Master of Science Architecture, Urbanism & Building Sciences

Sustainable Design
Graduation Studio
Emphasis: Climate Design

Active-Green System within Working Environments in Hot Humid Climate Conditions in Guayaquil, Ecuador
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Student Name: Tatiana Armijos Moya
Student Number: 4319842
tatijos@gmail.com

Main mentor
Prof. Dr. Ir. Andy van den Dobbelsteen
A.A.J.F.vandenDobbelsteen@tudelft.nl

Second mentor
Dr. Ir. Marc Ottelé
M.Ottele@tudelft.nl

Advisors:
Drs. Ing. Bob Ursem
W.N.J.Ursem@tudelft.nl
Ing. Michael Maks Davis
davismaks@evolutionecoengine.com
Active Green System

Currently, air-conditioning systems have become essential instruments in order to achieve thermal comfort within office environments located within developing cities with hot humid climates around the world. Therefore within this project it is proposed to integrate a Living Wall System within the air-conditioning system in order to help achieving thermal comfort. In consequence, the planning, the process and the product were focused to answer the stated research question: What to expect from Living Wall Systems (LWS) connected to the HVAC system within working environments located in tropical climates in Ecuador?

Social context

Santiago de Guayaquil is the largest and the most populous city in Ecuador and it is located in the northwestern part of South America. As the rest of the coastal zone of Ecuador, Guayaquil has a hot humid climate. Due to the fact, that Guayaquil is located within the commercial center of the country because of its port, it is known as the “economical capital of the country”, due to the number of factories, companies and shops that exist in the city.

Guayaquil has been chosen as a location for applying the Active-Green project due to the fact that is the most important city within the coastal zone of Ecuador, where new projects are being developed and new technology and tools are been used in order to improve the quality of life of the people and it would be a platform to show and develop these new tools and promote them within the region.

The biophilia hypothesis suggests that there is an instinctive bond between human beings and other living systems within the nature. In consequence, applying Active-Green project within working environments brings nature inside to create warm and inviting spaces that reduce stress, oxygenate the air, and increase people’s overall well-being, resulting in healthier work and living areas that decrease absenteeism, increase productivity and overall satisfaction and happiness. Furthermore, interaction with plants, both passive and active, can change human attitudes, behaviours, and physiological responses. Moreover, plants are widely used to personalize and decorate offices, and they are important in impro-
understand three main principles and some case studies, which are Thermal Comfort, Dehumidification and Green wall systems. The aim within this phase was to understand and analyze the principles that are going to help to answer the research question. All this principles were integrated within the third phase; thus, some design strategies were developed within a draft design, regarding the hot humid climate conditions of the place. Based on those strategies, the system and prototype were designed within phase fourth. Finally, the fifth step includes the evaluation of the system, conclusions and recommendations.

Besides literature review, consulting with mentors was important to determine some boundary conditions and design strategies that help following the planning established within P2 evaluation. At the same time, within this process I developed independence and that allowed to look for my own solutions and answers; sometimes in scientific papers, sometimes with some experts, and sometimes with experiments. Andy van den Dobbelsteen as a first mentor was extremely helpful not only in the technical aspects regarding Architectural Engineering Technology and Climate Design, but in guiding it well, which helped not to lose the motivation within the process. Marc Ottele, as an expert in green wall systems was extremely helpful in the well understanding of green wall systems and its elements. Finally, Michael Maks Davis and Bob Ursem were very important in the development of this project due to their knowledge and experience regarding green systems and environments.

Within the process some mathematical models were developed in order to establish some parameters of evaluation and then compare them with the results of the mock up analysis. Thus, optimizing the design. Besides, through construction of the mock up and its analysis some elements and materials of the design were changing, such as the growth medium, the kind of plants to be used, the direction of the air flow, among others. Thus, the best options were chosen in order to optimize the design. The final product is a modular Living Wall System that is connected to the central air conditioning system of an office building in order to help to improve the thermal comfort within a working environment.
Conclusions and Recommendations

Active green system will be integrated with the building’s mechanical system. Therefore, recycled and fresh air can be supplied to the building’s interior through the living wall and thus the air is cleansed and humidified by the plants and growing medium. The evapotranspiration from living walls also contributes to the lowering of temperatures around the planting.

A high humid climate reduces the effect of the living wall system substantially acting as an evaporative cooler. Therefore, the need to integrate a dehumidification process, in this case a desiccant material, to remove excess moisture is compounded by the additional latent load added. However, an interior living wall system in a dry climate would reduce the load on the HVAC system more than one in a humid climate.

Limitations

Regarding that the project is a new system within the market, the initial costs of the system could be an issue. But it is propose to test the system as an educational system to improve the thermal comfort and it can be promoted within a specific kind of market that is going to will to invest in this new green technology. Some studies have shown that the humidity produced by a Living Wall System (LWS) is neglected, due to the fact that LWS increases the humidity in a really small percentage, producing few impact within the environment, however it could be a limitation of the project. In fact, the presence of a indoor green wall helps to improve an air-conditioning environment due to the fact the these kind of environment are usually to dry that generate some discomfort within the workers.
climate, and the potential for not needing a dehumidification process at all in an arid climate is possible. Several dehumidification processes and strategies were analyzed and desiccant dehumidifiers seem to be more suitable to be apply in this system because a desiccant material can be regenerated, so it can be used again. What is more, it can use waste heat in order to regenerate. Desiccant dehumidifiers have many benefits such as providing precise humidity control, removing bacteria and other microorganisms and they can use waste heat to regenerate, as mentioned before.

As it was mentioned before, cooling and desiccant-based dehumidification systems are most economical when they are used together. In fact, the technologies complement each other; each strength of desiccants covers a weakness of cooling systems and vice-versa. Therefore, it is proposed to integrate Active-Green within the central air-conditioning system and help it to produce thermal comfort within the building.

Active Green will have significant effects on the amount of energy used by the standard HVAC system in the sense that re-circulating the air through the Living Wall System will omit the process of cooling outdoor air because the indoor air will already be at the desired temperature and humidity level. Therefore, energy and cost savings would be large to not have to cool outside air. In fact, The cost of energy to regenerate the desiccant is low when compared with the cost of energy to dehumidify the air by chilling it below its dew point.

Besides, the Desiccant based air conditioning system uses a humidifier as part of the process due to the fact that the air inside sometimes is too dry therefore, it needs some moisture. Therefore, Active Green System helps decreasing the loads for the humidifiers as well. (Fig. 125)

Moreover, Active Green System will integrate recycled rainwater within the irrigation system to re-circulate through it again with added nutrients. However, the amount of water needed to sustain healthy plants must be analyzed in order to prevent overwatering to gain cost savings in energy reduction by resizing the water pump.

The aim is to transform the biowall into a living laboratory, helping to quantify the benefits of this beautiful structure. The intent of the interior living wall system was to help purify air within indoor spaces, reducing the need to mechanically introduce fresh air, which is costly to heat and cool. It reduces energy use of other HVAC components. However, it did not reduce net energy use due to high energy consumption of the Living Wall System components.

Aside from construction and monetary considerations, the potential to add healthful and possibly energy saving greenery within a working environment will improve productivity and well-being of the occupants.

Finally, analyzing the mathematical model and the mock up tests, it is concluded that Active Green System works as an evaporative cooler, but in hot humid climates a desiccant needs to be integrated in order to control the humidity level. In fact, within Active Green System the temperature is lower than outside temperature and the humidity is high; thus, it requires a dehumidification process in order to achieve thermal comfort. It reduces the energy demand for cooling and humidifying the air. It requires extra energy for the regeneration of the desiccant and the fans. It does not reduce the equipment required for the central air-conditioning system, but it reduces the loads.

**Benefits for the Occupants**

Active Green System will remove indoor contaminants known to affect occupant health which could take the form of improved well-being. In fact, it will reduce indoor VOCs and other compounds that are linked to poor air quality and sick building syndrome. Thus, reducing stress levels and increasing productivity.

What is more, the inclusion of plants within a working environment will reduce absenteeism among workers due to improvement in the work environment.

The system offers a pleasing aesthetic to the environment. The system greens the indoor space, and there are increasingly strong links between greening the indoor space and the well-being of the occupants.

**Points for Further Research**

NASA researchers suggest efficient air cleaning is accomplished with at least one plant per 100 square feet of home or office space. Other research has
shown that micro-organisms in the potting mix remove benzene from the air. Future designs should account for a deeper understanding of how the plants filter the air. The majority of the VOCs are actually filtered through the root system of the plants. Further research into which processes actively engage or inhibit VOC filtration must be taken into account for subsequent designs.

Besides, it is important to develop a further research in the use of recycled water within the system in order to optimize the energy efficient of the Active Green.

Finally, the energy efficiency of dehumidifiers is measured by its energy factor, in liters of water removed per kilowatt-hour (kWh) of energy consumed or L/kWh. In general, a higher energy factor means a more efficient dehumidifier. It is recommended to conduct a study about the optimization of the energy consumption and efficiency of the system.