings and the demand will rise in future.

The study observed that the objective of lighting control as an energy conservation scheme can be achieved if the government imposes tougher standards on commercial building energy usage. The adoption of these systems is already on the rise due to the recent requirements enforced by DEWA. The paper also has identified that the sheer amount of buzz and activity in the construction industry is seen as an opportunity to enforce lighting power budget requirements though it will have its share of challenges that are specific to the region. Building owners will then highlight their buildings as energy efficient and justify the initial cost to their customers and lighting control can then become a standard feature in each building. The work identified that Dubai has the technology, infrastructure and most importantly, the government with a readiness and vision in place, for the automated lighting control to develop and establish as a must-have feature in each building.

This study attempted to highlight the prevalence and penetration of lighting control systems in Dubai with an aim of providing some insight as to how these systems will evolve in future in the region. There is a need for more holistic performance indicators and design procedures in daylighting systems that can be developed specific to the (hot) region, taking into account the heat gain factor. The satisfaction and comfort index analysis done on the general public who has been given the personal control option can also throw light on the need to develop and bench mark the design criteria, which could be region specific. More work is continued by this researcher in identifying and evolving a suitable model for allowing flexible adaption to the environmental factors and user preferences.

ACKNOWLEDGMENTS

The authors express their acknowledgments to the management of Birla Institute of Technology and Science, Pilani (Rajasthan) and BITS- Pilani Dubai for offering their support and facilities in the completion of this work.

REFERENCES

Aboulnaga, M.M., 2006. Towards green buildings: Glass as a building element the use and misuse in the Gulf Region. Renew. Energ., 31: 631-653.

Akashi, Y. and J. Neches, 2005. Potential recommendations for illuminance reductions by load-shedding. Lighting Res. Technol., 37: 133-153.

Al-Ajmi, F.F. and V.I. Hanby, 2008. Simulation of energy consumption for Kuwaiti domestic buildings. Energy Build., 40: 1101-1109.

Al-Sallal, K.A., 2006. Easing high brightness and contrast glare problems in universal space design studios in the UAE: Real models testing Renew. Energ., 31: 617-630.

Al Tamimi, E., 2006. Setting up in Dubai: Business Investor's Guide. 4th Edn., Cross Border Legal Publishing, Dubai.

Chan, A.T. and V.C.H. Yeung, 2005. Implementing building energy codes in Hong Kong: Energy savings, environmental impacts and cost. Energy Build., 37: 631-642.

Dubai Explorer, 2007. Explorer Publishers. Dubai

Gulf News, 2008. Developers Seek Highest Level of Green Buildings. 1st Edn., Al Nisr Publishing, Dubai, pp: 3.

Hughes, C.J., 2008. Desert mirage? UAE makes green pledge. Architectural Record, 196: 14-14.

Iqbal, I. and M.S. Al-Homoud, 2007. Parametric analysis of alternative energy measures in an office building in hot and humid climate. Build. Environ., 42: 2166-2177.

Kazim, A.M., 2007. Assessments of primary energy consumption and its environmental consequences in the United Arab Emirates. Renew. Sustain. Energ. Rev., 11: 426-446.

Keith, L., 2005. LEED-Certified lighting pays off in other ways. Consulting Spec. Engr., 37: 55-56.

O'Brien, J., R. Keivani and J. Glasson, 2007. Towards a new paradigm in environmental policy development in high-income developing countries: The case of Abu Dhabi, United Arab Emirates. Progress Plan., 68: 201-256.

Omar, E.A. and F. Al-Ragom, 2002. On the effect of glazing and code compliance. Applied Energy, 71: 75-86.

Radhi, H., 2008. A systematic methodology for optimising the energy performance of buildings in Bahrain. Energy Build., 40: 1297-1303.

Sanderson, S.W., K.L. Simons, J.L. Walls and Y. Lai, 2007. Innovation challenges in the lighting industry: From 1990 to 2006. Proceedings of the Conference on Globalization and Innovation. February 11, New York, USA. Rensselaer Polytechnic Institute, NY, pp: 1-1.

Snoonian, D. and T.S. Bowen, 2005. In lighting, a little intelligence goes a long way. Architectural Record, 193: 146-148.

Tregenza, P., 2003. Tropical daylighting. Lighting Res. Technol., 35: 1-2.

Yannas, S., 2007. Dynamic structures. Proceedings of the 2nd PALENC Conference: Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, September 27-29, Crete, Greece. Gulf Research Project, AbuDhabi, pp: 1-6.