Journal of Engineering and Applied Sciences 12 (Special Issue 5): 6939-6946, 2017
ISSN: 1816-949X

Environmental Benefits of Air Plant Green Roofs in Hot and Humid Climate

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Abstract: According to the study, green roofs also benefit their surrounded environment. It has been accepted as a sustainable built environment for both microclimate and macroclimate. The analysis of environmental benefits extensively considered from the emission in the production process, air quality improvement, carbon reduction, habitat creation, mitigation of urban heat island effect, reduction of flood risk, infrastructure improvement, recreational space and increase surface function for human well-being. This study had studied the environmental benefits of intensive green roofs, extensive green roofs and air plant green roofs. The review from secondary data showed the data of environmental benefits from intensive green roofs and extensive green roofs. The environmental benefits of air plant green roofs had been measured under the similar environmental circumstance in hot and humid climate in Thailand. The Crassulacian Acid Metabolism (CAM) or xerophyte and epiphyte plants were selected and used in the air plant green roof. It was found out that those plants required less maintenance. However, two common species of CAM plants in this study are air plants which are Spanish moss and Tillandsia cotton candy. With that reason, the classifications of green roofs have been represented by different environmental benefits. Therefore, the consideration of environmental benefits of green roofs is indispensability and supports the decision making for the utilization of green roofs.

Key words: Air plant green roofs, environmental benefit, Tillandsia cotton candy, Spanish moss, CAM, species

INTRODUCTION

The increasing number of population growth and the expansion of urbanization are continually going higher. The developments are based on the demand of human needs and satisfactions. We have learned that the development of infrastructure and agriculture may demolish our natural resources. For example, the rapid development of dwelling in Malaysian, ranked as the thirtieth of world's green house gas emissions (Suleiman *et al*., 2015) the community had contributed energy consumption and 40% of carbon emission had defected natural ecosystems in country in the last decades. In Nigeria, widely developing cities is growing up together with the environmental problems (Agboola *et al*., 2015).

In the meantime, the developments of construction sector and the utilization of non-renewable materials in buildings, infrastructures and public utilities result in environmental problems (Fernandez *et al*., 2013; Kim *et al*., 2015). The increasing temperature in cities areas is believed to be the cause of Urban Heat Island (UHI) phenomenon (Kiesel *et al*., 2012; Santamouris, 2014; Lin *et al*., 2013). The material of buildings, pavements and constructions (cement and asphalt) in the city reflects and absorbs heat from solar radiation (Takebayashi and Moriyama, 2007). In general, footprint of buildings in the area has similar size to the building rooftop. So, if rooftops materials reflect and absorb solar radiation, it will be the main barrier of the heat transfer to the building. The roof areas, therefore have environmental benefits and can save up the energy in buildings. The utilizations of green roofs in cities can also help environmental issues in the current situation (Chen, 2013; Peng and Jim, 2013; Kim *et al*., 2016). For example, one of the economic development frameworks for property companies in Brusa, Malaysia, 2020 also prepared for the climate change mitigation and environmental protection (Jim and Peng, 2012).

The graph shows the change of maximum temperatures for 6 months in Hatyai, Songkla, Thailand from 2011-2015. According to the study, temperature in Hatyai changes dramatically over five years. In April 2015, the temperature went up to 35.29°C which is higher than April 2011. At that time, the temperature used to be around 3.11°C. (Fig. 1). Hatyai generally receives most of average maximum summer temperatures in April which is 31.4°C.

Green roofs on commercial buildings are widely used in order to support the cooling requirement that increase the efficiency of insulation in buildings and reduction of the overall thermal transfer value (Chan and Chow, 2013). Green roofs also use the technology for improving

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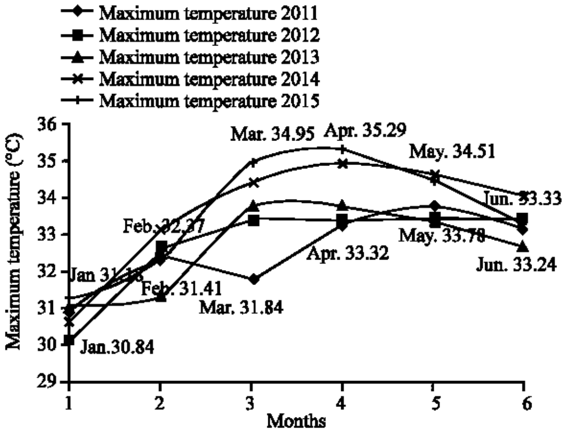


Fig. 1: Comparision of maximum temperature in January, 2011 until June, 2015 at Hatyai, Songkla, Thailand

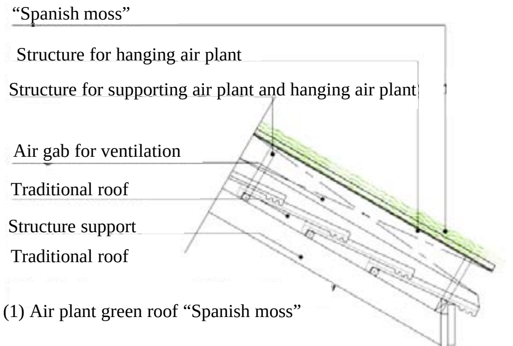
environmental quality (Lin *et al*., 2013; Clark *et al*., 2008; Mechelen *et al*., 2014) and climate change in cities (Williams *et al*., 2010; Garrison *et al*., 2012), urban ecosystem (Bianchini and Hewage, 2012ab; He and Jim, 2010), green infrastructure (Clark *et al*., 2008) and built environment (Benvenuti, 2014). The growing number of the expansion of green roofs came from environmental benefits, environmental awareness and ecological advantages (Nawaz *et al*., 2015; Berardi *et al*., 2014). Green roofs is one mitigation way for urban heat island effects (Jim and Peng, 2012). The evapotranspiration reduces heat (Poe *et al*., 2015; Marasco *et al*., 2015) and mass transfers (Ouldboukhitine *et al*., 2014a) due to transpiration of plants, soil and water irrigation (Ouldboukhitine *et al*., 2014b). The characteristics of passive technique by green roofs provide the influence parameters of heat transfer and evapotranspiration are leaf area index, fractional coverage, refection coefficient and stomatal resistance (Tan *et al*., 2015; Berardi *et al*., 2014; Saadatian *et al*., 2013). The barriers of green roofs through lifecycle cost analysis have been discussed in various studies before (Bianchini and Hewage, 2012) for example, the intensive of maintenance requirement (Coutts *et al*., 2013) irrigation system (Mechelen *et al*., 2015) construction cost (Carter and Keeler, 2008) waterproofing layer, substrate material, structure support and vegetation failure risks (Berardi *et al*., 2014). Air plant green roofs have been developed and designed as to decrease several barriers of green roof in hot and humid climate.

This study aims at studying, comparing and identifying multidisciplinary insights of the environmental benefits in air plant green roofs, both *Tillandsia usneoides* L. “Spanish moss” and *Tillandsia recurvifolia* Hooker “Cotton candy”. Furthermore, the objective of this study is trying to make a clear understanding and recognizing their potentials of environmental benefits of air plant green roofs.

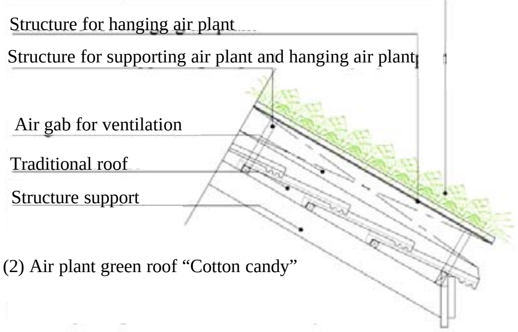
Fig. 2: 1) *Tillandsia recurvifolia* Hooker “Cotton candy” and 2) *Tillandsia useoides* L.“Spanish moss”

An overview on air plant green roofs: Sustainable development and environmental friendly are the major concepts of air plant green roofs. Air plants in the Crassulacean Acid Metabolism (CAM) have the outstanding characteristics of epiphyte rootless and xerophyte. *Tillandsia usneoides* L. “Spanish moss” and *Tillandsia recurvifolia* Hooker “Cotton candy” was chosen for the study in this study (Fig. 2). The selection criterias of air plant were considered from the qualifications of low plant weight, low construction, high weather resistance, low or zero maintenance, affordable price and convenient purchasing.

The main characteristics of air plant green roofs are the thickness of growing media which needs to be >10 cm. The construction technique has to be simple and easy for the installation and maintenance in both sloped roofs and traditional roofs. The weight of structures and plant should be lower than 5-10 kg/m^2. The roof is inaccessible area because of the sloped roof plant. The diversities and types of plants are quite limit because of the feature of lightweight structures, for example Spanish moss, cotton candy and other air plants. The drainage and irrigation system are not necessary because it can be utilized with the infrastructure of the original roof. The structure of air plant green roofs includes vegetation layer (Spanish moss or cotton candy), lightweight structure (welded wire mesh and hanging structure) and air gab between air plant and traditional roof. Air plant green roofs can be compatible with the developed techniques of modular system (Fig. 3). Leaf Area Index (LAI) of air plant depends on plant species. In this term, Spanish moss is colloquially called as air plant and grows up on hanging structures, wire or tree branch. It costs low maintenance cost because the foliage growth rate is very slow there is no aerial roots and the length is approximately 6 m. Spanish moss



(1) Air plant green roof "Spanish moss"



(2) Air plant green roof "Cotton candy"

Fig. 3: Structure of air plant green roofs both "Cotton candy" and "Spanish moss"

requires very little water and can absorb nutrients from the ambient air and rainfall. It is in the bromeliad family and Tillandsia genus.

The main characteristic of air plant green roofs is the double roof skin which can reduce an extreme of solar radiation and ambient air temperature. The air gab between air plant and material roof is a space for convection before entering into building. The shading of air plant can also extend the durability of roof materials.

MATERIALS AND METHODS

The method of this study consists of primary and secondary data. The primary data was conducted from both intensive and extensive green roofs. It can be collected from air plant green roofs of Spanish moss and cotton candy. The environment can obtain these benefits consequently.

RESULTS AND DISCUSSION

Environmental benefits of air plant green roofs: The installations of air plant green roofs can mitigate environmental problems and build environment in communities (Zuo and Zhao, 2014). In this study, the analysis of environmental benefits consists of several principle components (Fig. 4).

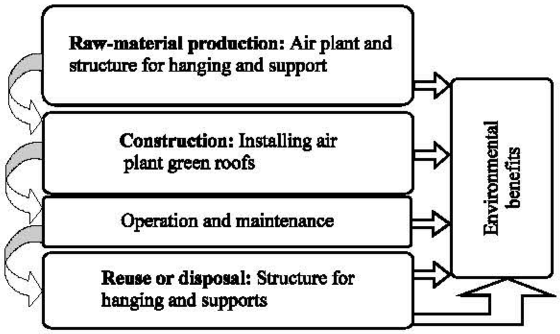


Fig. 4: Process flow analysis on environmental benefits of air plant green roof

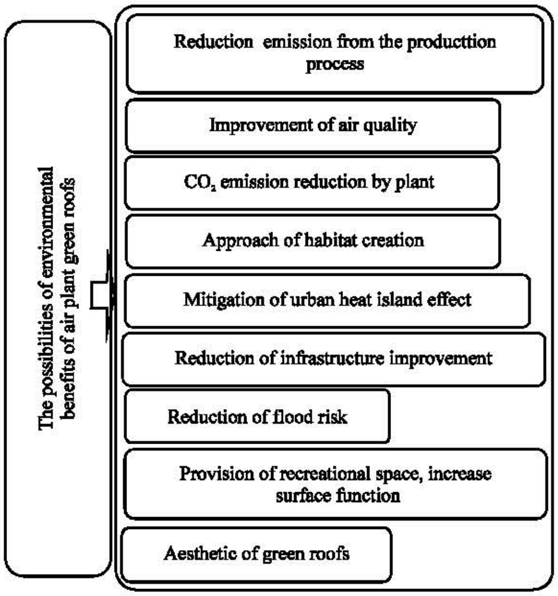


Fig. 5: Principle components analysis on environmental benefits of air plant green roofs

Moreover, it considers from resource usage and pollution reduction through the process of raw-material production, construction, operation or maintenance and reuse or disposal (Fig. 5 and Table 1).

Emission from the production process: Of air plant green roofs can be considered from the emitted toxic from raw-material (plant and structure) manufacturing, usage and disposal into environment. The goal of production process on green roofs is zero toxic emission. However, Bianchini and Hewage estimated the air pollution cost from different factors depending on material substrate that the total of air pollution cost for intensive green roofs is about 5.90-14.06 $/m^2 and extensive green roofs is (polymers layer) between 14.06-22.20 $/m^2 (Bianchini and Hewage, 2012). In this study, both types of air plant green

Table 1: Data of environmental value of air plant green roofs (Cotton candy and Spanish moss) from primary data

	Values ($\$/m^2$)		
Benefits	Cotton candy	Spanish moss	Types
Emission from production process	0.0587 One time	0.0587 One time	Cost
Improvement in air quality	4.43-11.08 Annual (Bianchini and Hewage, 2012)	1.53-3.83 Annual (Bianchini and Hewage, 2012)	Benefit
CO_2 emission by plant	0.55-0.65 Annual (Martin *et al*., 1981)	1.60-1.88 Annual (Martin *et al*., 1981)	Benefit
Approach of habitat creation	0-10.19 Annual (Bianchini and Hewage, 2012)	0-10.19 Annual (Bianchini and Hewage, 2012)	Benefit
Mitigation of urban heat island effect	4.72-6.61 Annual (Bianchini and Hewage, 2012)	4.72-6.61 Annual ((Bianchini and Hewage, 2012)	Benefit
Infrastructure improvement	7.80-25.80 One time (Evans, 2008)	7.80-25.80 One time (Evans, 2008)	Benefit
Reduction of flood risk	0.70-2.41 Annual (Bianchini and Hewage, 2012)	0.70-2.41 Annual (Bianchini and Hewage, 2012)	Benefit
Provision of recreational space	-	-	Benefit
Aesthetic of green roofs	8.86-13.29 Annual (Bianchini and Hewage, 2012)	2.30-3.83 Annual (Bianchini and Hewage, 2012)	Benefit

roofs use mild steel or low carbon steel as to cover the structure which can be reused for construction. Therefore, the related process of carbon emission depends on the source of steel and the carbon intensity of electricity generation (Birat *et al*., 1999). The scenario of intermediate steel industry in Thailand showed that, it can reduce the emission of GHGs. It was changed due to the ecological and economic new generation Arc furnace (ECOARC) during 2011-2030 (Kerdporn and Wangjiraniran, 2013). The demanded amount of covering steel structure is about 4.19 kg/m^2. Lars Mathiesen illustrated the CO_2 emissions of Asia in 1995 as 0.7 per ton of crude steel (Koo *et al*., 2014) while the Kyoto protocol considered the carbon tax at 20 $/ton of CO_2 emission. Therefore, the CO_2 emission cost of air plant green roofs is fluctuated around 0.0587 $\$/m^2$.

Improvement of air quality: The polluted substances on green roofs are NO_2, SO_2, CO, PM_{10} and O_3 (Currie and Bass, 2008). The improvements of air quality relate to the physical and mental health outcomes of the human in urban dwelling directly (Bonnefoy, 2007). Yang had quantified the removal level of air pollution on green roofs in Chicago for one year that it contains of 52% of O_3, 27% of NO_2, 14% of PM_{10} and 7% of SO_2 (from 1,675 kg in 19.8 ha) (Wu *et al*., 2014). Bianchini and Hewage (2012) made an estimation on the air quality improvements of green roofs by considerating the quantity of nitrate, dust and particulate in the air. This research also calculated the air quality benefits of green roofs, the result stayed between 0.025 and 0.03 $\$/m^2$ (Bianchini and Hewage, 2012). Spanish moss and Cotton candy air plant improve air quality with photosynthesises and air filtrations from the use of carbon dioxide, toxicant, heavy metal and dust as its nutrient (Srivastava, 2012). Moreover, the toxicants in the air and water can be removed from metabolism process. The environmental benefits of air quality on air plant green roofs was estimated and considered from the amount of toxicant, nitrates, heavy metal and dust. The benefit of initial cost of air quality was about 2-5%. Therefore in term of production cost, benefit of "Cotton candy" is around 4.43-11.08 $\$/m^2$ and "Spanish moss is between 1.53-3.83 $\$/m^2$.

The reduction of CO_2 emission: By plant had different potential according to the types of the plants (Getter and Rowe, 2006). According to the Kyoto protocol in 2008, it accounted for the CO_2 emission manual and also stated that carbon tax reduction was 20 $/ton. Bianchini and Hewage (2012) illustrated the intensive and extensive green roofs which could deduct the carbon reduction tax as 1.4-1.7E-4 $\$/m^2$. Martin and Siedow described that the CO_2 reduction by Spanish moss in daytime is approximately 25%. They also indicated a wide range of temperature, irradiance and water content. The high rate of CO_2 affected the increasing humidity rate relatively especially at night time. Consequently, 1 m^2 of Spanish moss green roofs areas can reduce the CO_2 rate about 0.0072 and 0.0085 kg (Martin and Siedow, 1981). Therefore, the carbon reduction benefit of both air plant green roofs can be estimated as 1.60-1.88 $\$/m^2$ for Spanish moss and 0.55-0.65 $\$m^{-2}$ for Cotton candy.

Approaches for habitat creation: On green roofs have particularly outstanding benefits for biodiversity, restoration ecosystem and reduction of habitat loss (Porsche and Kohler, 2003; Blank *et al*., 2013). Portland city has invested approximately 275,000 $/acre as to increase natural habitats (Evans, 2008). At present, community areas have to face with various problems, i.e., traffic, building construction and human-made environment. Furthermore, green roof can protect species and create natural habitats for small animals such as bird, butterfly, insect and bee (Carter and Keeler, 2008; Coutts *et al*., 2013). Bianchini and Hewage made an estimation about the increasing number of habitat creation. They said that it will approximately benefit 30% of intensive green roofs at 0-20.4 $\$/m^2$ and 15% of extensive green roofs between 0-10.2 $\$/m^2$ (Bianchini and Hewage, 2012). The habitat creation benefit of air plant green roofs assumed to be 15% for both cotton candy and Spanish moss. Therefore, in term of habitat creation on air plant green roofs, its benefit can go from 0-10.19 $\$/m^2$.

Mitigation of urban heat Island effect in city: The growth of urbanizations, building and infrastructure lead to the increasing of urban heat Island effect (Ouldboukhitine *et al*., 2014a, b). Normally, city center has higher air temperature than the surface temperature in rural or suburban (Coutts *et al*., 2013). The albedo from construction surface such as building, concrete and asphalt has typically ranged between 0.1-0.2 (Kiesel *et al*., 2012) which is lower than green roofs (the albedo of green roofs range from 0.7-0.85) (Rosenzweig *et al*., 2006). One of mitigation strategies of urban heat island effect is the utilization of green roofs (Zinzi and Agnoli, 2012; Gagliano *et al*., 2015). Trees and plant roofs can reduce temperature. It surely can lead to the reduction of the energy demanding on heating and cooling systems (Carter and Keeler, 2008). Bianchini and Hewage (2012) considered the mitigation benefit of urban heat Island effect on green roofs at 8.3 and 1.2E-3 $/m^2. In this case, the estimation of UHI phenomenon in these air plant green roofs is at 10-14% of the energy consumption in residential buildings (Zinzi and Agnoli, 2012). Moreover, the estimation of the benefit value is between 4.72 and 6.61 $/m^2.

Reduction of infrastructure improvement: From green roofs is a social benefit on the stormwater management in the city which can decrease infrastructure both operation and maintenance in municipality (Lee *et al*., 2013; Getter *et al*., 2009). Green roofs can reduce pressure from the storm water in drainage system in city area during the peak flow period. In addition, it can decrease the amount of rainwater runoff in city and neighborhood (Kohler and Poll, 2010). The infrastructure costs for stormwater management in Portland city valued at 30 $/m^2 per year. The benefit of stormwater volume reduction from green roofs can be estimated between 25 and 86% (Evans, 2008). In this study, both air plant green roofs are considered the annual benefit for saving the infrastructure costs in city from 7.80-25.80 $/m^2.

Reduction of flood risk: On green spaces can reduce the damage to life, property and economic in cities and countries. Obviously, the growth of urbanization results in the decreasing of green surface such as tree, park and forest. It was widely known that the green space can support the stormwater runoff in urban areas. Furthermore, World Bank considered the loss in the worst flood disaster in Thailand, 2011 to be up to B1, 356 billion ($40,419 million) The city of Portland also discussed about the adsorption capacity of water runoff from green roofs at 26-86% of rainwater. Bianchini and Hewage (2012) calculated the green roofs benefit of flooding reduction from 7.1-2.4E-3 $/m^2. Therefore, cotton candy and Spanish moss could save in term of money to reduce flood risk between 0.70-2.41 $/m^2.

Provision of recreational space and increase surface function: Of green roofs or living roofs are the potential of intensive green roofs (Saadatian *et al*., 2013). It can support the reduction of green space and increase the quality of life in city. The value of recreational spaces on intensive green roofs can resemble with public parks (Garrison *et al*., 2012). From the study, the intensive green roofs in the City of Toronto can improve green area in city approximately at 20 $/m^2 (De Sousa, 2003). On the other hand, air plant green roofs and extensive green roofs cannot provide the provision of recreational space for the approaching of human activities. In this case, occupants in urban area and surrounding buildings could receive the comfortable of sight visual perception from the slope of green roofs. It provides human wellbeing related to the visual comfort and associated view which are spiritual values (Feng *et al*., 2015).

Aesthetic: Of green roofs came from the enhancing between the built environment of facade building and the green city. One of the major principles of architectural design is aesthetic aspects. On the other hand, aesthetic value are hard to defy or make an estimation, since its value comes from personal appreciation or decision. Commission for Architecture and the Built Environment (CABE) in England realized the importance of aesthetic value. Projects on creating built environment such as architecture, urban design and public space are introduced. Parks and green spaces are the alternative to provide amenities and enhancing people's quality of life. The identification of the aesthetic value depends on the willing to pay. The aesthetic value of building that is adjacent to the park in city can increase the rising of property value around 6%. The building that has the perspective of green space will increase the price up to 8% of property value. Respectively, the property that located close to green space and has directly green perspective can increase the value of building from 7.3-11.3%. Bianchini and Hewage (2012) assumed the probabilistic of aesthetics benefit for intensive green roofs from 5-8% of initial construction cost and the addition value between 8.3- 43.2 $/m^2. For extensive green roofs, it is estimated from 2-5% of property value and the increased of property value could be from 2.6-8.3 $/m^2 (Bianchini and Hewage, 2012).

CONCLUSION

The evaluation of aesthetic value on air plant green roofs has different assumption because the physical descriptions of plants are different. Distinctively, cotton candy plants have silver white leaves and largely bloom pink flowers once time per year, the diameter of cotton candy is about 13-15 cm. The flowers of Spanish moss are very tiny and inconspicuous bloom. The flowers of air plants profit to aesthetic value therefore it can increase the value of property. In this study, the aesthetics value of cotton candy considered the value higher than Spanish moss. The aesthetics benefit of Cotton candy estimated between 4-6% of initial's cost of air plant. Therefore, the addition value of cotton candy estimated from 8.86-13.29 $/m^2. Consecutively, Spanish moss estimated from 3-5% of property value or from 2.30-3.83 $/m^2.

ACKNOWLEDGEMENTS

This research was partially supported by the Higher Education Commission, Thailand and Faculty of Architecture, Rajamangala University of Technology Srivijaya. The researcher really appreciates for the help and support from Mr. Wannat Hirunchulha, the Director of Songkla Inland Fisheries Research and Development Center and the colleagues for the research facilities and experimental location.

REFERENCES

Agboola, O.P., S.D. Zakka and M.S. Zango, 2015. Towards sustainability of open space's planning and management in Nigeria: The role of science and technology. J. Technol. Sci. Eng., 77: 51-57.

Benvenuti, S., 2014. Wildflower green roofs for urban landscaping, ecological sustainability and biodiversity. Landscape Urban Plann., 124: 151-161.

Berardi, U., G.A. Hoseini and G.A. Hoseini, 2014. State of the art analysis of the environmental benefits of green roofs. Appl. Energy, 115: 411-428.

Bianchini, F. and K. Hewage, 2012a. How green are the green roofs? Lifecycle analysis of green roof materials. Buil. Environ., 48: 57-65.

Bianchini, F. and K. Hewage, 2012b. Probabilistic social cost-benefit analysis for green roofs: A lifecycle approach. Build. Environ., 58: 152-162.

Birat, J.P., J.P. Vizioz, D.D.L. Pressigny, Y.M. Schneider and M. Jeanneau, 1999. CO2 emissions and the steel industry's available responses to the greenhouse effect Rev. Metall. Cah. Inf. Tech., 96: 1203-1216.

Blank, L., A. Vasl, S. Levy, G. Grant and G. Kadas *et al*., 2013. Directions in green roof research: A bibliometric study. Build. Environ., 66: 23-28.

Bonnefoy, X., 2007. Inadequate housing and health: An overview. Int. J. Environ. Pollut., 30: 411-429.

Carter, T. and A. Keeler, 2008. Life-cycle cost benefit analysis of extensive vegetated roof systems. J. Environ. Manage., 87: 350-363.

Chan, A.L.S. and T.T. Chow, 2013. Evaluation of overall thermal transfer value for commercial buildings constructed with green roof. Appl. Energy, 107: 10-24.

Chen, C.F., 2013. Performance evaluation and development strategies for green roofs in Taiwan: A review. Ecol. Eng., 52: 51-58.

Clark, C., P. Adriaens and F.B. Talbot, 2008. Green roof valuation: A probabilistic economic analysis of environmental benefits. Environ. Sci. Technol., 42: 2155-2161.

Coutts, A.M., E. Daly, J. Beringer and N.J. Tapper, 2013. Assessing practical measures to reduce urban heat: Green and cool roofs. Build. Environ., 70: 266-276.

Currie, B.A. and B. Bass, 2008. Estimates of air pollution mitigation with green plants and green roofs using the UFORE model. Urban Ecosyst., 11: 409-422.

De Sousa, C.A., 2003. Turning brownfields into green space in the city of Toronto. Landscape Urban Planning, 62: 181-198.

Evans, D., 2008. Cost benefit evaluation of ecoroofs. City Portland Bur. Environ. Serv., 20087: 1-22.

Feng, C., H. Zheng, R. Wang, X. Yu and Y. Su, 2015. A novel solar multifunctional PVTD system for green building roofs. Energy Convers. Manage., 93: 63-71.

Fernandez, C.R., T. Emilsson, F.C. Barba and M.A.H. Machuca, 2013. Green roof systems: A study of public attitudes and preferences in Southern Spain. J. Environ. Manage., 128: 106-115.

Gagliano, A., M. Detommaso, F. Nocera and G. Evola, 2015. A multi-criteria methodology for comparing the energy and environmental behavior of cool, green and traditional roofs. Build. Environ., 90: 71-81.

Garrison, N., C. Horowitz and C. Lunghino, 2012. Looking up: How green roofs and cool roofs can reduce energy use. Address Climate Change, Protect Water Resources, Southern California.

Getter, K.L. and D.B. Rowe, 2006. The role of extensive green roofs in sustainable development. HortScience, 41: 1276-1285.

Getter, K.L., D.B. Rowe, G.P. Robertson, B.M. Cregg and J.A. Andresen, 2009. Carbon sequestration potential of extensive green roofs. Environ. Sci. Technol., 43: 7564-7570.

He, H. and C.Y. Jim, 2010. Simulation of thermodynamic transmission in green roof ecosystem. Ecol. Modell., 221: 2949-2958.

Jim, C.Y. and L.L. Peng, 2012. Substrate moisture effect on water balance and thermal regime of a tropical extensive green roof. Ecol. Eng., 47: 9-23.

Kerdporn, K.W. and A.S. Wangjiraniran, 2013. Potential of greenhouse gas emission reduction by using ECOARC technology in intermediate steel industry in Thailand. Energy Res. Inst., 10: 16-31.

Kiesel, K., K. Orehounig, S. Shoshtari and A. Mahdavi, 2012. Urban heat island phenomenon in Central Europe. Proceeding of the 1st International Conference on Architecture and Urban Design, April 19-21, 2012, Epoka University, Tirana, Albania, pp: 821-828.

Kim, C.J., J. Kim, T. Hong, C. Koo and K. Jeong *et al*., 2015. A program-level management system for the life cycle environmental and economic assessment of complex building projects. Environ. Impact Assess. Rev., 54: 9-21.

Kim, J., T. Hong, J. Jeong, C. Koo and K. Jeong, 2016. An optimization model for selecting the optimal green systems by considering the thermal comfort and energy consumption. Appl. Energy, 168: 682-695.

Kohler, M. and P.H. Poll, 2010. Long-term performance of selected old Berlin greenroofs in comparison to younger extensive greenroofs in Berlin. Ecol. Eng., 36: 722-729.

Koo, C., S. Park, T. Hong and H.S. Park, 2014. An estimation model for the heating and cooling demand of a residential building with a different envelope design using the finite element method. Appl. Energy, 115: 205-215.

Lee, J.Y., H.J. Moon, T.I. Kim, H.W. Kim and M.Y. Han, 2013. Quantitative analysis on the urban flood mitigation effect by the extensive green roof system. Environ. Pollut., 181: 257-261.

Lin, B.S., C.C. Yu, A.T. Su and Y.J. Lin, 2013. Impact of climatic conditions on the thermal effectiveness of an extensive green roof. Build. Environ., 67: 26-33.

Marasco, D.E., P.J. Culligan and M.W.R. Gillis, 2015. Evaluation of common evapotrans piration models based on measurements from two extensive green roofs in New York city. Ecol. Eng., 84: 451-462.

Martin, C.E. and J.N. Siedow, 1981. Crassulacean acid metabolism in the epiphyte Tillandsia usneoides L. Spanish Moss responses of CO2 exchange to controlled environmental conditions. Plant Physiol., 68: 335-339.

Mechelen, V.C., T. Dutoit and M. Hermy, 2014. Mediterranean open habitat vegetation offers great potential for extensive green roof design. Landscape Urban Plann., 121: 81-91.

Mechelen, V.C., T. Dutoit and M. Hermy, 2015. Vegetation development on different extensive green roof types in a mediterranean and temperate maritime climate. Ecol. Eng., 82: 571-582.

Nawaz, R., M.A. Donald and S. Postoyko, 2015. Hydrological performance of a full-scale extensive green roof located in a temperate climate. Ecol. Eng., 85: 66-80.

Ouldboukhitine, S.E., G. Spolek and R. Belarbi, 2014a. Impact of plants transpiration, grey and clean water irrigation on the thermal resistance of green roofs. Ecol. Eng., 67: 60-66.

Ouldboukhitine, S.E., R. Belarbi and D.J. Sailor, 2014b. Experimental and numerical investigation of urban street canyons to evaluate the impact of green roof inside and outside buildings. Appl. Energy, 114: 273-282.

Peng, L.L. and C.Y. Jim, 2013. Green-roof effects on neighborhood microclimate and human thermal sensation. Energies, 6: 598-618.

Poe, S., V. Stovin and C. Berretta, 2015. Parameters influencing the regeneration of a green roof's retention capacity via evapotranspiration. J. Hydrol., 523: 356-367.

Porsche, U. and M. Kohler, 2003. Life cycle costs of green roofs a comparison of Germany, USA and Brazil Ulrich, RIO3-World Climate. Energy Event, 2003: 1-5.

Rosenzweig, C., S. Gaffin and L. Parshall, 2006. Green roofs in the New York metropolitan region: Research report. Masters Thesis, Center for Climate Systems Research, NASA Goddard Institute for Space Studies, Columbia University, New York, Manhattan.

Saadatian, O., K. Sopian, E. Salleh, C.H. Lim and S. Riffat *et al*., 2013. A review of energy aspects of green roofs. Renewable Sustainable Energy Rev., 23: 155-168.

Santamouris, M., 2014. Cooling the cities a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Solar Energy, 103: 682-703.

Srivastava, J., 2012. Environmental Contamination. InTech, Rijeka, Croatia,.

Suleiman, J.H.S., N.M. Balubaid, E.E.I. Zakari, 2015. Dewelling factors effect on residental building energy consumption. J. Technol. Sci. Eng., 77: 41-45.

Takebayashi, H. and M. Moriyama, 2007. Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. Build. Environ., 42: 2971-2979.

Tan, C.L., N.H. Wong, P.Y. Tan, S.K. Jusuf and Z.Q. Chiam, 2015. Impact of plant evapotranspiration rate and shrub albedo on temperature reduction in the tropical outdoor environment. Build. Environ., 94: 206-217.

Williams, N.S.G., J.P. Rayner and K.J. Raynor, 2010. Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia. Urban For. Urban Green., 9: 245-251.

Wu, W., H. Yang, D. Chew, Y. Hou and Q. Li, 2014. A real-time recording model of key indicators for energy consumption and carbon emissions of sustainable buildings. Sensors, 14: 8465-8484.

Zinzi, M. and S. Agnoli, 2012. Cool and green roofs: An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. Energy Build., 55: 66-76.

Zuo, J. and Z.Y. Zhao, 2014. Green building research current status and future agenda: A review. Renewable Sustainable Energy Rev., 30: 271-281.