Green Air Conditioning

– Using indoor living wall systems as a climate control method

This article seeks to present an optional cooling tool based on the integration of a Living Wall System (LWS), a fan and a dehumidification process (desiccant) to reduce the use of an HVAC system. This study showed that it is possible to use the evapotranspiration of plants for air-cooling and humidity control.

Keywords: Indoor Environment, Climate control, Living Wall System, Evaporative cooler, Biofiltration.

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In the current world, people spend on average 80%-90% of their time indoors; consequently, the risks to health may be greater due to indoor air pollution than to outdoor air pollution. Doctors around the world face lots of complains about the fact that people feel sick because of the misuse of air conditioning system within their offices and they pay very expensive bills every year, so they can work in a "comfortable place". In many cities across the world, the air-conditioning system has become an essential instrument to achieve indoor comfort within most of the buildings. Thus, it is important that engineers, designers, manufactures and all the professionals involved in keeping a good the indoor environment explore new alternatives to improve the current systems since there is an increasing energy requirement for cooling and air-conditioning of buildings in cities, rising indirectly, the urban heat island (UHI) and climate change. Nowadays, Living Wall Systems (LWS) are an emerging technology that utilize the potentials of plants in living environments, regarding the fact that there is an instinctive bond between human beings and other living systems within nature (**Figure 1**). Using plants as design elements in working environments brings nature inside to create warm and inviting spaces that reduces stress, oxygenate the air, and increases your overall well-being, resulting in healthier work and living areas that decrease absenteeism, increase productivity and overall satisfaction and happiness in people's lives.

Figure 1. Living Wall System, Quito, Ecuador.

Some studies have shown that common indoor plants may provide a valuable strategy to avoid rising levels of indoor air pollution and cleaning the air inside buildings through biofiltration and phytoremediation (Wolverton, 1989); and it provides a natural way of helping combat Sick Building Syndrome (SBS) (Fjeld, 2000). Besides, it has been shown that it is possible to use the evapotranspiration of plants for air-cooling and humidity control around the plant environment (Davis & Hirmer, 2015). The use of vegetation as tools to improve the overall indoor environment is a field that needs more research to prove the real impact of the different green systems in the indoor environment; therefore, this project aims to conduct a multidisciplinary research to explore, validate and evaluate the efficacy in terms of indoor comfort within office environments of LWS climate control systems.

I am Tatiana Armijos Moya, I come from Quito, Ecuador where I got my degree as an Architect at the Pontifical Catholic University of Ecuador. I worked at the University for two years as a researcher in sustainable design. In 2015, I got my diploma as a Master of Science Specialized in the field of Building Technology in the Faculty of Architecture and the Built Environment, TUDelft. Currently, I am PhD candidate within the Green Building Innovation Research Group also at TUDelft with the guidance of my supervisors; Prof.dr.ir. Andy van den Dobbelsteen, Prof. dr. ir. Philomena Bluyssen, and Dr.ir. Marc Ottele.

Evaporative coolers

Plants absorb water and nutrients from the environment and carry them from one zone (leaves) to another (roots) where their roots represent a hanging system. For instance, epiphytes, tropical plants such as English Ivy, Peace Lily, Reed Palm, Boston ferns and Tillandsia, are plants that get their water from the air instead of through their roots. They are common houseplants that filter the moist out of the air thus reducing excessive humidity levels. Regarding temperature control, the evapotranspiration from plants contributes to the lowering of temperatures around the environment. In this study, some strategies where reviewed and a prototype was built to evaluate its performance within a hot humid environment.

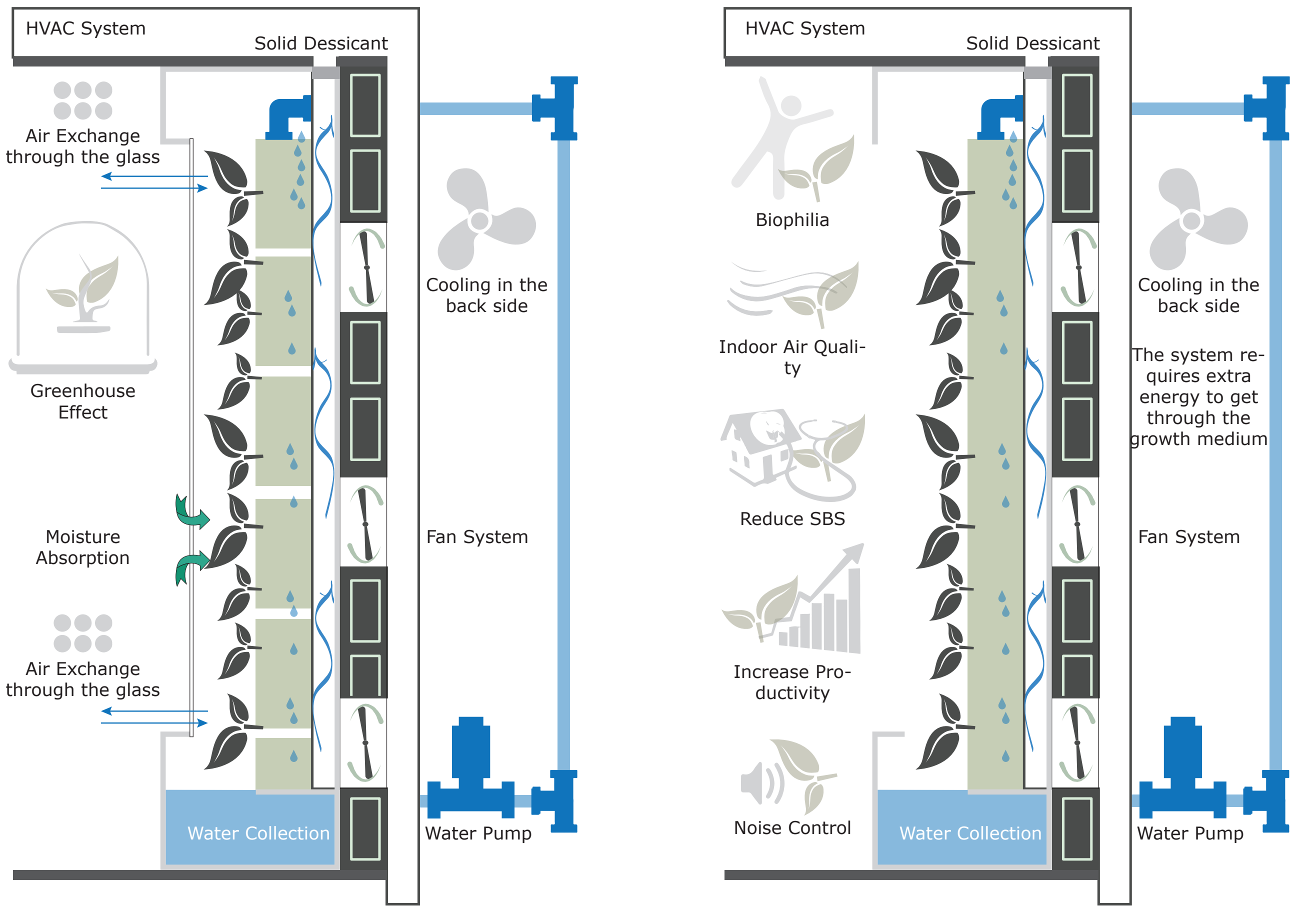
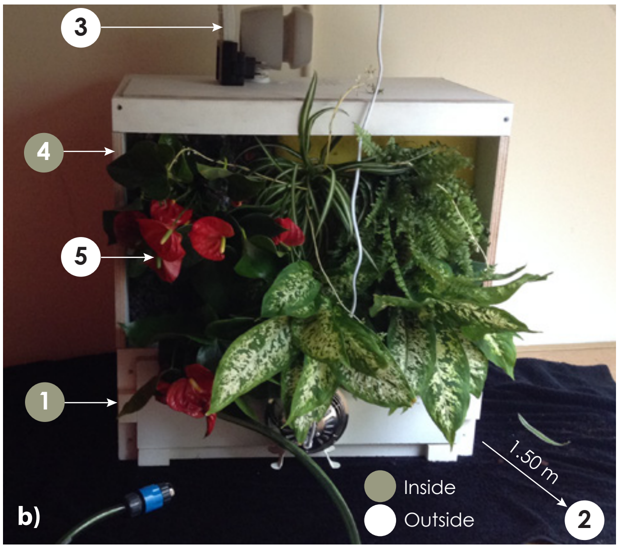


Figure 2. Diagrams of the alternatives for LWS. (Armijos Moya, 2016)

It was considered that a highly humid climate reduces the effect of the living wall system substantially, acting as an evaporative cooler; therefore, it was necessary to integrate a dehumidification process within the system. Several dehumidification processes and strategies were analysed where desiccant dehumidifiers appeared to be more suitable to apply in this system because it can be regenerated, and it be used again. In fact, for future applications, it may use waste heat to regenerate. Desiccant dehumidifiers have several benefits, such as providing humidity control, removing bacteria and other micro-organisms and they can use waste heat to regenerate, as mentioned before. Regarding these factors, it is proposed to use calcium chloride ($CaCl_2$) as a desiccant dehumidifier because of its properties in control of relative humidity, its flexibility, and size particles, residual water produced (Lewis, 2002).

As mentioned before, a prototype was built (**Figure 3b**) to examine the construction system and climate behaviour of the system. The prototype was assembled as a plug-in system constituted by a wooden box (0.60 m x 0.60 m) with mineral wool and cotton as growth media that provides a structural system for the plants to grow in and it must have the perfect balance between porosity, aeration and water absorption capacity. Furthermore, a fan (15 W, 230 V, 50 Hz) was integrated in the bottom part of the system. This allows cooling down the air before it enters the air gap behind the substrate, because the air passes over the water



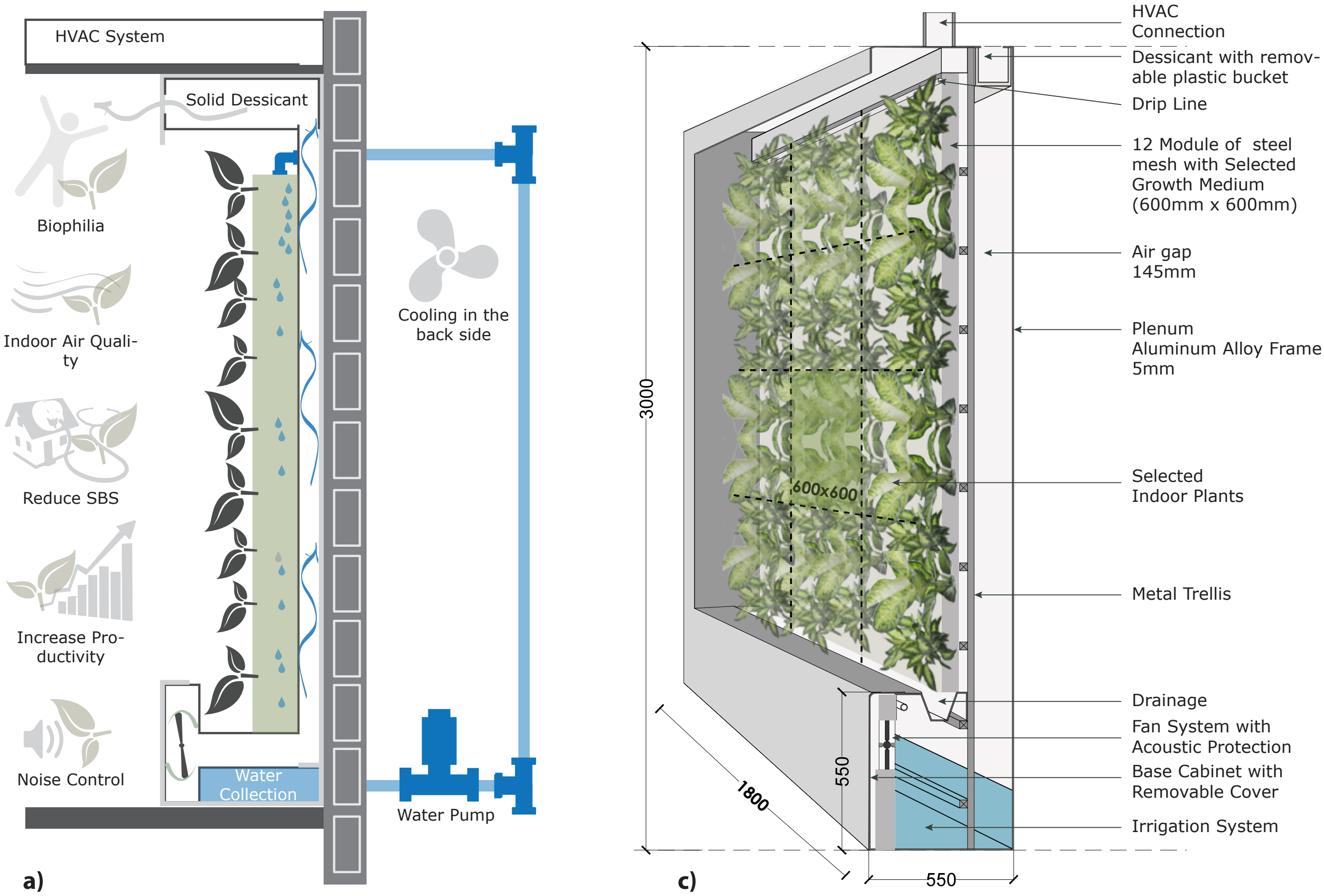


Figure 3. Prototype. **a)** Diagram of the LWS Design, **b)** LWS scaled Prototype and Data logger location, **c)** Section. (Armijos Moya, 2016)

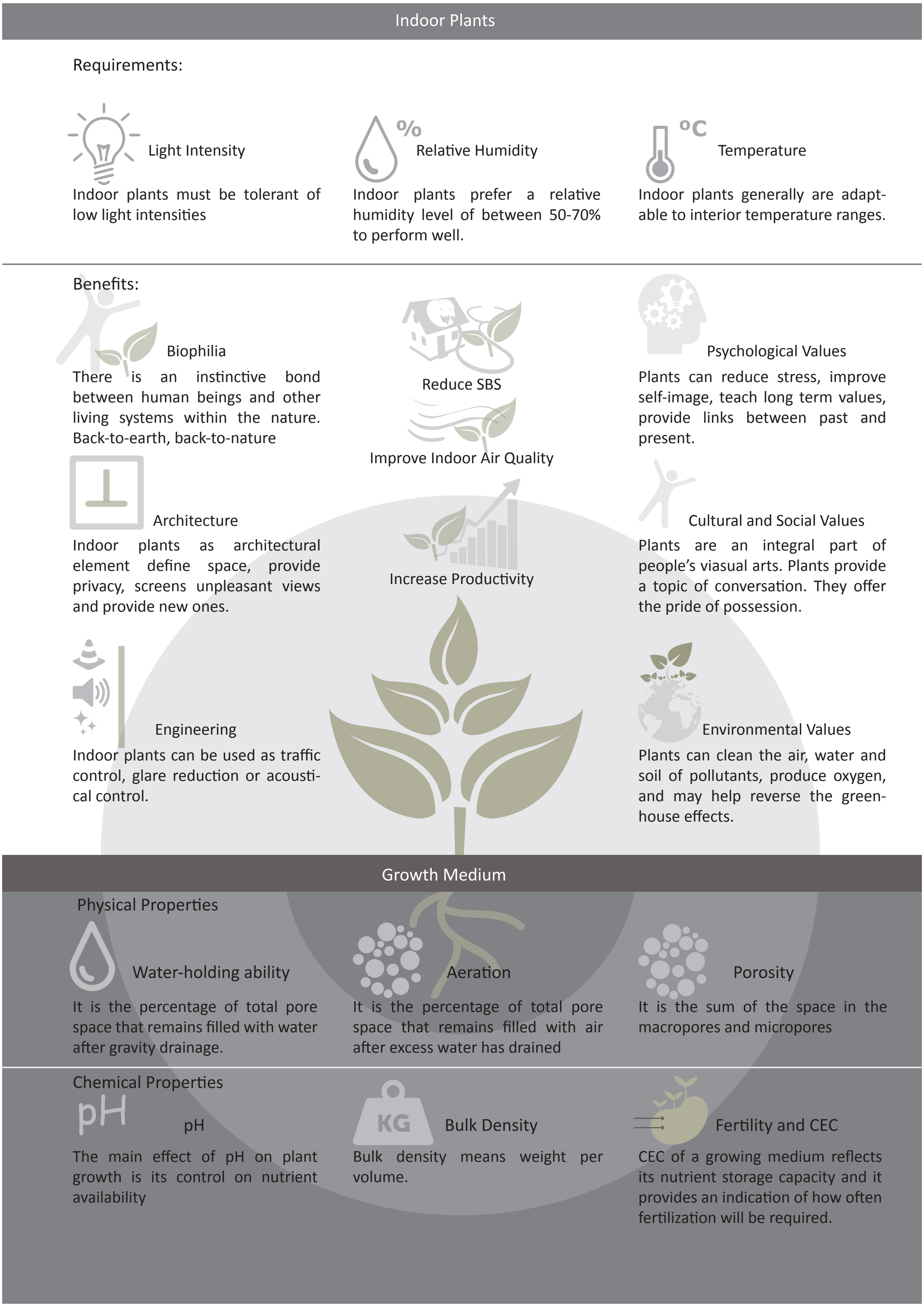


Figure 4. Indoor Plants: Benefits and Requirements.

storage of the system. This location of water allows a better cooling effect within the system and it allows an easier maintenance. The selected desiccant ($CaCl_2$) was placed in the top of the air cavity to dehumidify the air before it leaves the system to the outside (**Figure 3).**

The evapotranspiration from this living wall, the fan and the desiccant working together contributed to the lowering of temperatures around the planting environment.

To build an optimum system, some requirements were taking in account to select the type of plants to be used, such as light conditions, climate conditions and growth medium. Consequently, non-pollinating and, medium- and low-light-tolerant plants, and an inorganic growth medium were used (**Figure 4**).

Regarding all these aspects, spider plants and anthuriums were tested during this evaluation because they are epiphytes, which are plants that absorb moisture from the environment to get their nutrients. The plants were pre-grown and re-pot within the LWS to allow them to adapt to the new growth medium. Irrigation is provided at different levels along the prototype, using a drip irrigation method using gravity to let water flow through the growing media.

Conclusions and recommendations for further research

After the evaluation, the system presents several positive results such as reducing the temperatures around the system with a green climate control method (LWS) which generate pleasant and healthier environment. Some challenges were faced during the study. First, the rise of relative air humidity (RH) in the areas with plants is one of the major issues. In fact, a highly humid climate reduces the effect of the LWS acting as an evaporative cooler; thus, it was necessary to integrate a dehumidification method within the system, in this case a desiccant material, to control the moisture level in the environment. Subsequently, it seems that this green climate control system will reduce the load on the HVAC system more significantly in a dry hot climate due to the natural evapotranspiration of the system; thus, not needing a dehumidification process at all.

On the other hand, the air conditioning system is like the lungs of any building. It draws in outside air, filters it, controls and maintains the temperature, humidity, air movement, air cleanliness, sound level, and pressure differential, circulates air around the building, then expels a portion of it to the outside environment. However, it is in constant competition between the air cooled and air circulated. Air must be circulated to ensure a good air quality, but the air conditioning unit relies on a closed cycle, where if new air is brought in it needs a greater amount of cooling. Therefore, it is expected that this method will have important effects on the amount of energy used by a standard HVAC system regarding that recirculating the air through the LWS will omit the process of cooling outdoor air because the indoor air will already be at the required temperature and humidity level. It is recommended that for further applications the building where the system in going to be integrated should incorporate a solar thermal collector or a gas heater to help regenerating the desiccant. What is more, the desiccant-based air conditioning systems, in general, also use a humidifier as part of the process because the air inside sometimes is too dry. Therefore, this system will most likely help to decrease the loads for humidifiers as well.

There is still a lack of solid and significant figures available to understand all the possible benefits of an active LWS as a climate control system such as the true pollutant-removal mechanisms, and even more the effect of these systems within the energy performance of the building. For forthcoming studies, this system is going to evaluate the possibility of reducing the levels of indoor pollution through phytoremediation and biofiltration. ■

Phytoremediation

Use of plants to remove pollutants from the air, water and soil. Plants have been shown to uptake air pollutants via their stomata during normal gas exchange.

Biofiltration: the process of drawing air in through organic material (such as moss, soil and plants), resulting in the removal of organic gases (volatile organic compounds) and contaminants with a mechanical system involved.

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