The Potential of Applying Green Wall in Dense Urban Areas: Case Study - University of Jordan Street

Khaled Al-Omary [1], Muna Alsukkar [2]

[1.] Department of Architecture, University of Jordan, Amman, Jordan
[2.] Department of Architecture, University of Jordan, Amman, Jordan
alsukkarmuna@gmail.com

Abstract: Green wall is a promising technology and a new design strategy for sustainable building, considered a solution for modifying the urban microclimate and mitigating urban heat island by minimizing the continuous rising temperature in city cores and dense areas, the space available for greening is very limited and green wall can be applied to the exterior facades of the buildings. The study aims to provide with the impacts of the green wall thermal performance for building in dense area of Amman like the university of Jordan street-Queen Rania Al-Abdullah street and count thermal advantages bring by green wall system in comparison to the existing conventional system, the study suggests a green wall building façade design for the existing buildings front of the main gate of university of Jordan side of mixed use building, based on the computer simulation results for the existing construction. The results indicated that the effect of green wall on the building façade succeeds in lowering the urban heat island effects and enhancing comfort at the urban level, reducing the external temperature in dense urban areas, this could be generalized to dense areas where the climatic conditions and building characteristics are quite similar to the study area in this paper.
[Khaled Al-Omary, Muna Alsukkar . **The Potential of Applying Green Wall in Dense Urban Areas: Case Study - University of Jordan Street .** *J Am Sci* 2017;13(8):77-84]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 9. doi:10.7537/marsjas130817.09.

Keywords: Amman, University of Jordan Street; climate change; urban heat island UHI; building façades; green wall,; computational fluid dynamics (CFD).

1. Introduction

Climate change which it's impact's in Jordan are already taking place. (Solh, 2010) (Abdulla, 2004) Climate change is defined as "a change which is attributed directly or indirectly to human activity. (IPCC, 2007) Urbanization if haphazard can increase the urban temperature, energy use, carbon emissions, pollutants, municipal water demand, ozone level and human discomfort and diseases. (Simpson, 2002) City centers are affected from the Urban Heat Island (UHI) that is resulting from the small portion of trees and vegetation in cities and from the darker surfaces which are responsible for the large solar radiation absorbance. the environmental impact of such transport habits, as a Jordanian case, the Jordanian summer maximum temperature in average 32o C for the highlands and 38o C for the Jordan valley and eastern deserts, winter temperature from 1-17o C in highlands and desert area, 8-21o C in Jordan Valley, also about 85% of Jordan total area is a desert (MOA, 2009), If climate change continues at its current pace, the Kingdom is expected to witness a 1-2°C increase in temperatures by 2030-2050, resulting in transformation of semi-arid lands, some 80% of the country's total area, into arid deserts, according to environment experts (Namrouqa, 2009) and that's all due to the increasing population in Jordan as shown in table (1). By one estimate being that for each passenger in the city need 17 trees every year to cover our annual CO2 emissions of 1,464.4kgs. 51 million trees need to be planted every year in Amman to cover transport emissions (Hamdan, 2016) but sadly there are limited available spaces especially in a dense area in Amman. Appropriate urban policies must therefore be activated innovating the manner in which buildings and cities are designed, constructed and managed in order to improve their performance in energy use (Zanon, B., And Verones, S., 2013).

Table 1. Some environmental facts in Jordan, Source; (DOS, 2011)

Year	**2007**	**2012**	**2015**	**2020**
Population (Million)	5.72	6.31	6.64	7.14
Domestic Needs (MCM)	295	328	347	377
Industry & Remote Areas	65	77	100	120

Greenery can improve urban, green roofs and green walls have direct impacts on the urban environment, they can improve building performance mainly for space cooling in certain circumstances (Castleton, 2010) However, the limited space for greening on rooftop leads to the application of vertical greenery in densely populated urban areas. Actually, it is not a new concept when using green walls for decorating and cooling a building during hot summer. In recent decades, vertical greenery has attracted an increasing attention as it can contribute to preventing the urban areas from changing into a deteriorated environment and adjusting urban microclimate (C.Y. Cheng, 2010) The use of plants attached to the building walls is a bioclimatic strategy that has grown in popularity due to the savings in building energy consumption, using vegetation on building walls is an effective passive design strategy that has benefits at the urban, building, and human scales. At the urban scale, this strategy mitigates the heat island effect and reduces the CO2 emissions (E. Alexandri, 2008). The microclimate could be adjusted by the plant-covered layer acts like a solar barrier that would reduce the absorption of solar energy by reflecting the incident solar radiation. Furthermore, plant-covered walls not only could offer the thermal comfort within a building (P. Sunakorn, 2011), but also could restrict the wind effect and manage the humidity of the building environment (K. Kontoleon, 2010). Thus, vertical greenery offers an alternative way to overcome the open land scarcity due to its flexible shape, aesthetic value and heat island mitigation impact (C.Y. Cheng, 2010). And there are other several benefits, lowering energy consumption and greenhouse gas emissions, Reduction of UHI, improving air quality, reduction of noise pollution and improvement of health and well-being.

1.1 Green wall definition

Green walls are walls that are either partially or completely covered with vegetation, Green wall, green façade, living wall, and vertical green and vertical garden are descriptive terms that are used to refer to all forms of vegetated wall surfaces (Ottele M, 2011).

According to their growing method, there are two major categories, namely: “support” and “carrier”. The support systems use some structures to assist plants upwards while carrier systems are installed on the vertical surface with the media. The support systems are commonly termed as “green facades” and the carrier is called “living wall” (Jaafar et al., 2011).

Green façades are walls that are covered with climbing plants or cascading vegetation. At first, builders make climbing plants climb directly on walls. But recently, they usually build supportive frameworks and make plants climb on them for fear that the root systems of some plants will harm the structure of the building, Living walls, also called bio-walls or vertical gardens, are made with three parts: a metal frame, a PVC layer and an air layer (do not need soil). Due to its extremely light weight, we can build it almost everywhere and in any sizes. The living wall system supports several of plant kind; this system needs more protection than green wall for the reason of vegetation density and diversity. Therefore, researchers developed a special system, self-automated watering and nutrition system, to make maintenance of the living walls easy, living wall contains modular and continuous. Modular living wall consists of planting boxes arranged on the vertical surfaces of buildings. The plant box has growth supply and can be replaced regularly. Continuous living walls are known as Vertical Gardens. The continuous living walls are the combination of modular living walls (Wise GEEK, What are green walls?), living walls can be internal or external to the building envelope and can be broadly classified into three systems (Susan, 2008).

-Panel system: which are comprised of pre-planted panels that are brought on site and connected to the structural system and the mechanical watering system.

-Felt system: where the plants fitted into felt pockets of growing medium and attached to a waterproofed backing which is then connected to structure behind.

-Container/trellis system: where plants grown in containers climb onto trellises, irrigation drip-lines are usually used in it to control watering system.

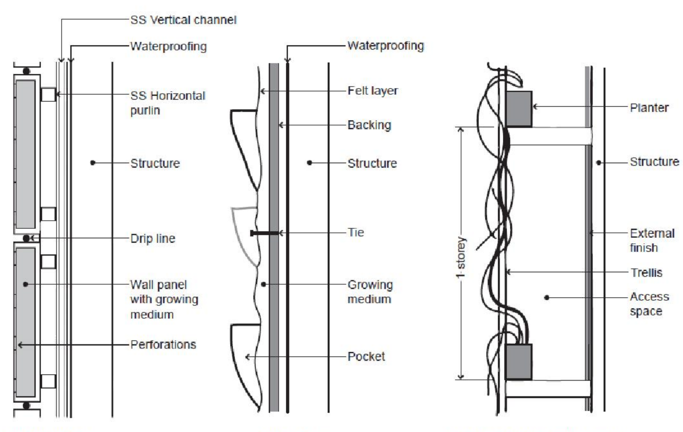

Figure 1. The three generic living wall systems (Source: Susan Loh. Drawing by M. Murray)

2. Literature review

Green facades have historically been used in buildings and more researches have been found in green facade than the LWS. Since they do share some similar features, researches on green facade are also useful for understanding the LWS. This a review on both fields is performed.

Green facade

Prez et al. (G. Prez, L. Rincn, A. Vila, J.M. Gonzlez, L.F. Cabeza, 2011) verified that a microclimate between the wall of the building and the green facade is created, and it is characterized by slightly lower temperatures and higher relative humidity. Kontoleon and Eumorfopoulou (K. Kontoleon, E. Eumorfopoulou, 2010) found that the influence of a green layer of the wall surface is more pronounced for east or west oriented surfaces. Wong et al. (N.H. Wong, 2009) performed a simulation research and found that green facade is able to lower the mean radiant temperature values and that 50% greenery coverage and a shading coefficient of 0.041 can reduce the envelope thermal transfer value of a glass facade building by 40.68%. Sunakorn and Yimprayoon (P. Sunakorn, C. Yimprayoon, 2011) studied climbing plants as vertical shading devices for naturally ventilated building in terms of influencing air temperature and wind velocity. The indoor air temperature of the bio facade room remains lower than the control room during daytime. The bio facade also improves ventilation for a naturally ventilated room. Perini et al. (K. Perini, M. Ottel, A. Fraaij, E. Haas, R. Raiteri, 2011) studied the difference between the green facade attached directly to the wall and the green facade attached indirectly to the wall (with an air gap). A small temperature reduction of 1.2 ◦C was found on the surface of the wall behind the direct green facade compared to the surface of the bare wall, and a reduction of 2.7 ◦C was found in the indirect greenery system.

The LWS

Wong et al. (N.H. Wong, A.Y.K. Tan, Y. Chen, K. Sekar, P.Y. Tan, D. Chan, K. Chiang, N.C. Wong, 2010) studied eight different LWS and green facades installed on free standing concrete walls. The LWS with modular panels showed a better capacity in reducing the temperature of the wall surface and having the lowest diurnal range of average wall surface temperature fluctuation, comparing to the green facade. The maximum reduction of the wall surface temperatures by the cooling effect of the LWS is 11.58 ◦C. Olivieri et al. (F. Olivieri, F.J. Neila, C. Bedoya, 2010) studied a LWS in an experimental building and found that during diurnal hours, the indoor temperature of the LWS was 20% lower and had a smaller fluctuation than the temperature in the space without vegetation. Perini et al. (K. Perini, M. Ottel, A. Fraaij, E. Haas, R. Raiteri, 2011) showed the potential of the LWS in reducing the wind velocity around building facades: a decrease from 0.56 m/s to 0.10 m/s starting from 10 cm in front of the facade of the air cavity. Alexandri and Jones (E. Alexandri, P. Jones, 2008) simulated the thermal effects of green roof and green walls on the urban environment. Simulated results show that green walls have a stronger effect than green roofs inside the urban canyon. The combination of both green roofs and green walls could bring temperatures down to more comfortable levels and achieve energy saving for cooling buildings from 32% to 100%. In sum, existing research about the green facade and the LWS shows that both the systems have great potential in reducing building surface temperatures, promoting energy saving, as well as mitigating Urban Island Effect. No existing research has studied the thermal environment of the microclimate between the LWS and the wall, nor explained the mechanism of its cooling effect.

3.1 Study Problem:

Jordan is challenging climate change, environmental crises and energy saving issues, all this make architects, engineers and planners are slowly beginning to realize the necessity of green architecture where new sustainable strategies and technologies started to emerge in terms of green buildings such as green walls which are considered a new prospect for the phenomenon of urban heat island and energy conservation aspects understand the importance of, from this point, Jordan must seek new sustainable planning approaches.

In respect for many researchers discussed the importance of urban vegetation role in heat island mitigation, this research will display the meanings, the advantages and the techniques of the green wall as a part of the sustainable strategy for the urban context in Amman. Modelling of green wall systems on the facades of buildings in the study area will be developed for assessing their thermal performance of reduced external temperature in urban areas.

3.2 Study Objectives:

The objective of this study is to highlight a modeling approach to assess the thermal impacts of green wall, and try to give solution adopted for any purpose by architects and town planners by reconstructing new technology for facade based on environmental factors where this research examines an analytical study in street of university of Jordan to implement the green wall in façade of the street elevation. In order to reduce the Urban Heat Island Effect represented by external temperature in urban areas.

This study assumes that; on an urban scale properly green wall cladding for the existing façade of the street can reduce summertime external temperature in a dense area via evapotranspiration, in addition reduce carbon emissions both directly and indirectly.

4. Materials and Methods

4.1 Introduction to the study area

Table 2. Climatic data for Amman city (1975–2006). Source: (Abdel-Aziz & Al-Kurdi, 2014)

Month	Average minimum daily temperature (°C)	Average maximum daily temperature (°C)
January	4	12
February	4	13
March	6	16
April	9	23
May	14	28
June	16	31
July	18	32
August	18	32
September	17	31
October	14	27
November	10	21
December	6	15

Amman is the most densely populated regions in Jordan with 38% of the total population live there (Abdel-Aziz & Al-Kurdi, 2014). It is challenging problem of UHI effect. This challenge alongside rapid population growth and traffic problems are putting Amman in a huge problem concerning urban sprawl and sustainability. While the amount of forest and tree cover in the Greater Amman Municipality (GAM) accounts for less than 1% of total land, if both natural and planted areas are included (GAM, 2008). Amman must find suitable solutions to protect and restore environmental quality. The green wall is a helpful sustainable strategy; integrated the green wall system into the existing building facades could be part of the solution to social and environmental problems. Table (2) below summarizes the climatic data for Amman city. This study will focus only on summer season, specifically on a hot day in June; because what is expected from such study is to figure out the amount of reduction in external temperature.

4.2 Study area:

The study area is located in Amman, Jubaiha district, Queen Rania Al-Abdalla Street, opposite to the main gate of the university of Jordan, with coordinates 32°00′54.5″N 35°52′07.9″E. It is located within 1 km of the city center and therefore it is under the UHI effect. It experiences hot summer with a number of days where peak air temperatures exceeding 53°C, check Table (2). The site includes numbers of adjacent test buildings that are fairly similar characteristics (areas and material), see Figure (2) below. And there is no tree appearance and there is no space for planting trees in the study area, Buildings distribution on the site, setbacks from the street and street building façades are illustrated in Figure (3).

Figure 2. Study area Queen Rania Al-Abdalla street, Amman. Source: (Google earth, 2016).

Figure 3. Street Elevation of the Study area. Source: (The Authors, 2016).

4.3 Study area selection criteria:

The study area was chosen for a number of reasons; (1) it should be located within the city center and under the UHI effect. Armson, Stringer and Ennos (2012) clarified that an area located within 3 km of the city center will still be under the UHI effect, (2) the availability of data needed for modeling and simulation (building height, material, age and orientation, lot size, tree characteristics, etc), (3) the study area is preferred to be flat, relatively void of topographical features which could seriously affect the simulation results, (4) a good representative of

Mixed use, since this study targets dense areas with heavy transportation and traffic, (5) the study area with virtually no tree cover or spaces to propose green cover by planting trees, and (6) the study area must typically experience warm summers.

5. Methodology and research methods:

This study is intended to measure the effect of green wall on the external temperature reduction in urban areas which has the urban heat island effect. In order to fulfill the main research objectives; (1) study area selection based on the discussed criteria It was conducted at Amman, Jubaiha district, Queen Rania Al-Abdulla Street opposite to the main gate of the university of Jordan; (2) characterizing the existing buildings' facades within the study area through site visits and aerial photographs derived from Google earth; (3) collecting data about buildings materials and construction through observation; Methodology constitutes of three main steps; (1) design a new model on the existing test selected two buildings' facade where located in the study area to investigate the impact of green wall on thermal performance and its role in reducing the external urban temperature and generalize the results on the other buildings in the study area that fairly similar characteristics (areas and material) (2) analyze data to judge if the results support the study hypothesis or not and (3) finally the study will set up recommendations for professional concerned.

5.1. Simulation tools:

(1) Building characteristics (material, height,... Etc.) And (2) suggested green wall on facades will be added; the Autodesk® Re8vit® Architecture software will be used for modeling then computational fluid dynamics (CFD) software will be used, in order to; (a) stimulate the thermal performance and external temperature before and after applying the proposed green wall; (b) generate realistic results that would be confirmed by measured data.

Autodesk® Revit® Architecture software was used in modeling phase for some reasons; to model the real condition of the site and buildings (including the layers of walls specifically the elevations, because this study is focused on the evaluation of an existing site and condition, ensuring the reality of evaluation and simulation is critical. Additionally, Revit can pass the geometry, as well as the thermal properties of materials and other variables, into the analysis software like computational fluid dynamics (CFD) file format. While computational fluid dynamics (CFD) was selected in this study for several reasons; (1) it has the ability to flexibly import models from Autodesk Revit Architecture, (2) it is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows by simulating the interaction of liquids and gases with surfaces (3) manufacturer use this software in order to predict the performance of the products before manufacturing and (4) it can stimulate what this study is looking for. (Computational fluid dynamics) (Autodesk CFD).

5.2. Simulation Structure

In order to study the relation between external temperature reduction and green wall in summer, and after simulation tools being selected and simulation variables were addressed this structure was designed:

(1) Modeling the real condition of the study area using Autodesk R Revit R Architecture software. (2) Perform simulations with computational fluid dynamics (CFD) software. (3) Insert the climatic data, including temperatures, and solar radiation June was chosen to be studied for the summer season (4) Simulates the ambient temperature for the current situation of the study area. (5) Locating green wall with modification in respect to the study area see Figure (6) specify the material properties (7) design the conditions of analysis by entering temperatures during the day and making It changeable every two hours. (8) The coordinates of the location in order to study the solar radiation and temperature accurately simulates reality (9) Addition the analysis information: solving, and make the study of temperature variable for the time: transient, it is considered that the study periods will be every half hour and an average of two trials each period, to get fast and accurate results (10) start the process of analysis and get results, and start identifying them. (11) The effects of the suggested green wall on external temperature reduction will be calculated.

Figure 4. The suggested green wall to the street elevations of the Study area. Source: (The Authors, 2016).

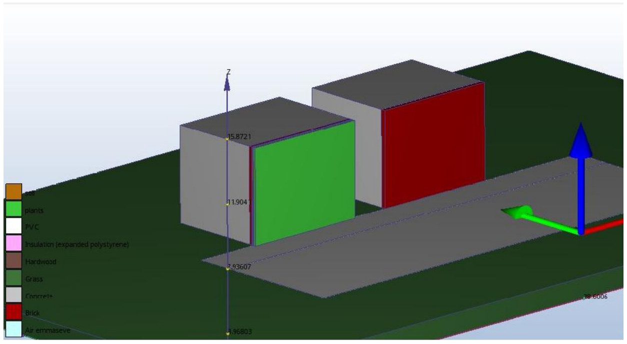

Figure 5. Applying the suggested green wall to the street elevations of the Study area. Source: (The Authors, 2016).

The Method of analysis was to simulate the local environment in terms of wind speed, temperature, radiation, and identified the site by using coordinates, and we gave holographic materials Pavement fixed characteristics, to analyze its response to heat and solar radiation in terms of absorbed heat (heat flux) and quantity of the reflected heat them to see the impact on surrounding (ambient temperature).

6. Results

Results showed that the absorbency green wall heat flux much higher absorbency than regular walls, which confirms that it, contributes significantly to reducing the temperature of the surrounding area during the day.

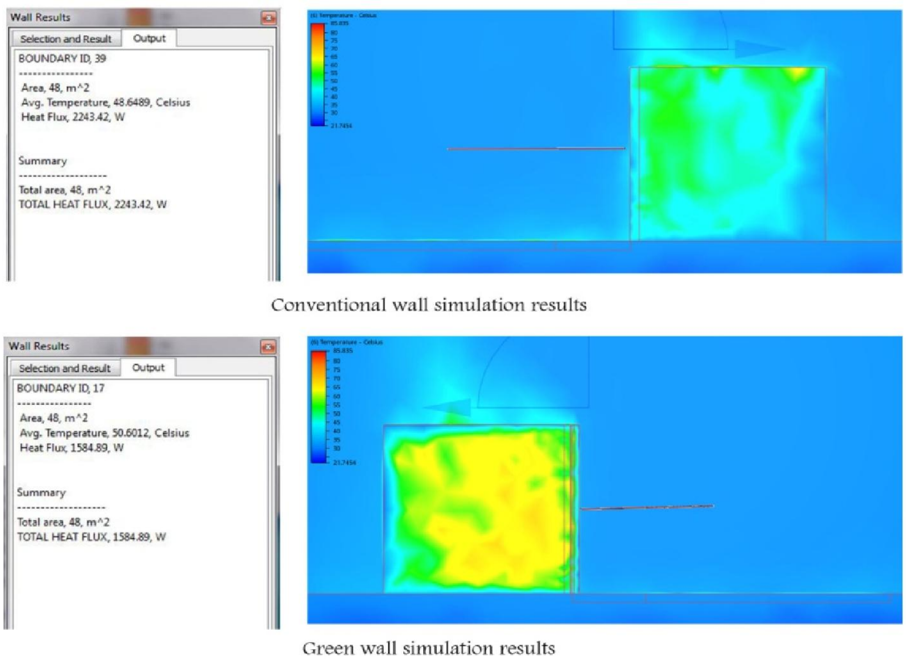

Figure 6. Simulation results for two situations. Source: (The Authors, 2016).

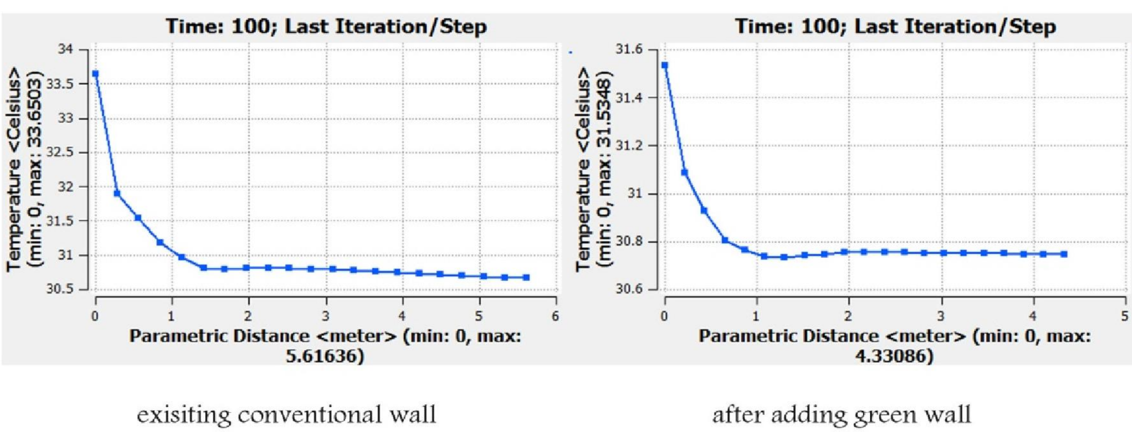

Figure 7. Ambient temperature for two situations. Source: (The Authors, 2016).

The difference in temperature 2.12 in the green wall it represents the value of all the Instantaneous difference which will increase with the length of exposure to heat both walls along the day, as it will lead to increased heat absorbed by the walls a different rate as follows:

Green Wall will absorb a large amount of heat, and thus the amount of energy or the reflected heat will be low, which means low temperature air in contact with, and vice versa for the conventional wall.

7. Conclusion & Recommendations

After the analysis of the case study and literature reviews, valuable recommendations are suggested to the municipalities and the community:

- Integrate the green wall system to the existing street façade in Amman dense areas, as well as Jordan in general, is a plus point in mitigating the UHI effect, thus reducing energy consumption by reducing the ambient temperature in dense urban area.
- Integration the green wall could improve the aesthetics of the urban environment in Amman.
- It is recommended to conduct more studies concerning the green wall impact on energy use during winter in Amman as well as Jordan.
- A more comprehensive approach towards Amman is advised. More effort should be put in trying to assess green wall impact on energy not only for mixed use building, but rather for different buildings function and typologies.

References

1. What are green walls? (N.d.). Retrieved from Wise GEEK.: http://www.wisegeek.com/what-are-green-walls.htm.
2. Abdel-Aziz, D., & Al-Kurdi, N. (2014). Estimating the Effect of Urban Trees on Summertime Electricity Use and Air Quality Improvement in Urban Areas –Amman as a Case Study. Journal of Environment and Earth Science, 4.
3. Abdulla, F. W.-G.-Q. (2004). Status of Jordan renewable energy sector: problems, needs and challenges.
4. Autodesk CFD. (N.d.). Retrieved from Autodesk: http://www.autodesk.com/products/cfd/overview.
5. C.Y. Cheng, K. C. (2010). Thermal performance of vegetated cladding system on façade walls. Build. Environ. 45, 1779-1787.
6. Castleton, H. S. (2010). Green roofs; building energy savings and the potential for retrofit. Energy Build. 42, 1582–1591.
7. Computational fluid dynamics. (N.d.). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Computational_fluid_dynamics
8. DOS. (2011). Retrieved from department of statistics: http://www.dos.gov.jo/sdb/dos_home/dos_home_e/main/index.htm.
9. E. Alexandri, P. J. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Build. Environ. 43.
10. E. Alexandri, P. Jones. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Building and Environment 43.
11. F. Olivieri, F.J. Neila, C. Bedoya. (2010). Energy saving and environmental benefits of metal box vegetal facades, in: Management of Natural Resources. Sustainable Development and Ecological Hazards II.
12. G. Prez, L. Rincn, A. Vila, J.M. Gonzlez, L.F. Cabeza. (2011). Green vertical systems for buildings as passive systems for energy savings. Applied Energy 88.
13. Hamdan, W. (2016). Sustainability Perspectives for Amman. Retrieved from http://www.ecomena.org/sustainability-amman/.
14. http://www.ecomena.org/sustainability-amman/. (N.d.).
15. K. Kontoleon, E. E. (2010). The effect of the orientation and proportion of a plant-covered wall layer on the thermal performance of a building zone. Building and Environment 45.
16. K. Kontoleon, E. Eumorfopoulou. (2010). The effect of the orientation and proportion of a plant-covered wall layer on the thermal performance of a building zone. Building and Environment 45.
17. K. Perini, M. Ottel, A. Fraaij, E. Haas, R. Raiteri. (2011). Vertical greening systems and the effect on air flow and temperature on the building envelope. Building and Environment 46. MOA, M. o. (2009).
18. N.H. Wong, A. T. (2009). Energy simulation of vertical greenery systems. Energy and Buildings 41.
19. N.H. Wong, A.Y.K. Tan, Y. Chen, K. Sekar, P.Y. Tan, D. Chan, K. Chiang, N.C. Wong. (2010). Thermal evaluation of vertical greenery systems for building walls. Building and Environment 45.
20. Namrouqa, H. (2009). Jordan to carry out Studies for new projects to cut greenhouse gas emissions.

21. Ottele M, P. K. (2011). Comparative life cycle analysis for green façades and living wall systems.. Energy Build.
22. P. Sunakorn, C. Y. (2011). Thermal performance of biofacade with natural ventilation in the tropical climate. Procedia Eng. 21, 34-41.
23. P. Sunakorn, C. Yimprayoon. (2011). Thermal performance of biofacade with natural ventilation in the tropical climate. Procedia Engineering.
24. Solh, M. (2010). Ensuring Food Security in a Changing Climate: How can Science and Technology help? International Conference on Food Security and Climate Change in Dry Areas. .
25. Susan, L. (2008). Living wall- a way to green the built environment.
26. Wise GEEK What are green walls? (N.d.). Retrieved from http://www.wisegeek.com/what-are-green-walls.htm.
27. Zanon, B., And Verones, S. (2013). Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools. Land Use Policy, 32, 343-355.

8/25/2017