CZECH UNIVERSITY OF LIFE SCIENCES – PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS

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BACHELOR THESIS

Green Walls in Urban Environments – Reasons for Installation and their Effect on the General Public

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BACHELOR THESIS ASSIGNMENT

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Thesis title

Green Walls in Urban Environments – Reasons for Installation and their Effect on the General Public

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Objectives of thesis

The objective for this BEE thesis is to explore the history of and options for green facades in urban environments. The thesis will first discuss the general components of green walls and facades, such as their main benefits from a climatic, ecological, and aesthetic point of view. Further, this research aims to discover whether a green facade on a building has an impact on consumer behavior and public opinion of the firm by possibly conveying a ”sustainability” that may or may not be present or promoted in the products offered by the company. Potential motivations such as the influential role of banks and state subsidies will also be investigated, focusing on Vienna, Austria for focused study and analysis.

Methodology

This research will begin with a review of current literature on the topic of green walls and building facades.

Focused interviews will be conducted with different corporations who use green facades on their businesses. Also interviews with consulting architectural firms who prepare the designs for green walls will beconducted. The location for the interviews and study will be Vienna, Austria. Various experts in the field of green walls, in addition to surveys to determine consumer perception will be made, particularly with businesses such as Raiffeisen Bank, Ikea, etc.

Recommendations will be provided for how other businesses can adopt the strategies employed by thosebusinesses who have adopted the strategy of green facades to better promote their corporate philosophyand marketing strategies. Again, Vienna, Austria is the focused study area due to new municipal incentivesand requirements for green facades in that city.

The proposed extent of the thesis

50+ pages

Keywords

green walls, green facades, green infrastructure, Vienna

Recommended information sources

Hindle, R.L., 2012. A vertical garden: origins of the Vegetation-Bearing Architectonic Structure and System(1938). Studies in the History of Gardens & Designed Landscapes: An International Quarterly, 32(2), pp.99–110.
Jørgensen, L., Dresbøll, D.B. & Thorup-Kristensen, K., 2014. Root growth of perennials in vertical growingmedia for use in green walls. Scientia Horticulturae, 166, pp.31–41
Perini, K., Ottele, M., Haas, E.M., et al., 2011. Greening the building envelope , facade greening and livingwall systems. Open Journal of Ecology, 1(1), pp.1–8.
Roseland, Mark. 1998. “Toward Sustainable Communities.” Chapters 1 and 2. Pp 2 – 26. New SocietyPublishers: Canada

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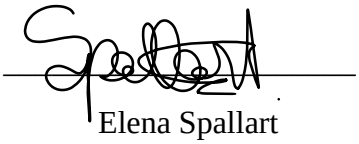
Prague on 22.02.2022

DIPLOMA THESIS AUTHOR’S DECLARATION

I hereby declare that the work presented in this thesis, to the best of my knowledge, is my independent original work, under the supervision of Peter Kumble. I have listed all literature and publications from which I acquired information.

21.03.2022



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Abstract

This bachelor's thesis attempts to develop an understanding of some of the fundamental benefits that green facades can provide in urban environments by mitigating negative effects of the changing climate, air pollution and biodiversity / habitat loss due to expanding cities and a growing human population. Through evapotranspiration, shading and insulation not only the local microclimate is influenced positively but also indoor temperatures of buildings, leading to reduced energy consumption. Furthermore, green facades offer habitat for flora and fauna which is lost through urbanization and play a role in conserving biodiversity as well as absorbing toxic pollutants from the air.

Moreover, the research focuses on determining, if green walls placed on commercial businesses have an influence on the public perception and image of a company and, if so, in which way. Does a green facade convey a "green" image that may not comply with a company's real environmental impact? Focusing on Vienna, Austria, this research aims to identify what role governmental initiatives and banks as money-borrowing institutions are playing in influencing corporations to install structures like green facades and thereby, eventually contributing to the problematic greenwashing phenomenon.

Key Words: Green Walls, Green Facades, Green Infrastructure, Vienna

Abstrakt

Tato bakalářská práce se pokouší porozumět některým zásadním přínosům, které mohou zelené fasády v městském prostředí přinést, a to zmírněním negativních účinků měnícího se klimatu, znečištění ovzduší a ztráty biologické rozmanitosti / stanovišť v důsledku rozšiřování měst a rostoucí lidské populace. Prostřednictvím evapotranspirace, stínění a izolace se pozitivně ovlivňuje nejen místní mikroklima, ale také vnitřní teploty budov, což vede ke snížení spotřeby energie. Zelené fasády navíc nabízejí životní prostor pro flóru a faunu, která se urbanizací ztrácí, a hrají roli při zachování biologické rozmanitosti i při pohlcování toxických škodlivin z ovzduší.

Výzkum se dále zaměřuje na zjištění, zda zelené stěny umístěné na komerčních podnicích mají vliv na vnímání a image podniku veřejností, a pokud ano, jakým způsobem. Vytváří zelená fasáda "zelenou" image, která nemusí být v souladu se skutečným dopadem podniku na životní prostředí? Tento výzkum se zaměřuje na Vídeň v Rakousku a jeho cílem je zjistit, jakou roli hrají vládní iniciativy a banky jako instituce půjčující peníze při ovlivňování podniků, aby instalovaly konstrukce, jako jsou zelené fasády, a tím případně přispívaly k problematickému fenoménu greenwashingu.

Klíčová slova: Zelené stěny, zelené fasády, zelená infrastruktura, Vídeň

Table of Content

1. Introduction

The human species has managed to create extraordinary things. It has often been written that it is the dominant species and has gained skills that – as far as we know – no other species has yet attained. However, it is also a species that destroys its own habitat. We pollute the air we breathe with excessive amounts of carbon dioxide, nitrous dioxide, particulate matter and more, consequently the Earth's climate is rapidly changing (Jayasooriya et al. 2017, Höök & Tang 2013). Our cities are expanding (Haaland & Konijnendijk 2015), taking up more land that once was habitat to other species and their ecosystems each day, resulting in biodiversity-loss (Elmqvist et al. 2016). This thesis summarizes how green walls, specifically in the urban environment, possess the ability to mitigate some of the effects that the before mentioned challenges have on the urban habitat. Using nature wisely can offer cost effective solutions that do not only benefit us but other species as well. Their advantages will be presented in the literature review of this thesis.

As humans we are programmed to make assumptions and jump to conclusions (Elder & Richard 2002). But what if that characteristic is used against us for business purposes? Greenwashing is a phenomenon that describes the communication of environmental sustainability of a brand / product / service etc. even though the truth may not align with the picture painted (De Freitas Netto et al. 2020). When a company uses certain product designs, packaging or architectural structures, a message may be conveyed that fools costumers into thinking, paying for that service contributes positively to environmental protection. Do green walls have that potential? Can a green facade trick a consumer into thinking whatever is found in the store behind the green envelope is a more ethical purchase than any other store? And how do governmental incentives in Vienna, Austria influence companies' choice to install such a green facade? Does the city indirectly promote green washing by big brands? And what about banks? Does Raiffeisen International Group, as a financial institution with Austrian roots have that effect, potentially by providing beneficial treatment to institutions with structures such as a green facade? Through interviews, a survey, and other research this thesis provides answers to these questions.

2. Objectives

This thesis deals with green facades in urban environments. First, general aspects such as benefits of green facades will be explored. Further, my research aims to find out whether a green façade on a company's building has an impact on consumer behavior and public opinion of the firm by possibly conveying a "sustainability" that may or may not be there. Potential motivations such as the influential role of banks and state subsidies will also be investigated, focusing on Vienna, Austria.

3. Green Wall Systems

Today, the term "green wall" generally refers to a building's facade, that is amended by a vegetative system, consisting of a set of components, whether directly attached to the wall or supported by a structure (Palermo & Truco 2013). This chapter will review what systems are most commonly used to vegetate walls in urban environments in order to provide a common understanding of the matter before elaborating on their effects on the general public.

Already in ancient times such as during the Roman and the Greek Empires, vegetation was used in the Mediterranean region to cover the walls of buildings, providing a cool climate inside during hot summers (Manso & Castro-Gomes 2016). Even 2,500 years ago the Babylon Hanging Gardens included some sort of green walling (Palermo & Truco 2013).

Figure 1 Hanging Gardens of Babylon by Natalia Dobrovolska (Artstation)

During the seventeenth and eighteenth centuries, the trend resurfaced, and it became more common to have climbing plants such as woody vines covering the buildings' facade in central Europe, North America, and the UK. In the 20th century architectural movements such as German Jugendstil contributed to more than 254,000 square meters of green facades between 1983 and 1997 only in Berlin (Manso & Castro-Gomes 2016).

Green walls can be classified into different categories depending on the features and functional elements of the system and their implementation.

3.1 Green facades

The traditional way of growing vegetation on the face of a building is typically referred to as green facade. It includes minimal technical support and advancement -usually featuring climbing plants. This “class” can be classified even further into two different categories; a direct or an indirect green facade (see Figure 2).

3.1.1 Direct green facades

Direct green facades represent biota being directly attached to the wall of the building without using any support to spread along the surface. Thus, using the plants natural behavior to cover the facade. These systems may or may not be rooted in the ground at the bottom of the wall. As e seen in Figure 2, direct green facades can include a vegetation box filled with soil to support the roots of the plants if the ground is impermeable or is not qualified for other reasons. No matter if rooted in a box or the natural ground, this system does not require a lot of maintenance. However, the growth time of the folios or evergreen plants can result in it taking a few years to fully cover a wall.

3.1.2 Indirect green facades

Indirect green facades are supported by a structure that can be made of various materials ranging from stainless steel cables to wooden grids or other support systems for vegetation to attach to in the growing process. The continuous or modular solutions direct the plants’ development, guiding them into the growing direction. By creating a gap between the wall and the plants weather conditions such as rain can become less of an issue regarding falling of vegetation.

As shown in Figure 2, no matter if a direct or indirect system is applied, vegetation boxes for rooting can be installed at different heights, therefore avoiding being damaged by water runoff on the ground created through environmental conditions (Palermo & Truco 2013, Manso & Castro-Gomes 2016).

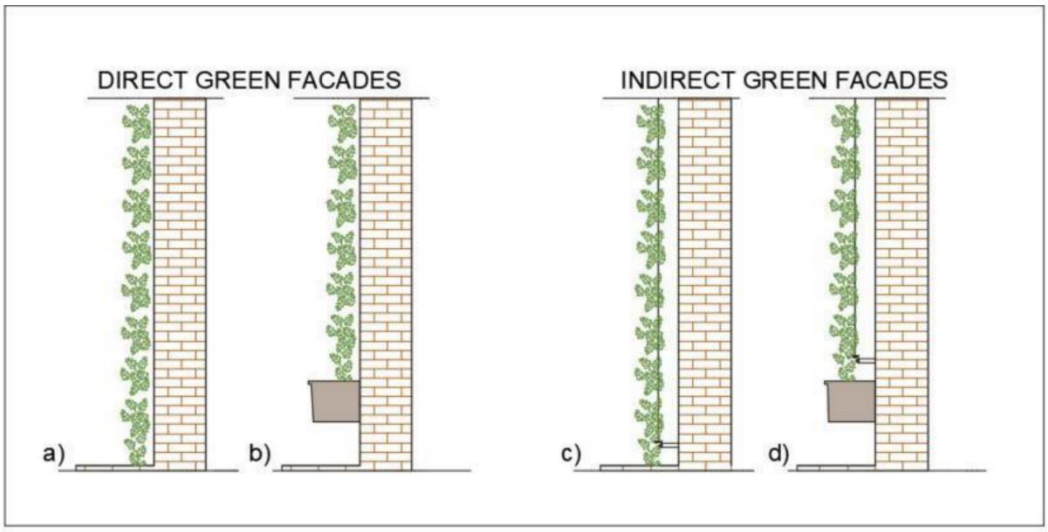


Figure 2 Different types of Green Facades: (a) Direct Green Facade with vegetation planted into soil; (b) Direct Green Facade with plants rooted in box; (c) Indirect Green Facade with vegetation planted into soil; (d) Indirect Green Facade with plants rooted in box (Palermo & Truco 2013)

3.2 Living Walls

Living Wall Systems are very effective and can cover a large surface area of a building facade in a short time (Palermo & Truco 2013). A variety of different plants can be used, ranging from succulents to shrubs and grasses. Living Wall Systems are better when trying to green a tall multi-story building. Just like green facades, they can be subcategorized based on the application method used:

3.2.1 Continuous Living Wall Systems

In Continuous Living Wall Systems, plants are not based in soil but instead they grow in a lightweight and absorbent screen such as felt, which is formed into pockets. Each of these pockets serves as breeding ground for one plant. The whole system consists of different layers. Starting with a fixed frame indirectly attached to the wall leaving space in between, creating an air pocket which can be used for insulation and may help improve resilience toward environmental conditions such as snow, rain and wind (Palermo & Truco 2013, Manso & Castro-Gomes 2016). The frame is attached to a base panel in order to protect the wall from humidity. This base panel holds more layers such as permeable, flexible and root proof screens, that are stapled to the base. The

outermost layer is cut into pockets, where plants will be inserted individually (Manso & Castro-Gomes 2016).

Continuous Living Wall Systems, also known as vertical gardens (named by the French botanist Patrick Blanc), have been integrated in many famous architectural structures.

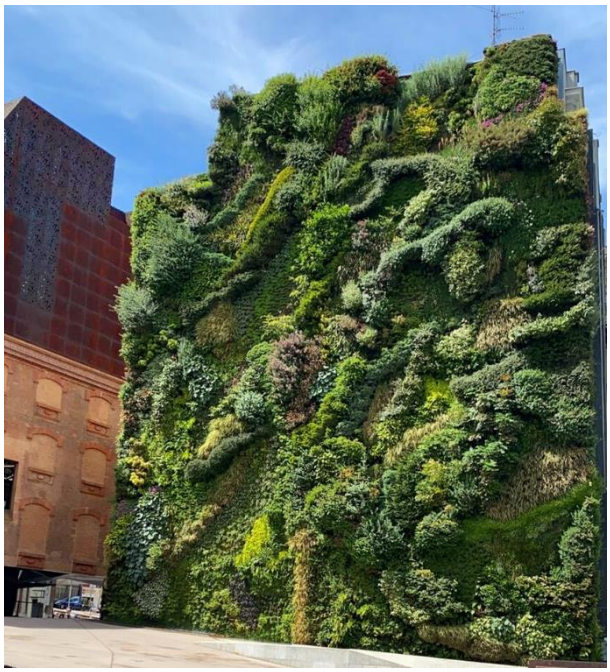


Figure 4 Continuous Living Wall, Caixa Forum Madrid, Spain (GreenRoofs.com)

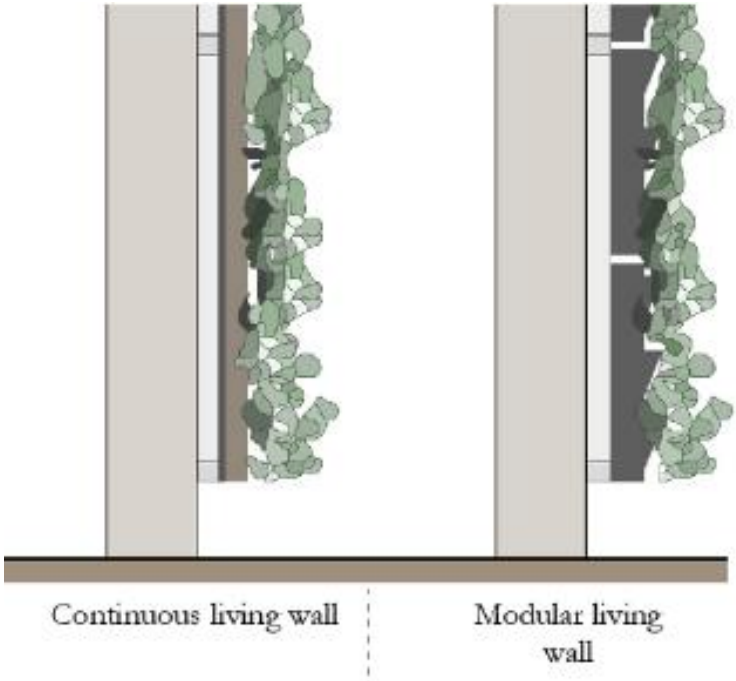


Figure 3 Visualization of difference between Continuous Living Wall and Modular Living Wall (Gunawardena und Steemers 2019)

3.2.2 Modular Living Wall Systems

The structure for modular Living Wall Systems varies depending on the type of form. These can range from trays, vessels, planter tiles to flexible bags.

The Structures for modular trays are commonly the following ones:

Interconnected structures made of light materials and are often used to form modular trays. These materials include for instance plastics such as polypropylene and polyethylene or metals like aluminum, stainless or galvanized steel. In order to keep the plants from falling these modules often create a grid upfront.

Structures for trays and vessels on the other hand are rather connected to a frame, which is attached to the wall, trays and vessels often have hooks or mounting brackets on the backside to hold themselves upon.

Figure 5 Modular Green Wall at Changi Airport, Singapore (GWSLivingArt.com)

Figure 6 Modular Living Wall System (Pinterest.com)

Figure 7 Modular Living Wall System (Pinterest.com)

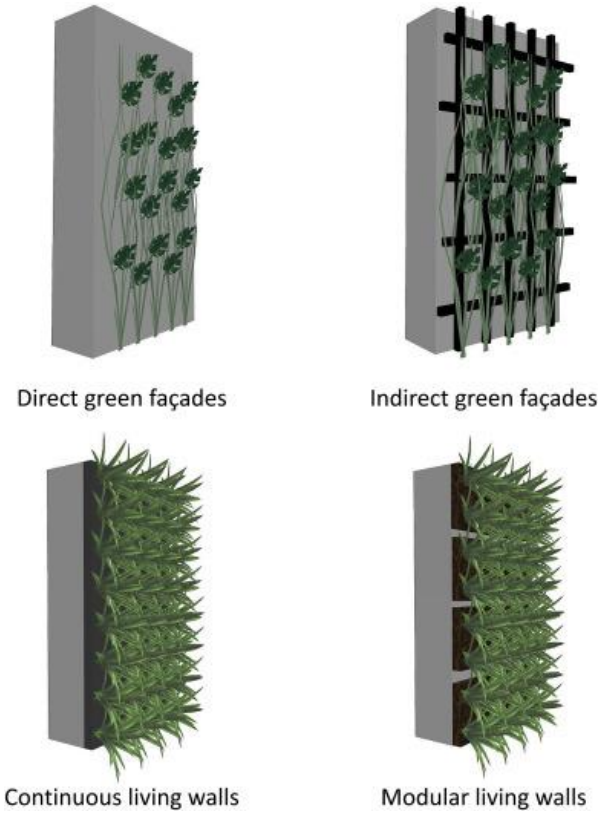


Figure 8 Visualization of difference between Continuous Living Wall and Modular Living Wall as well as Direct and Indirect Green Facades (Cortês et al. 2021)

4. Benefits of Green Walls

Green Facades have multiple beneficial effects on the urban environment and its citizens, three fundamental aspects are explored in this chapter.

4.1 Green Walls as Habitat

The worldwide human population is increasing, and cities seem to be growing at an unprecedented rate with 50% of humanity living in cities in 2010 and an expected 70% of all people in 2050 (Haaland & Konijnendijk 2015). The consequence of population growth and the tendency to migrate into cities leads to expansions and or densification of urban environments (Mohajeri et al. 2015). Hence, the need for sustainable urban development has become critical for the survival of our species and way of life. This includes resource efficient systems, and the maintenance and or creation of healthy and sustainable quality of life for all. Cities can develop in many ways; urban sprawl is one of them. Characteristics of urban sprawl are low-density housing, segregated land-use for both industrial and residential purposes, inadequate public transportation, resulting in excessive demand for the usage of automobiles for mobility and a huge consumption of land for residential development (Nechyba & Walsh 2004). Consequently, finite resources such as sources of energy and land for growing food are not used efficiently, provoking an enlarged environmental footprint, loss of biodiversity and other ecosystem disruptions mitigating ecosystem services valuable to humans (Haaland & Konijnendijk 2015) As mentioned before economic, social, and nature-related benefits stress the crucial benefits these services add to our lives. Other modern forms of city development are neo-traditional development, urban containment, and especially dense compact cities (Handy 1992). Following the goal of minimizing expansion and destruction of habitat, increase of land usage, soil sealing, land segregation, noise, and light pollution, etc. city planners focus on increasing local population density, optimize connectivity of public transportation and availability of cycle lanes. Although densification of cities is aiming to be more sustainable way of city development, than traditional expansion, it does bring negative effects with it. Often green areas within the metropoles have to be sacrificed in order to provide housing for people, that is also why quality of life decreases and crowding may happen (Haaland & Konijnendijk 2015). According to Elmqvist et al. (2016) it is predicted that urban land near protected areas shall enlarge by no less than three times within the 30 year period of 2000 to 2030. In 2000 this area has already amounted to

450,000 km^2 around the world. Within the same timeframe urbanized land in biodiversity hotspots is expected to increase by an average of four times (Elmqvist et al. 2016). Biodiversity hotspots are localities or zones with the Earth's highest concentrations of native and/or unique species, that often are found nowhere else (known as "endemic species") (Reid 1998). In order to qualify as a biodiversity hotspot there must be at least 1,500 species of endemic vascular plants and at least 70% of the zone's primary native vegetation has to be lost (Elmqvist et al. 2016). The authors also mention, that by 2030 more than 25% of all endangered species will be affected by expansion of urban areas in a direct or indirect manner, as at least 25% of the world's protected areas (only including terrestrial zones) are located in close proximity of 50km of a city. Direct effects include the obvious change in land cover and degradation as well as for instance alterations in soil. Indirect influences consist of variation in water and nutrient availability and a rise in abiotic stressors like air pollution. Respectively, mid-latitudinal Africa probably will undergo the biggest change, increasing the urban land in proximity of 50 km to protected area by 20 times (Elmqvist et al. 2016). As seen in Figure 9, China is forecasted to have more urban land within the 50 km radius of their protected areas than western Europe or North America (Elmqvist et al. 2016).

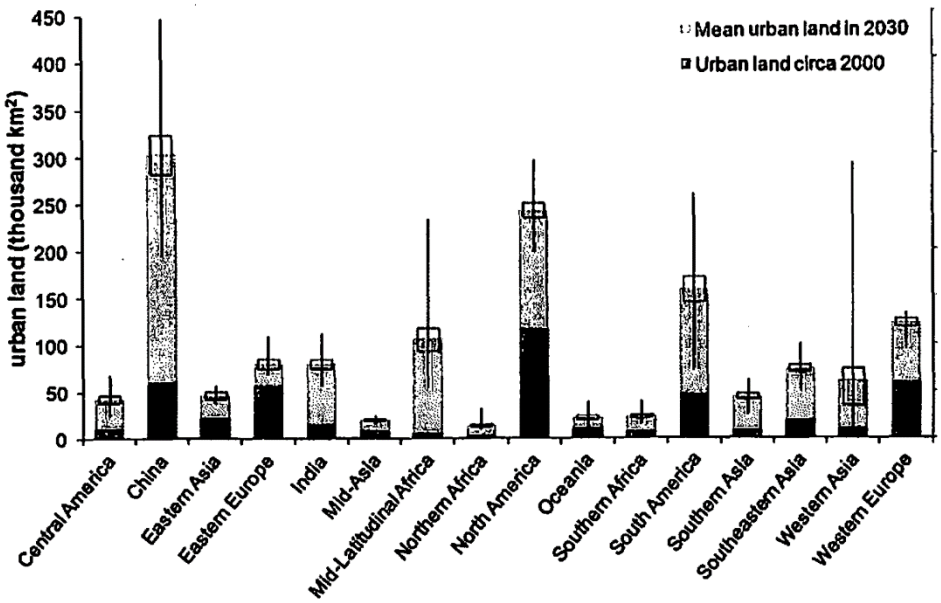


Figure 9 Urban extent within 50 km by geographic region around 2000 and forecasted for 2030 (Elmqvist et al.)

The results of an experiment (Elmqvist et al. 2016) show that almost 80% of estimated species loss by 2030 will be accounted for by urban expansion. This tremendous loss occurs due to activities such as illegal poaching of animals and plants, illegal dumping and the introduction of invasive, non-native species, all of which are more likely to happen in close proximity of human development.

As the density and area of cities are increasing, the biodiversity that can be found within these metropoles is drastically decreasing. Traditionally most biodiversity can be found in green infrastructure such as gardens, parks and corridors as well as rivers. These should be placed tactically in order to allow the organisms to move around and migrate, as it plays an essential role in many ecosystems. Implementation of additional green infrastructure is a necessity to ensure health and well-being of city dwellers (Collins et al. 2017). This is where green walls come into play. Greening large areas within cities is costly and inefficient if vertical "lost land" could also be used. It is a way to adopt vegetation without losing economically important housing space. There are many designs that allow integration into old building structures as well as modern ones. Green facades could function as corridors for organisms to move around within a city or like a pathway through it. If interconnected greenery is not possible steppingstones are important. Steppingstones represent isolated patches of habitat elements that are successive and placed tactically to ensure species success to move. Depending on patch size, heterogeneity, quality, and quantity dispersal of species and thereby biodiversity can be supported (Mayrand et al. 2018).

Figure 10 Urban greenery as steppingstones for species dispersal (Mayrand et al. 2018)

Green walls could eventually function as such steppingstones when designed and located accordingly. Additionally, they could provide habitat for arthropods such as nematodes, arachnids, beetles, or even for bees, etc., providing a necessary and critical ecosystem service. This phylum provides essential ecosystem services such as

pollination or decomposition and is therefore crucial for human and ecosystem health. Also, green walls can play an important role for birds in highly fragmented areas (Mayrand et al. 2018), as they provide breeding sites (Mayrand et al. 2018). thereby fauna with low dispersal capabilities could be saved, as green walls not only provide the habitats but also shelters while trying to disperse in the city matrix, overcoming barriers such as streets and buildings. For species with high dispersal capabilities, which often include species with the ability to fly, green walls can act as extra habitat, thereby enhancing their abundance in urban areas and protecting biodiversity. However, cities are still too sparsely vegetated. This becomes evident when looking at data published in 2018 (Mayrand et al. 2018) describing the amount of green spaces in European Cities. France, for example only entails 30 ha of green walls, which represents less than 1% of all urban green spaces in 2016 (Mayrand et al. 2018). However, not just the abundance matters to biodiversity but also the location and connectivity of green walls to other green landscapes within a city. Studies have proven stone walls, which are part of a network, to exhibit a faster development of vegetation, than isolated walls (Mayrand et al. 2018) (also because stone walls resemble natural cliffs and rocks) (Chen et al. 2020). This also underlines the importance of establishing similar conditions in moisture and temperature on interconnected walls and roofs for fauna to be able to migrate and colonize successfully. When planning, landscape architects should keep in mind which flora and fauna these walls are supposed to serve in order to adapt height, texture, substrates and other impacting conditions for these specific living organisms. However, always paying attention to avoid homogenization of the habitat. Unfortunately, it was indicated that no study has yet been conducted on green walls providing habitat for larger animals, which could provide revealing information on whether well-connected green roofs and walls could be used as corridors for wildlife. (Mayrand et al. 2018). According to Mayrand et al. (2018) spontaneous flora has been measured in different climates on retaining walls. The research resulted in 159 species, part of 77 families in tropical regions and between 207 and 300 species of vascular plats as well as 60 mosses in the European region. The same authors mention, that 60,000 taxa of invertebrates have been inventoried on stone walls and also note, that the portion of British spiders that can be classified as mural species is 10%. Vertical greening systems can provide food supply, shelter for predators and prey, cliff-nesting

opportunities for lizards and birds, flower-loving animals such as butterflies, bees and bumble bees and bristly flies, but also mammals such as bats, voles or shrews.

The main factors influencing habitat on a vertical surface that are listed in the article by Mayrand et al. (2018) are weathering (exposure, moisture, wind), structural elements (age, texture of construction materials, inclination, color, heterogeneity of material), but also maintenance (cleaning, gardening) and pollution as well as interaction with animals. Due to all these influences in combination with stochastic events biodiversity found on walls in urban environments can be described as stress tolerant, capable of coexisting and having a wide ecological amplitude.

In the table shown below (Table 1) recommendations can be found on adapting different kinds of vertical greening systems in order to function as habitat for biodiversity, based on problematics, that can be defined for each system (Mayrand et al. 2018).

Table 1 Recommendations for vertical greening system to function as habitat for biodiversity (Jayasooriya et al. 2017)

Feature	VGF	Disadvantages	Recommendations
Support	Modular LWS	Limited substrate volume for individual plants and limited chance for roots to extend and share substrates.	Enlarge rooting by proposing new containers.
Growing media	Modular LWS	Frequent and difficult soil management operations.	Stimulate the microbiological activity in substrates instead of supplying fertilizers.
			Choose plants with lower nutrient requirements, eventually with symbiotic interaction capacity.
			Leave a part of the decayed plants materials to accumulate organic matter.
Green coverage	GF	Limited choice of climbers for diverse climatic zones.	Additional research for native climbers needed.
	LWS	A large repertoire of exotic species.	Using native species and natural habitats as templates for assemblages.
	GF	Less likely to attract a wide range of wildlife.	Increase the functional diversity by selecting plants with different functional traits (e.g., flowering periods, plants visited by animals for nectar, pollen, or fruits, both deciduous and evergreen species, annual and perennial species).
			Allow the growth of spontaneous plants.
			Allow the coverage changing along the year through ecological processes (seasonal effect).
	LWS	Disturbance of companion wildlife because of frequent maintenance.	Decrease the intensity of maintenance by tolerating few spontaneous species with no impact on the system safety, and the seasonal effect.
	LWS	High probability of poor performance and more need for replacement	Choose native plants adapted to constraint environment.
			Plant diverse assemblages of vegetation according to the wall height and the gradient of ecological conditions (e.g., exposure and wind).
			Seedlings rather than pregrown plants.
Water	LWS	High consumption of irrigation water	Improve flows (e.g., water and nutrients) within the entire wall.
			Choose species with lower water requirements.
			Use rain water for irrigation.

LWS, Living Wall System; *GF*, Green Facade

4.2 Green Walls to mitigate Air Pollution

As mentioned in chapter 4.1, the predominant part of the human population lives in urban areas and forecasts presume the number to be rising significantly. Thus, many people accumulating in certain areas, leading to high environmental pressure pollution is of great concern. This includes mismanaged solid waste, leakage of potentially toxic waste-streams into water bodies and the ground water system as well as air pollution. Air pollution can be measured over cities with only a few million inhabitants but tends to get worse with increasing population size. Consequentially mega cities with more than 10 million inhabitants are affected the most. This can be attributed to the increasing number of pollution sources concentrated in one area with dense housing, traffic and industry.

The air pollution that is usually measured is described as particulate matter (PM). PM consists of numerous components such as small particles (dust and soil grains, etc.) but also liquid droplets comprising organic chemicals, metals, acids, and many other trace elements. A categorization has been made by the WHO depending on the particle's size; Coarse particles PM_{10} (particles with an aerodynamic diameter smaller than 10 μm) as well as fine $PM_{2.5}$ and ultrafine particles of $PM_{0.1}$ (Cong Liu et al. 2019). These particles are inhalable and hence, cause health issues in humans and animals, since they are small enough to enter the pulmonary capillaries and eventually reach the brain (Wright & Ding 2016). They are a result of combustion processes (for example from vehicle exhaust) and can be formed through atmospheric chemical transformation (Cong Liu et al. 2019). The European Geoscience Union published an article on PM origins in five southern European cities (EGU 2016). Causes of particulate matter release into the atmosphere include, as mentioned, vehicle exhaust and non-exhaust. The compounds released during these processes are not only primary polluters, meaning the compounds themselves already cause harm, but they simultaneously carry potential of secondary pollutants, reactions with other compounds must take place first in order for them to be harmful. Other important sources include biomass burning (often as result of heating efforts), local dust, industrial emissions from metallurgy for example and natural contributions from sea salt and spray or Saharan dust transported through wind (Amato et al. 2016).

Other air quality indicators in ambient conditions include Carbon Monoxide (CO), Ozone (O_3), Nitrous dioxide (NO_2), sulfur dioxide (SO_2) and Lead (Pb) (Jayasooriya et al. 2017).

The health effects of $PM_{2.5}$ air pollution have been more and more discussed recently, with a study suggesting 800,000 premature deaths per year in cities with populations greater than 100,000 (Krzyzanowski et al. 2014). Another paper (Cong Liu et al. 2019) presents data supporting that short-term exposure to PM_{10} or $PM_{2.5}$ is related to an increase in cardiovascular and respiratory mortality in more than 600 cities around the world. Thus, this study, funded by the National Natural Science Foundation of China, underpins the link between mortality and PM concentrations (Cong Liu et al. 2019). Worldwide annual deaths on the account of outdoor air pollution are estimated to amount to 4.2 million together with an increased risk of respiratory and cardiovascular diseases (WHO 2021). This resonates with the claim that the $PM_{2.5}$ air quality guidelines established by the World Health Organization are exceeded in Mega Cities, leading to ~96% of their population being exposed to concerning low air quality (Krzyzanowski et al. 2014). An assessment made by Krzyzanowski et al. (2014) has indicated that urban ambient particulate matter is the ninth largest risk factor for disease burden out of 67. In Eastern Asia the rank higher to being the fourth biggest risk factor, sixth in Southern Asia and seventh in North, West and Sub-Saharan Africa along with the middle east (Krzyzanowski et al. 2014).

An article published in the 2008 International Low Impact Development Conference proposes that in terms of plants' capacity to trap air pollutants like CO_2, studies have demonstrated that grassy plants are capable of trapping 4.38kg/m² per year; shrubby plants have the capacity for 8.76kg/m²; and climber plants can trap 6.57kg/m² (Roehr et al. 2008).

An increase in plant material can decrease the particulate matter concentration in urban air since leaves of vegetation are able to take up gaseous pollutants such as CO_2 through their pores and capture particulate matter on their surfaces. A team of researchers from the EHP, the Environmental Health Perspectives, suggest that street canyon vegetation could mitigate Nitrogen Dioxide (NO_2) and PM_{10} concentrations which are two of the most harmful and concerning urban air pollutants. Many investigations conclude that urban vegetation does not increase air quality in a manner that is significant enough for beneficial effects on health of urban dwellers, however

it must be considered, that humans are not usually found hundreds of meters up in the atmosphere but rather on pedestrian level. This means, that the air purification effect has to be measured and considered on a local scale and not for the entire atmosphere. The research done by the EHP considered air lingering in street canyons through which the contact time of pollutant scrubbing plants with harmful compounds is increased. They found that 40% of NO_2 and 60% of PM_{10} can be absorbed when street canyons are vegetated. This Figure stands in contrast to the 7-30% of average annual reductions that were previously estimated when considering the whole atmosphere. Similar reductions were found in a separate investigation on ozone pollution, whereas that study was conducted in an urban forest as opposed to a street. Models indicate that the depletion of NO_2 through vertical urban vegetation is 10 times as high as the cleansing effect of horizontal vegetation. For PM_{10} the factorial is 12 (Kessler 2013).

The following table (Table 2) shows quantified removal of selected air polluters, that function as indicators of urban air quality. The term "Green Wall only" refers to the modeled effects if no new trees were planted or other green infrastructure, such as green roofs were installed in the cities of interest (Melbourne, Sydney, Brisbane, Perth, Darwin) (Jayasooriya et al. 2017).

Table 2 Annual pollutant removal through different vegetation systems (Jayasooriya et al. 2017)

	Annual NO_2 Removal (Kg)	**Annual SO_2 Removal (Kg)**	**Annual PM10 Removal (Kg)**	**Annual CO Removal (Kg)**	**Annual PM2.5 Removal (Kg)**	**Annual O_3 Removal (Kg)**
Trees Only	964	125	1474	10	43	1885
Green Roof Only	109	30	443	10	14	357
Green Wall Only	87	26	314	10	10	298

As one can see in the picture provided (Figure 11) regardless of the building heights green walls work with different kinds of wind flows and particle dispersion and can thereby effectively contribute to carbon sequestration (Kumar et al. 2019).

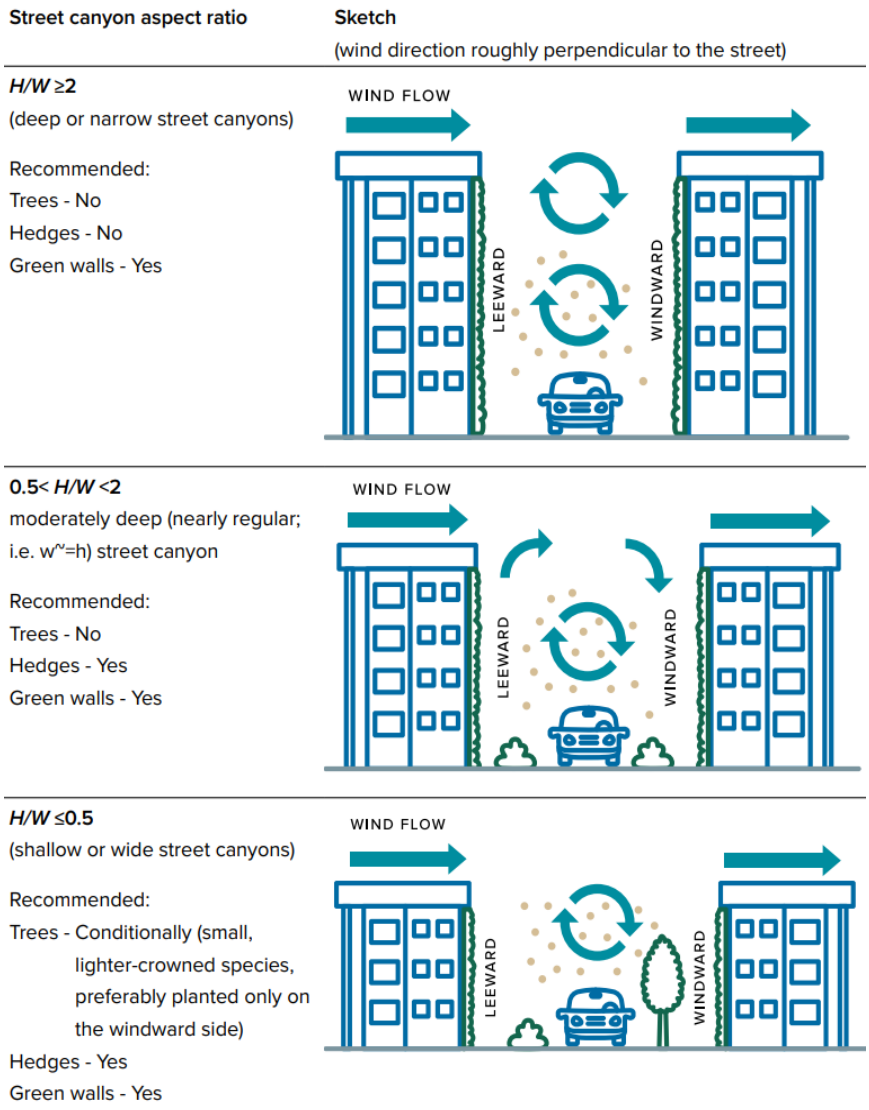


Figure 11 Recommendations of street side vegetation under the aspect of street canyon height (Kumar et al. 2019)

Additionally, green walls further contribute to higher air quality by reducing buildings' energy consumption as stated in chapter 4.3. Thereby less Energy has to be produced and less harmful particles are emitted into nature through burning of fossil fuels. Besides the beneficial health effects cleaner air has on humans, the positive contributions of higher air quality do not end there. By lessening greenhouse gas concentrations in our atmosphere climate change can also be mitigated.

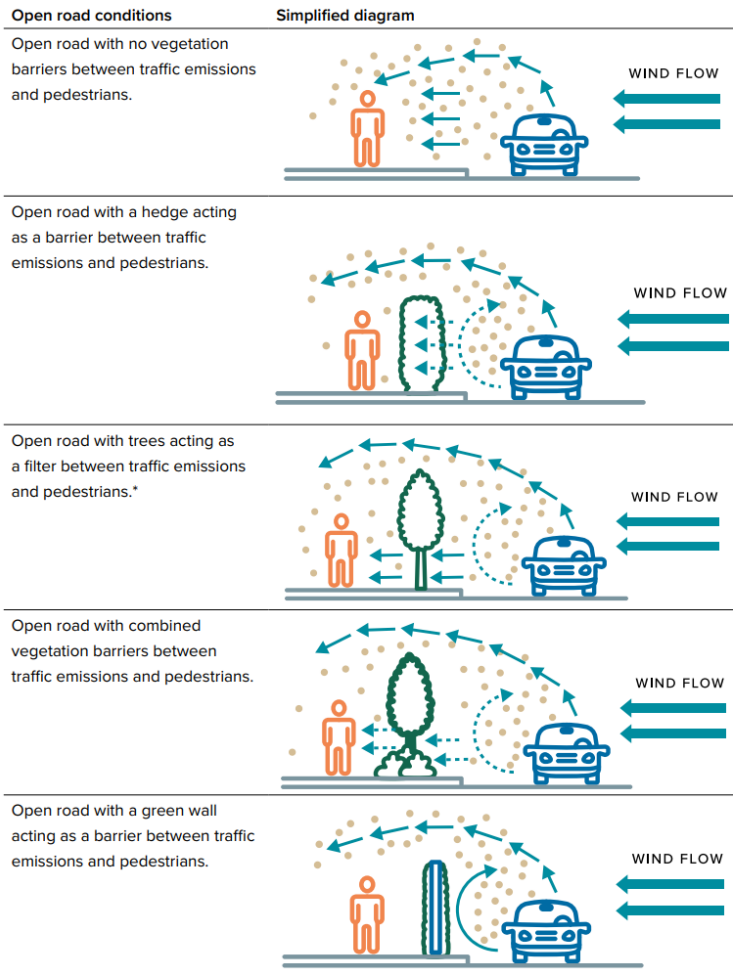


Figure 12 Simplified diagram of beneficial presence of green wall between traffic and pedestrians (Kumar et al. 2019)

4.3 Green Walls to combat Urban Heat

As commonly known, the earth's climate is changing (Caney 2015). Changes in the earth's climate are very natural, and during in the past 650,000 years seven cycles of glacial advances and retreats have been recorded (Sun & Rosenbach 2020). The reason for these changes is slight variations in the earth's orbit, that have an impact on the intensity and amount of solar radiation that our atmosphere receives. However, currently the planet's surface is heating up at an unprecedented rate, not to be found at any point in history (Climate.Nasa.Gov/Evidence 2022). Since the late 19th century the planet's average surface temperature has increased by 1.18 °C (Climate.Nasa.Gov/Effects 2022). Especially in the last 40 years thermometers have reached new peaks, reaching ultimate highs in 2016 and 2020 – the warmest years recorded in history (Climate.Nasa.Gov/Evidence 2022). This can be reasoned with an increase in greenhouse gas emissions such as carbon dioxide into the atmosphere

together with other trace gases released directly or indirectly through human activities. (Höök & Tang 2013)

The presence of gases such as carbon dioxide, methane and nitrous oxide have an immense impact on the Earth's atmospheric temperature due to their ability to absorb heat, that is radiated back from the Earth's surface. Before the atmosphere suffered recent anthropogenic impact, big portions of the sun's radiation entered the atmosphere, hit the Earth's surface, some were absorbed, most were radiated back into space and others were retained within, by gases like water vapor or minor atmospheric components such as carbon dioxide. Nowadays, the percentage of rays being absorbed is much higher (due to lower albedo) and the percentage of rays passing through atmosphere back into space is lower. The 'earth's Albedo' is an index used to quantify how well a surface reflects solar energy (shown in Figure 13).

By burning fossil fuels more trace gases and particulate matter that is harmful in large amounts are released, not only capturing heat but also attaching to naturally bright surfaces such as snow and ice, darkening them. This leads to a lower reflection rate and promotes the melting. Resulting in a further positive feedback loop as water in its

Figure 13 Visualization of oceanic Albedo under varying circumstances. The number in the top left of each image represents how much of the incoming solar radiation is reflected, the number in the bottom right represents the remaining percentage that is being absorbed by the ocean. (National Snow and Ice Data Center 2020)

liquid state reflects a lot less radiation as snow does. Further, by covering the planet's surface with dark materials such as concrete and asphalt through which the planets albedo is decreased, we enter a viscous cycle that results in hotter days and nights, a higher frequency and increased length of extreme heat periods will occur (Oleson et al. 2015).

The warming climate affects humans in many ways, especially people living within cities will get more and more uncomfortable as temperatures rise. The reason for that is the Urban Heat Island Effect. The term "Urban Heat Island Effect" describes a phenomenon of higher temperatures within urban environments as opposed to the

surrounding areas (Leal Filho et al. 2018). Reasons for that are 1) higher heat capacities of urban surfaces. This refers to the absorbance potential of the materials used in cities, such as dark asphalt. Also, heat is captured in street canyons, higher buildings allowing less wind circulation, which is known to cool down city and landscapes, leading to an increase in air conditioning usage and thereby contributing to more anthropogenic heat production. Further, as there is less greenery, evapotranspiration and shading cannot provide their natural benefits (Hoffmann et al. 2012).

The typical structure of dense cities, with their narrow street canyons allows trapping of radiation thereby increasing the surface temperature and also reducing airflow recirculation, consequently raising air temperatures as well (Djedjig et al. 2017).

Green walls can contribute to mitigation of the Urban Heat Island Effect among other things by lowering the building wall's temperatures, indoor air temperatures and the ambient air temperatures. Consequently, this provides comfort to citizens and thereby reduces energy usage and further promotion of a warming climate. These effects are achieved through three main cooling mechanisms: (Koch et al. 2020)

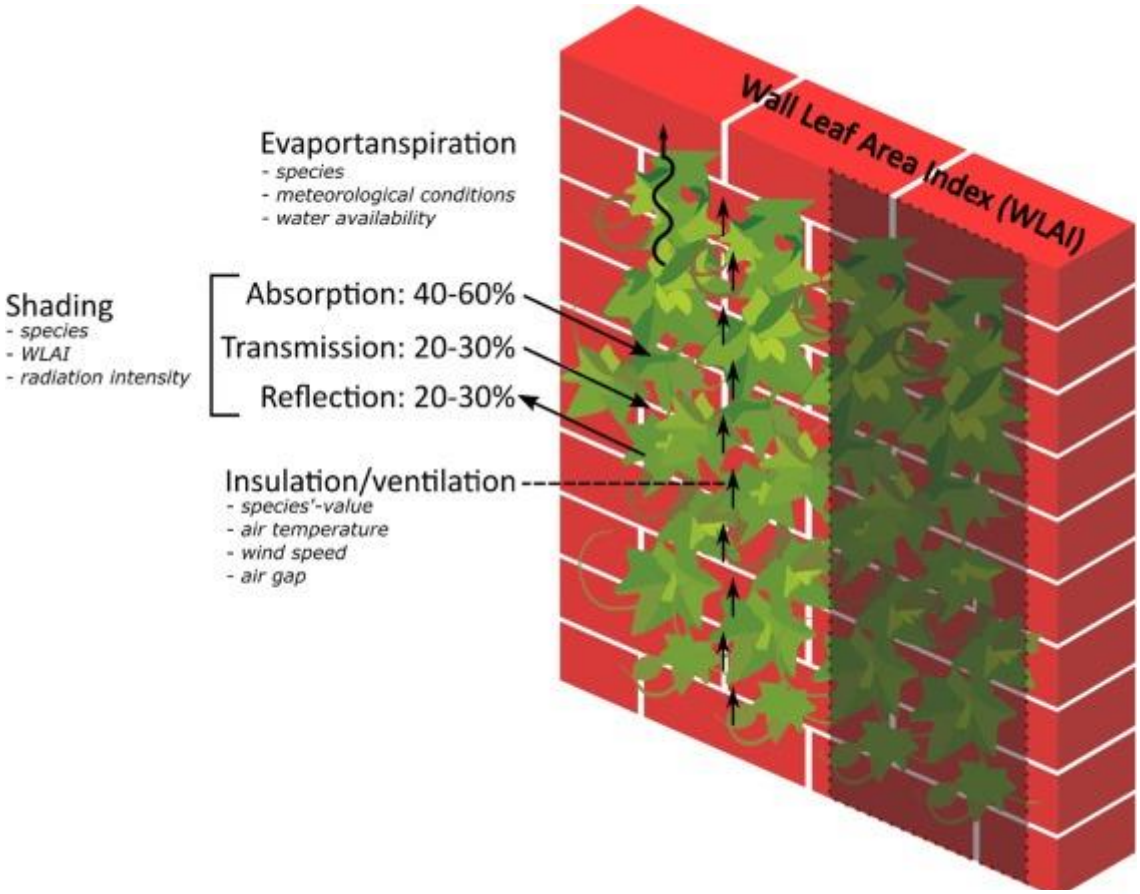


Figure 14 Three ways by which Green Walls can create a cooling effect (Koch et al. 2020)

4.3.1 Shading

According to Koch et al. 2020 in "Urban Heat Stress Mitigation with Green Walls: A review" cooling costs of buildings in warm climates can be reduced by up to 61% when green walls are installed. Shading prevents the surfaces protected by the plants from heating up as solar radiation is partially absorbed and reflected by plant material instead of reaching the building's wall. However, obviously the shading potential greatly depends on vegetation type, the thickness/number of layers of vegetation and many other factors. In the mentioned article it is stated that 55% of the incident solar radiation is not transmitted through one leaf layer and this rises to 69%, 73%, 78% and 88% with increasing layers up to five for *Parthenocissus quinquefolia*. Depending on the color and thickness much of the sunlight is reflected, depending on the leaf's albedo.

In cooler climates or winter however, the shading provided by the green wall can increase the energy consumption by 28% as buildings are not naturally heated up since sunrays cannot reach the building's surface, if evergreen plants are used. Therefore, the local climate has to be carefully considered when designing and planning a green wall. This is exclusively true when the sky is not covered by clouds, as Perini et al. performed an experiment in autumn in the Netherlands, where there is no direct sunlight. Only small temperature differences were recorded between a bare wall and a (i) direct Green Facade (ii) indirect green facade and (iii) a living wall system. The measured temperature differences amount to (i) 1.2 C°, (ii) 2.7 C° and (iii) 5 C°. However, when conducting the experiment in summer in Germany a reduction of the outside wall temperature by an indirect green Facade was 10.5 °C compared to a bare wall (Koch et al. 2020).

4.3.2 Evapotranspiration

Evapotranspiration implies two separate processes: Evaporation and Transpiration.

Transpiration is the process of healthy plant tissue losing water by opening of the stomata on the leaf's bottom surface in order to take up carbon dioxide and fulfill the photosynthesis process. Depending on the location of a plant, the surrounding environmental conditions such as humidity, temperature, wind, and quality of soil/substrate, the amount of transpiration varies. Only plants in non-stressed states (with sufficient water availability and good environmental conditions have high

transpiration rates (Koch et al. 2020). This is why maintenance and careful/informed planning of green walls plays a big role as irrigation and nutrient availability has to be insured to achieve the best possible cooling effect.

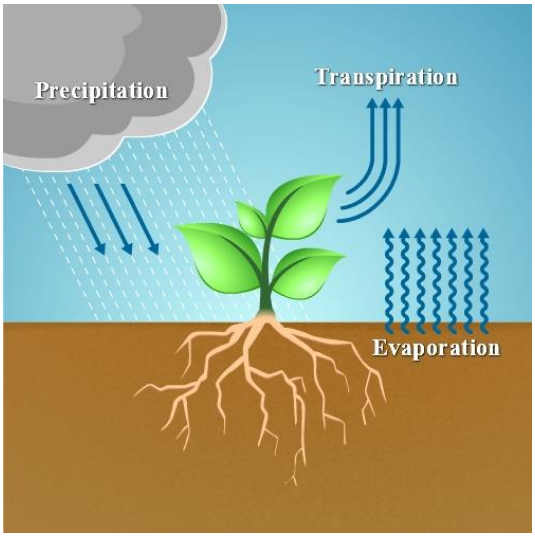


Figure 15 Simplified visualization of evapotranspiration (SupportSpruceIrrigation.com)

Evaporation describes the process of water moving from soil, waterbodies or drops of precipitation, that were intercept by plants, to the air in form of gas (Koch et al. 2020). As the evaporation of water from substrate leads to an additional cooling effect, soil based green wall systems can have an ancillary beneficial contribution to microclimate regulation. Those processes are presented in Figure 15.

Shading seems to have a greater impact on cooling a building than evapotranspiration has however, the latter influences the temperature of the ambient air on a larger local scale. For example, Daemei et al. (2018) published a study, for which outdoor air temperatures were measured at various distances from a Green Wall in a street in Tehran, Iran. The distances ranged from 0, 0.5, 1 and 2 meters from the wall. The results showed a decrease in air temperature in the street canyon of 0.8 °C. However, the authors seem to be disregarding other factors, that could influence this change in temperature such as wind speed and direction. A study of Djedjig et al. (2013) revealed an increase in relative air humidity of 6-8% in a street canyon, where one of the two walls was completely covered by greenery (Koch et al. 2020).

4.3.3 Insulation and Ventilation

As different kinds of green wall systems are installed, there is a tendency to insure placing plants in close proximity to one-another, thereby creating layering of leaves. This has obvious visual and aesthetic benefits as it creates a more vibrant and richer looking wall, but the layering of leaves comes with other positive side effects as well since air is captured in between the leave-layers and the wall (=air cavity). This air, as it is a stagnant layer can serve as insulation for the building, leading to fewer temperature-extremes of the surface (Djedjig et al. 2017). This consequence is especially relevant in winter, functioning as frost protection, but also preventing extreme highs in wall temperatures in summer. In addition, if living wall system are applied, the substrate, by being close to the building, offers additional buffering and protection of the architectural structure against extreme climate conditions. According to Tudiwer & Korjenic (2017) a green wall can make a difference in warmth of up to 3.5 °C (using an indirect green facade system and comparing the temperature of the underlying wall to the temperature of a bare wall). When conducting the experiment with a living wall system the difference in temperature only amounted to 0.5 °C. According to Koch et al. living wall systems act the same or even better than other commonly used insulating building materials. Another statement made by several authors, is that the presence of plant coverage obstructs the transfer of convective heat from the warm building wall to the environment at night during summer or in warm climates. A study by Perini et al. (2011) found that wind speed was almost non-existent within the foliage of a direct green wall compared to the wind speed measured in 10 cm vicinity of the wall. This phenomenon results in warmer walls during summer nights, being undesirable for human comfort in already warm climates, but can have a positive effect in less warm climates or wintertime. In order to ensure comfort in buildings with green walls that are located in hotter climates, the design can be adjusted, ensuring wind flowing through the leaves facilitating ventilation and convective cooling instead of insulation (Koch et al. 2020).

Applying measures such as green walls in order to improve the building's thermal performance can lead to a reduced usage of air conditioning and heating, decreasing power usage significantly and thereby contributing positively to climate change mitigation (Manso & Castro-Gomes 2016).

5. Methodology

In the scope of this Bachelor Thesis three different types of research have been conducted in order to obtain a multifaceted, overall picture, that is lit and looked at from different perspectives. The three types of research are 1) extensive literature review on selected topics, 2) two interviews with experts of their field and 3) an online survey that was administered to the general public.

5.1 Literature Review

One of the three types of research used to write this Bachelor Thesis was conducting a literature review. The reason for the application of this method of gathering information is the huge availability of findings from many different studies and investigations on the topic of interest. Advantage can be taken of the density of knowledge, that is present in digital databases and traditional libraries. Multiple databases were used in the process of identifying possible sources for this literature review. Primarily the search engine Google Scholar was operated to look for books, articles, theses and abstracts from academic publishers, professional societies, universities, and other sources in the relevant field of study. In the first phase of writing every chapter, I wanted to develop a strong understanding of range or variety of articles that are available and which of them seemed most relevant to my work. I did that by first applying broad descriptors, checking how many results could be found, also specifying the date of publication for each in the search result in order to develop a clear understanding of whether state of the art research is being done or if mostly literature from last century and/or beginning of the 21st century is available. The contrary phenomenon – only finding recently published articles would have been noticed and influenced the general picture as well. If the scope of results seemed satisfactory by consisting of mostly new but also outdated literature and by predominantly including the applied descriptors in the titles, Phase 2 would begin. This step included first opening the links to many of the articles found in the first phase (search of the databases) in separate tabs, based on relevancy (= containing of descriptors in title, focus of research appropriate to my topic of research). Then, I would read through the abstract of each of the opened articles and pay attention to the chapter's titles and subtitles and quickly read through the ones that seemed relevant to gain a general picture of the information available. I would then take note of all suitable chapters and where to find them later-on during the process of writing. Then, I would

make a list of new descriptors. These are either synonyms to the ones used beforehand and/or more specific in their nature. The same process is then applied: Opening the links to search results, that include descriptors in their titles and have an appropriate publishing date. Then reading through their abstracts and the chapter titles, investing more time in the sections with headings appropriate for the topic of interest. I would then close the tabs with articles, that have proven to not be as relevant as first supposed after reading through the abstract and getting an overview of the chapters. The articles that did seem relevant would be kept for later review in a tab. Using "Google Chrome" I would group the tabs depending on what part of my thesis it could be relevant for. For example, I would have a group called "Systems" for the chapter focusing on different Green Wall Systems available and parallel a group of tabs named "Heat" for the chapter dealing with the benefits of green walls to combat urban heat island effect and reduce energy consumption. In the Figure below an example can be seen.

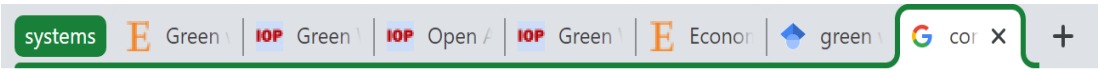


Figure 16 showing grouping of tabs under specific research topic as methodological approach in reviewing literature

Factors influencing source selection include the relevancy and popularity/integrity of the publisher. If articles were published by "Elsevier" for example, then they would be considered a more trustworthy source of information as opposed to some pdf file found in the width of the internet, that was not published by a known trustworthy source. Also, the number of references listed at the end of an article can indicate whether extensive research has been done as a foundation or in the process of writing, which again has a positive impact in the selection procedure of sources together with the number of citations that have been done.

The thematic descriptors (similar to key words) used for the chapter focusing on the benefits of Green Walls for Heat Mitigation were:

Urban Heat Green Walls, Urban Heat Island effect mitigation, Green Walls heat reduction, thermal effect green walls, heat stress reduction vegetation, adaptation mitigation to climate change, climate green wall, heat mitigation cities,

After getting a first overview on what research has been done on the topic of interest, I would write down how I would like to structure my chapter by using bullet points. Continuing with the example of the "heat" chapter I noted that I first want to give a

general explanation on climate change and provide a foundation for readers to understand that many cities, especially bigger ones are tending to get hotter every decade and thereby lay the foundation of understanding why heat is presented as a problem, that needs to be solved. After providing a general understanding of reasons why heat mitigation is and will be necessary in the future, the thermal effects of green walls are explained. In effect what I was trying to do is starting chapters with a broad overview and then narrowing down to more specific sections and more details.

I read certain segments of articles relevant to the section of my chapter that I was working on and then started writing on mine, switching back and forth between different sources of information and my document.

5.2 Survey

I started by brainstorming which types of surveys would make the most sense in order to capture a representative general picture of people's perception on green walls. I first considered standing on the streets of Vienna, located close to a building that uses external vegetation on their building facade, and asking people passing by on the street to participate in my survey, answering the questionnaire. I was considering standing in front of IKEA Wien Westbahnhof, a newly constructed IKEA store, which is prominent due to its design and integration of vegetation in its aesthetics. Also, the new Hornbach store would have been subject to my research as its new facade has captured the attention of a lot of media during the time, since its huge facade cover in vegetation can hardly not be noticed when walking by.

Figure 17 HORNBACH'S green facade on Mariahilfer Gürtel in Vienna, Austria quoting "Überall kann Garten sein" (translation: "garden can be everywhere") (Hornbach 2021)

However, I quickly concluded, that in order to reach an adequate number of people to make the survey statistically valid, asking strangers on the street would not be the most effective way of action. I then considered doing an online survey as this medium would allow the survey to be available to a much broader range of people, independent of their physical location. Conducting the survey online brings several benefits with it; some of these are listed below:

- A bigger and more diverse group of people can be included as the online survey is completely independent of the respondent's location. If the analogue survey were to be conducted in the first district of Vienna, the center of the City, where more people of higher socio-economic classes are to be found, the results might differ from a survey conducted in other neighborhoods such as the 10th district or certain outskirts. Providing the form on the internet will reach a broader respondent audience.
- The number of respondents also increases since they are able to take part in the survey whenever the time is right to them. When conducting the survey during traditional working hours in person, it would be assumed that a greater majority of people are at work in an office are not available to take a survey; if they are outdoors, many may be on their lunch break and have no time for a survey. However, by providing the survey form online, people from a broader range of occupations, including students, could take

part, irrespective of their working hours. These are only some of the reasons why I decided to proceed with an online survey.

Then several options for online survey tools where considered. These include “Google Forms”, “Survey Monkey”, “Survey Planet”, and many more- I chose to use “Google Forms”. I made note of several questions that should be included in the questionnaire while brainstorming, and also gathered further questions that came to my mind at later times in a “notes” application. The questions where selected based on relevancy, applicability to a wide audience and my research. For some multiple-choice questions, I decided to include pictures found on the internet. The survey was available in English and German in order to include a wider audience.

The preface to the questionnaire was this paragraph (English version):

My name is Elena Spallart, I am an Environmental Engineering student at the Czech University of Life Sciences in Prague. As part of my bachelor thesis, I, among other things, deal with the effects of green facades of corporations / institutions / service providers in urban environments on consumer behavior.
Your answers are of course completely anonymous. They can make an essential contribution to forming opinions on this highly contemporary topic and thus to the cityscape of Vienna. Please take approx. 4-5 minutes of your time to fill out this questionnaire.
Thank you a lot,
Elena

The German version had the exact same preface, translated, and can be found in the appendix.

After collecting a set of questions over the course of four months, reevaluating their relevancy, their phrasing and order in which they shall be presented, I registered a Google Account and implemented the questions into a new form. Even though I visited sites such as the IKEA Wien Westbahnhof myself and took pictures of it. I decided to use pictures found on the internet for each site so as to be of similar style, trying not to create any bias among the respondents. Once the form was done in German, I replicated it in English and published it on platforms such as Facebook. I chose groups that could include international and local people living in Vienna, such as “Uni Wien Studentinnen und Studenten” (translated meaning “Students of the University of Vienna”), a group with 12.695 members at the time. “Vienna International Students”,

with 8.262 members, and "Erasmus + International students Vienna/Wien 2020-2021", with close to a thousand members at the time of posting. I also published the survey in a group called "Study in Austria | International + Erasmus students (Housing, events,…)" and others. This way students and professionals of all ages and careers have access to the survey. Additionally, I sent out the link to distant family members who shared it with their contacts, incorporating people from all age groups and several different countries, reaching different socio-economic groups. All questions had to be answered in order to submit the survey except for 2 follow up questions based on a negative answer in the previous questions.

5.3 Interviews

While brainstorming the topic of my bachelor's thesis I quickly came to the conclusion, that opinions of experts/ people working in a field that touches on the topic from different perspectives are a valuable source of information, which I would like to incorporate into my work to have an even better representation of reality. After structuring my thesis and deciding on angels to approach the matter I reached out to *Die Umweltberatung* via Email and requested an interview. I roughly summarized what I would be asking about, however I did not attach the questionnaire. Their quick response lead to a Zoom Call with Mr. Björn Schoass, who is Head of Consultation for green facades and roofs. I requested to conduct the interview in English, yet – as his technical vocabulary is only profound in German – he denied that request and the interview took place in German. It lasted approximately 35 minutes.

Additionally, I reached out to Valerie Brunner, who is the Group Head for Institutional Clients at Raiffeisen International Group with the requisition to interview whoever may be the most appropriate person of expertise in the field. I described what my thesis was about and why I would like to know about the banks point of view. She contacted colleagues and added me to the email conversation. Following their responses, I contacted the person most suitable, Andreas Deutsch, Deputy Head of Department - Real Estate Finance at Raiffeisen Bank International AG. I sent him the list of questions and he agreed to conduct the interview in English, it lasted approximately 45 minutes.

Further, I decided to contact the Head of Corporate Social Responsibility of HORNBACH Holding AG & Co. KGaA, as a huge green wall was installed, located on Mariahilfer Gürtel, Vienna. I contacted them multiple times via email, asking for an interview and also attaching the questionnaire asking them to respond in a written format if there is no interest or availability for an oral interview. No response was received after my first attempts, however at after email number three they replied that they are not interested. The same procedure was executed with IKEA Austria, however no response was ever received.

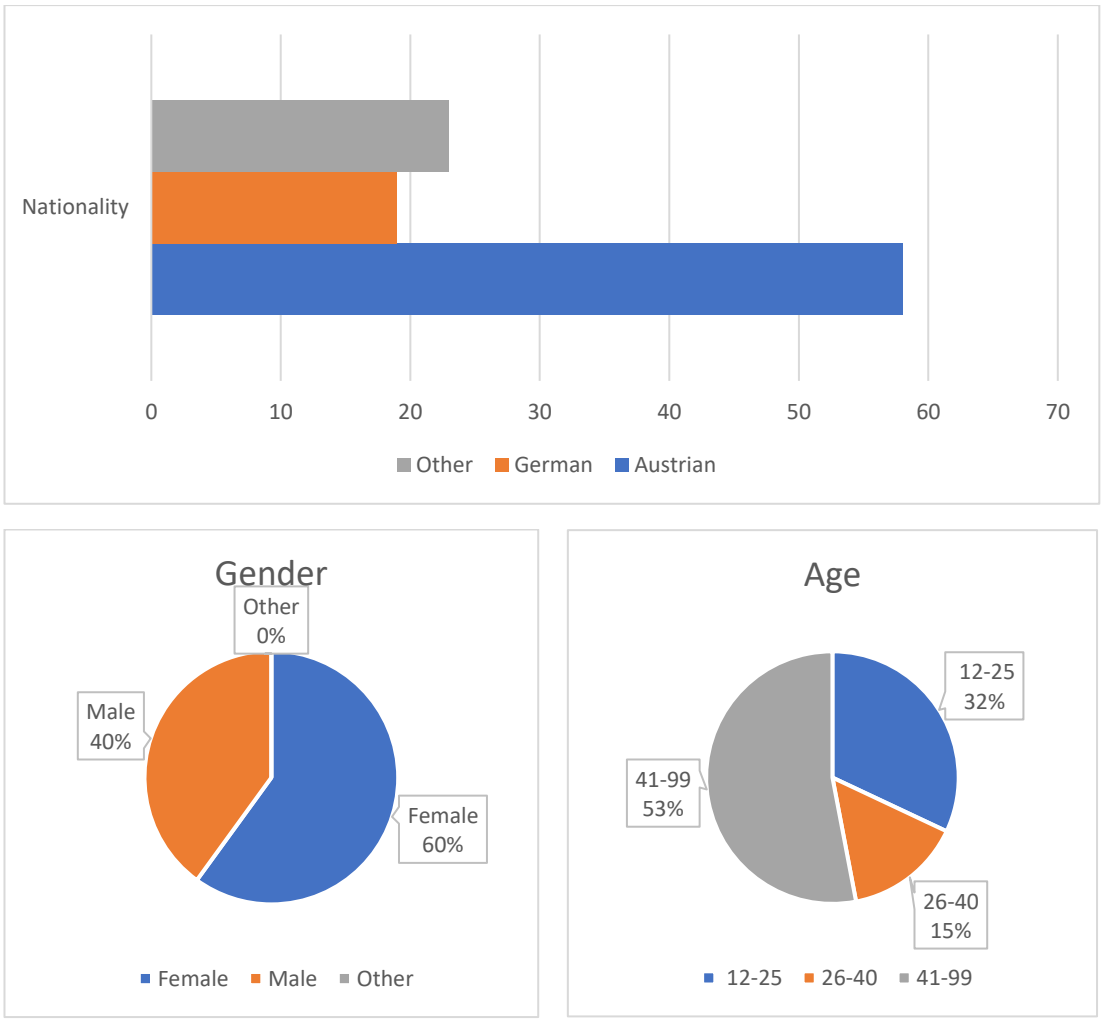
6. Results

This chapter summarizes the results obtained by conducting two kinds of research: a survey and two interviews.

6.1 Survey

About the respondents:

The online survey was published on November 16th, 2021 and was kept open until January 18th. In total, combining both the German and English survey, 79 answers were received within the first four days of posting the survey online. In total 100 people took part in the survey, 71 in the German version, 29 in the English one. As can be seen in the graphs provided below, the majority of participants have the Austrian nationality. The German form was quite balanced with 37 female and 34 male respondents, however when including the English survey 60/40 is the final count; no one marked “other” as their gender. The age group that has been represented the most is 41-99 in both the German and English surveys. Next are people with the age from 12 to 25; 32 of them took part. The remaining group of 15 people is 26-40 years old.



Graph 1 Nationality, Gender and Age of survey respondents

The information gathered about the respondents were withdrawn from question 1-3. In the following paragraphs answers to further questions are presented. Follow-up questions such as "briefly state why" are included in the data results which is why certain questions seem to be left out, however they are not. The survey in its entirety can be found in the Appendix.

Question 4

Seven people chose option A (Figure 21)

93% of respondents, 93 people, chose answer B for question 4, that can be seen below. Most people reasoned their choice by either saying it 1) looks more appealing, friendlier, more inviting and/or 2) they expect healthier, more organic, more sustainable food options and/or 3) they like the contribution to better air quality/climate change mitigation. The seven people who chose Image A did not have

reasons in common, they ranged from *need the parking space, no bugs, B looks artificial, A seems bigger*. One noteworthy justification was *B seems more expensive.*

Figure 18 Screenshot of question 4 and the available options

Question 6:

88% of people expected higher sales prices in the shop to be seen in Image C (Figure 19). Reasons for that are the architectural design and the associated construction costs. People believe that maintenance costs, and the costs of implementing a building as in Image C will result in higher prices for the end consumer.

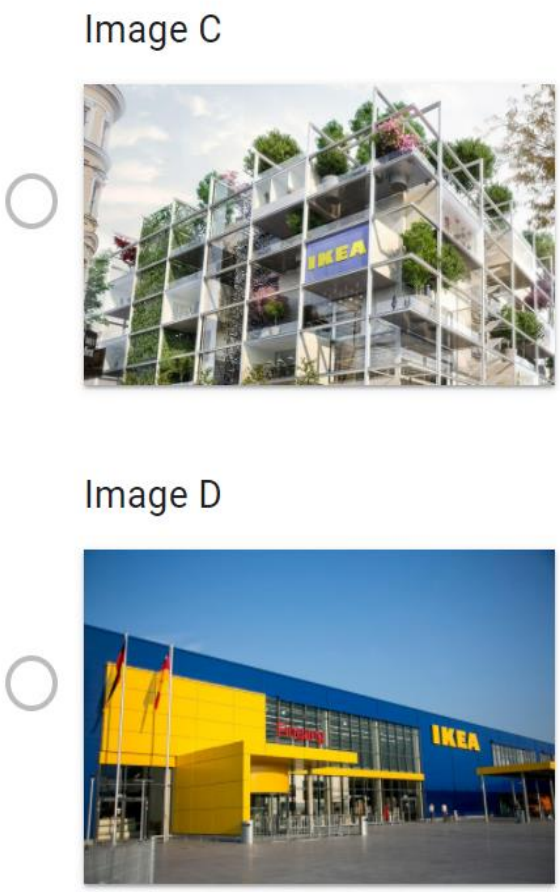


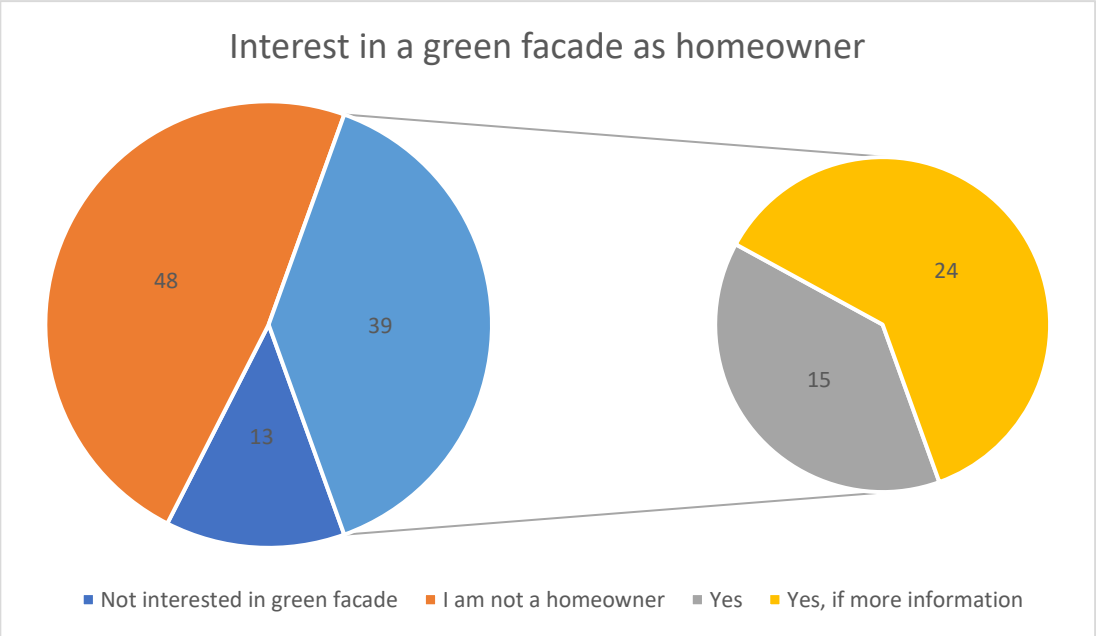
Figure 19 Question 6 and the available options

Question 8:

91% stated that in their experience finding a green facade within a city is a rather rare occasion.

Question 9:

Of the 52% of people that are homeowners, a little more than 46% or 24 people said they would install a green facade if they had more information on costs/maintenance/benefits. 15 people said they are indeed interested in installing a green facade on their home, even without further information. The remaining 25%, stated they are not interested in a green facade on their home. Their reasoning was mostly fear of installation and maintenance costs as well as insects entering the house.



Graph 2 Respondents' interest in installing a green facade as homeowners

Question 11:

96% of the surveyed find green facades aesthetically pleasing.

Question 12:

99% of people agree that green facades contribute positively to the cityscape.

Question 13:

98% of people would implement more green walls in Vienna if they had the chance to do so. Two people disagreed and stated it would compromise the architecturally beautiful city and that, as there are many old buildings under heritage protection, the facades might be damaged.

Question 14:

78% believe, after only being presented with the figure shown below, that the company is concerned with its impact on the environment. Justification of this opinion is mainly that the green facade shows commitment and involvement of the company and investing in such a structure comes with true interest in impact reduction. People stating *no* suggest that the green facade might simply be the move on the part of the company to improve their Public Relations and public perception of who and what the company is; few even mentioned that the facade likely is an attempt at "green washing".

Figure 20 The picture that the respondents were presented when answering question 14 (Ryan 2011)

Question 16:

75% state that the greenery on the building's facade gives the impression that the company is trying to maximize its positive ecological impact; 25% disagree.

Question 17:

60% of people have the impression that companies / organizations / corporations / etc., with overgrown facades use all means available to them to have the least possible negative impact on the planet.

Question 18 and 19:

72% of the respondents would like to have a green facade on the building they live in and 95% would like to like to have the view of a green facade from their apartment.

Question 20:

76 % answered that green facades give them the feeling, that the world / the economy is developing in a more sustainable direction.

Questions 24:

80% stated, that the change of design of Hornbach, Ikea Wien Westbahnhof, etc., has sparked new interest in visiting the stores.

Figure 21 IKEA Westbahnhof in Vienna, Austria

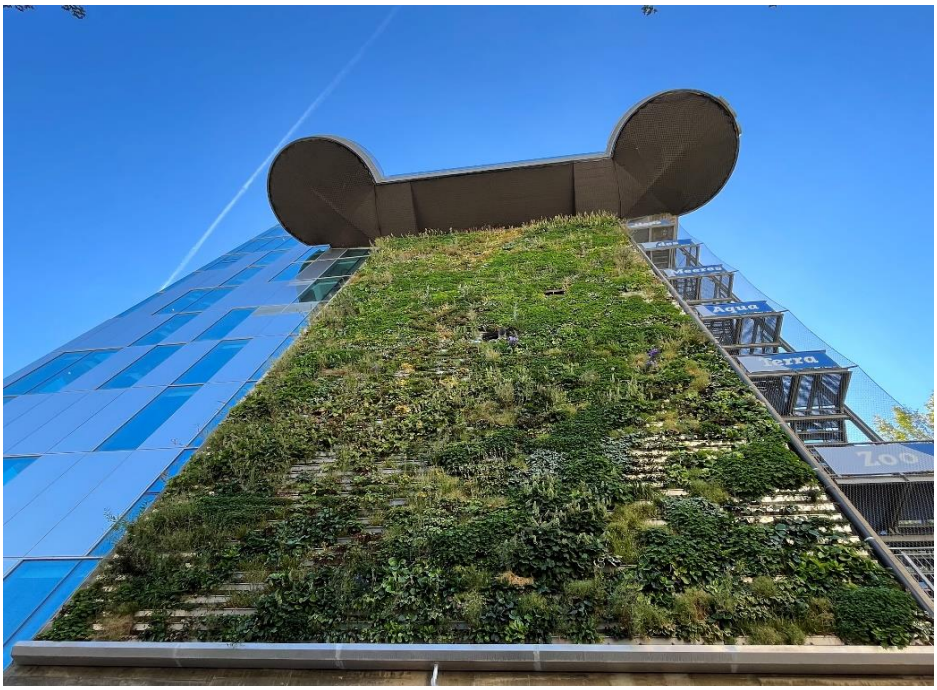


Figure 22 Haus des Meeres Museum Vienna, Austria

6.2 Interviews

6.2.1 Die Umweltberatung, Björn Schoass

16.12.2021

Figure 23 Die Umweltberatung Logo (DieUmweltberatung.com)

The company „*Die Umweltberatung*“ (German for “The Environment-Consultancy”) is a consultancy firm, that was established in 1986 in Niederösterreich, a state in the Republic of Austria and later expanded to the states Wien, Burgenland and Kärnten. Not only do they provide consultation for private individuals but also for companies, groups, communities and institutions, etc., and are specialized on the environmental aspects of subjects such as energy, waste, consumption, and building. They provide information on subsidies, and ways to harvest and use energy in the most environmentally sustainable way as well as how to build/insulate/use appropriate materials etc. in order to minimize heat loss and overconsumption of resources. The department most relevant for this bachelor thesis is the department of consultation for building greening.

The consultancy has been working together with the City of Vienna since its founding days and is financed by its environmental protection department. *Die Umweltberatung* has been receiving subsidies by the City of Vienna ever since it’s establishment, so since 1986. They mainly focus on providing information to the client on whether receiving subsidies is possible for their project, which systems could be appropriate (green wall, throughs, …) and offer their advice on which specific plants could be suitable for the best site-specific growth. They provide consultation and information and contacts to other firms, that can help with implementation of these ideas. *Die Umweltberatung* is not involved in planning or concepting, however they can connect clients with other companies found in *Grün statt Grau* (= translated “green instead of grey”). *Grün statt Grau* is a competence center for greening buildings, connecting people, products and projects.

In order to find out what the driving forces for companies’ installation of green walls could be, a list of three potential motivations is provided below.

1) Green washing: Improving their image to seem environmentally conscious
2) Incentives by banks and or state subsidies
3) Legitimately wanting to have a positive impact on the planet

Supporting statements to the hypothesis 2 which states that companies are inclined to install green walls by the option of receiving subsidies by the state or other institutions, have been made in the scope of the interview with Mr. Björn Schoass, who is the consultant for green building envelopes at *Die Umweltberatung*. He mentioned, that there indeed was an increase in consultation-requests after the subsidy program was introduced. According to him most companies contacting the firm for consultancy regarding green facades are interested in receiving the 5.200 € subsidy, that is provided for street-side facade vegetation. However, he also mentions that the typical clientele excluding individual private customers are rather small companies and not huge groups such as H&M. He reasons this by arguing that large corporations would be interested in huge installations to bring across an impeccable message to the customers. Such large installations easily exceed the 5,200 € support provided by the City of Vienna and since the willingness for a huge investment is already given, a small sum like the one mentioned will most likely not play a big role in decision making. He also mentions that companies like H&M, to whom it is important for the customer to see the green wall, as it promotes a "green" image, would invest in a more complex green wall installation, while small companies might just have climbing plants on their facades. So even though not all companies, especially not larger ones are motivated by this incentive, the sum is big enough for there to be a clear increase of 30% more consultations each year. As adaptation to and mitigation of climate change and urban sustainability play a big role in politics and media nowadays, the option of receiving subsidies for contributing positively is promoted. According to Mr. Schoass the relevancy of this state-of-the-art topic has also contributed to the increase in interest in green walling and thereby in consultations.

Further reasons for soaring attraction to green facades are the changing regulations and requirements to a) get the permission to install a living wall and b) to receive monetary support. As *Die Umweltberatung* is in constant contact with the pertinent office department of the City of Vienna, they provide feedback, critique and also updates on what the clientele is looking for and what should be improved. Thus, they contribute to having more people/institutions who already show interest in this construction effectively move forward with installing a green wall system.

Some of the requirements that need to be met in order to be allowed to even install a street-side green facade in Vienna, Austria include

1) The owner of the house has to sign a letter of acceptance, agreeing to the installation of greenery on the building envelope. If there are several owners, the majority of them has to consent to the implementation.
2) Examination of the cityscape compatibility needs to be undertaken. The Magistrate for architecture and City-Design has to approve, that the local city scape will not suffer under the construction planned.
3) Approval of other magistrates such as MA 37 (construction police for building permit) or MA 46 (permission to use road as is it public property), MA 28 (compatibility with underground pipes etc.) are also necessary.
4) When implementing a green wall on the street side which uses part of the space provided on the side walk (by using throughs for example), regulations require two meters to be left on the side walk for pedestrians.
5) Heritage protection does not allow green walling on the street side of protected buildings, however patio greening could be possible.

According to Mr. Schoass fulfilling these requirements are often the main reason why once interested clientele will back out before installation. This is why he sees importance in the constant communication with the City of Vienna, to communicate changes of interest, main challenges and other aspects of the collaboration.

6.2.2 Raiffeisen International Group, Andreas Deutsch

30.12.2021

Figure 24 Raiffeisen Bank International Group Logo (RBInternational.com)

Andreas Deutsch is the Deputy Head of Department in Real Estate Finance at Raiffeisen Bank International Group, located in the Head Quarters in Vienna, Austria and has been working for Raiffeisen for 12 years. According to Mr. Deutsch they have a loan portfolio of commercial real estate of approximately 3.5 billion booked in Vienna. They focus on all commercial real estate classes, meaning offices, hotels, real estate for logistics, warehouses, estate used for health care, and also residential real estate. They only take on large projects with a minimum financing volume of 25 million Euros which consequently results in mostly institutionalized projects. Main focus lies on the Austrian market, however Germany is the market with most bookings

in the portfolio. Second is Austria, followed by Romania, since they are present in Central Eastern Europe. There are separate Raiffeisen teams that are focused on individual real estate in those countries, since Mr. Deutsch's department focuses on large and international transactions.

Following questions were asked in order to find out if and how banks influence companies/institutions etc. to install green walls and other "green architecture". When asked if, as a lending organization, preferential benefits or incentives are provided to clients that are involved in sustainable projects he answers with a clear yes. However, he also explains that the preferential treatment is not in form of better credit terms or similar advantages but the fact that a client is even considered to be financed is the beneficial treatment he is talking about. For every credit decision of real estate projects, the question always arises if it is a sustainable certified project. A project, that is not certified will have it a lot harder to be admitted financing. According to him these values have been especially important to the real estate market and thereby the group for the past two to three years. The certificates that are excepted and eligible for green bond (Raiffeisen is the largest green bond in Central and Eastern Europe) are LEED (=Leadership in Energy and Environmental Design) ("Gold" is necessary), ÖGNI (Österreichische Gesellschaft für Nachhaltige Immobilienwirtschaft, translated: Austrian Society for Sustainable Real Estate Management) based on the European quality-certificate DGNB (=Deutsches Gütesiegel für Nachhaltiges Bauen, translated: German Seal for Sustainable Building) (again, the level "Gold" must have been achieved), and BREEAM (=Building Research Establishment Environmental Assessment Method) ("Very Good" is required).

However, depending on the type of real estate there are other ways in which the "sustainability" aspects are checked. In refurbished buildings for example insulation, walls or roof replacements and heating systems can have a positive impact on its rating. They have categories of A,B,C,D,E and if two steps of improvement can be seen or there has been an improvement in energy consumption, a project is eligible. This can be checked as owners of each building in the European Union have to provide an Energy Performance Certificate.

In the course of the interview Raiffeisen's ethical responsibility to follow and support "green" development and change is mentioned several times. Examples are brought up, for example the establishment of a department for sustainable finance and the bank

becoming a signatory of the Global Principles for Responsible Banking of the UN Finance Initiative in February 2021. When asked why Raiffeisen cares about whether their business partner is involved in "green projects" or how doing that reflects positively on Raiffeisen he responds by saying it lays in the provincial "DNA" of Raiffeisen who's founder days date back hundred years. Deutsch also claims that Raiffeisen helps former communist countries develop in a future oriented way, transforming into a modern economy that lays focus on environmental sustainability, changing their brownish economy to a greener one. Companies that are in the public light, governmental companies, stock listed companies that have to publish sustainability reports are more driven to apply changes. The more market players adapting to standards the more pressure. This evolution can partially be related back to banks like Raiffeisen being selective with their financial partners. Raiffeisen exclusively requires certificates, since the advanced technical knowledge to ensure "sustainability" of a project is not available within the bank which is why those aspects are usually outsourced. However, EU energy performance certificates and internal ESG ratings are valuated within the bank. In order to assess adequacy of a partner an ESG questionnaire was created, that is provided to clients. Although it is not yet mandatory it will be in the future as part of the rating system. The higher one's rating in the ESG, the higher your overall rating will be and the better the pricing for the client. This is one way how banks such as Raiffeisen indirectly but strongly influence the installation of green walls, green roofs etc. "*More sustainable projects will receive cheaper money*", is what Andreas Deutsch states. Raiffeisen tries to be as objective as possible which is why they don't give higher ratings to a green wall over a green roof for example as they don't pick out individual components for their credit decisions but instead try to approach the subject in a more holistic way. Even though he is not certain what percentage of the Bank's branches has green facades, he cannot confirm nor deny whether the motivation behind the installation is pr. In his personal perception the intention is rather to have a positive impact, even a small one, on the local community. He believes that by starting initiatives and briefing clients, advising them how to get better ESG ratings Raiffeisen motivates companies to choose a rather environmentally friendly path and contributes to sustainable development. They want to make sure, that clients are fit for the future and transform Raiffeisen's share portfolio into green finance.

7. Discussion

The results obtained by the survey indicate that what was presented as a hypothesis proved to be true: *Green facades can be used as a greenwashing tactic since it influences the customer's behavior and perception favorably for the company*. The effect of the behavioral influence includes choosing the store that has a green facade over one that does not and will in return have a positive and lucrative result for the business. Further, the public perception of the venture can be modified by exhibiting a green facade. The findings revealed that three quarters of people believe a business is trying to maximize its positive ecological impact when a green facade is installed and 78% believe that a business with a large street side green wall is concerned with its impact on the environment. About 60% are convinced that the company uses all means available to them to have the least negative possible impact on the planet. In the article "Concepts and forms of greenwashing – A systematic review" (de Freitas Netto et al. 2020) greenwashing is, among other definitions, defined as: "the act of misleading consumers regarding the environmental practices of a company or the environmental performance and positive communication about environmental performance". This definition resonates with the data collected from the survey. The reason why green facades can be used as strategic technique for greenwashing is that they seemingly convey an image or a set of values and actions that do not necessarily match with reality. The company or institution could have an extremely large negative impact on the planet and yet day-to-day costumers are fooled by the use of smart PR stunts into believing the business is trying their best to fight climate change and ecological disasters. This can have devastating consequences since public pressure for proactiveness and change in business practices is reduced when the public believes issues are taken care of. If not approached skeptically, some companies can hide behind "green talk", distant future goals and a simple design practice such as a green wall and are even encouraged in their behavior as they receive approval through monetary influx.

According to the research presented in this thesis, the role of banks in this matter does not directly encourage greenwashing however depending on their precision they could have such an effect indirectly. In the case of Raiffeisen Bank International Group, by expecting a certain standard of official certificates they avoid being fooled by "green talk" and green facades in the metaphoric sense, as energy consumption for example

is measured and can, if corruption is ruled out, not be glossed over. As they don't focus on single details but rather approach setting standards in a holistic way a green wall does not convince them of a business partner's sustainability. Nonetheless, not all money-borrowing institutions have such an approach and can either directly be fooled, or, if not trustworthy certificate issuers are chosen, attention can be deflected to minor actions such as a green facade in order to satisfy stakeholder requirements without sufficient measures taken.

Governmental incentives by the City of Vienna do not seem to be contributing to usage of green walls as a greenwashing practice since, according to Björn Schoass and common sense the 5,200€ are easily exceeded in the major architectural design practices that large corporations use to impress costumers.

It is no surprise that 72% of surveyed people would like to live in a building covered by a green facade as living walls seem to be a very welcome solution among the respondents. Note that the survey data is significant: 95% would like to have a view on a green facade from their apartment/building and 80% stated that interest in visiting a store with a green facade was sparked once the architectural design was changed. This suggests that people who live in the study area and who responded to this online survey are willing to pay higher prices when a store presents vegetated walls, as most agree to rather visit a store with such architectural design and simultaneously agree to believe to find higher sales prices in such a store. They believe prices are higher due to the architectural investment that had to be made however, one must also consider the reduced fixed costs as energy consumption can be reduced (heating/cooling).

The installation of a green facade in the urban environment can have significant positive impacts on the local microclimate and thereby contribute to human comfort by cleaning and cooling the air and providing psychological relieve as well as habitat for animals, which is why they should indeed be implemented on bigger scale. They can play a major role in adaptation to climate change in cities, however it is clear that they are not the solution to combat the challenges and issues that we ourselves as humans put upon us and all life on planet earth. They will not stop the climate from changing and natural disasters from increasing if no other measures are taken, nonetheless they can be an important contributor to adaptation to the new era. Further, it should also not be dismissed, that green facades do not only provide benefaction to humans but to ecosystems, that we disrupted and biodiversity that we are losing.

Ethical responsibility for including urban greening could thereby also be considered, as one could say it is our responsibility to try and mitigate the effects that our actions are having on local flora and fauna.

The vast majority of surveyed people (98%) agreed that they would support more green walls in Vienna if they had the chance to do so in a simple manner and I am of same opinion. Development in consciousness can be observed though erection of governmental structures and initiatives in Austria. The City of Vienna, to some extent, seems to be aware of their power to increase urban gardening by providing incentives, and paving away for green facade installation. Such measures should be replicated and improved in other cities and states around the world. Austria's capital also plans on making vegetated street side walls for buildings of certain size mandatory.

The mentioned positive aspects of green facade installation are important and key driving forces of execution however, green facades should not be used by companies to deflect from major negative environmental practices and promotion of a green image without appropriate action behind it. It is great to see big installations as evidently, they are a positive contribution to urban environments, however consumers must be critical of what assumptions they make and conclusions they jump to. Just as green colored packaging does not comply with "green" (environmentally friendly) contents, one should not stop demanding corporations to provide evidence for their supposed change.

I was not surprised that both the hypotheses "Green walls do affect consumer behavior" and "Green walls influence the opinion of the general public on companies" were proven to be true as greenwashing is a remarkable phenomenon of modern times. I was suspecting a greater direct influence of banks on companies' motives to hide behind a green facade in the metaphoric sense as I expected rather specific and tangible and less holistic beneficial treatment by money-borrowing institutions for costumers, that are involved in initiatives promoting environmental health. Furthermore, the little influence that the City of Vienna with its incentives has on larger companies was unforeseen but interesting to make sense of, together with the big success they have on private costumers and smaller shops whom they truly seem to nudge in the right direction with the money and service that is provided. The importance and effect that encompass green facades came as no surprise as I was previously aware of their benefits and value. The survey results however were a lot stronger in their nature than

expected. A tendency towards greenwashing was barely put to doubt before conducting the study, nevertheless I was not anticipating respondents to agree in such an eminent manner, as most questions were answered with approximately 80% conformity or higher. I would also like to note that not receiving a response or receiving a rejection by the companies I was trying to investigate was an answer as well; not scientific enough to be stated as a result but a personal note was taken. The questions I sent them encompassed questioning their real motivations and the driving forces leading up to their change in design. Writing this thesis was satisfying and gripping, I enjoyed the process.

8. Conclusion

As the human species has had and will continue to have a great impact on the planet's ecosystems, solutions must be found to combat the issues and mitigate the effects they have. These challenges include an ever-changing climate that, among other effects, results in prolonged and more intense heat waves that will be the cause of many problems, including food supply disasters, heat stress and discomfort, especially in cities. Green facades can not only mitigate extreme heat in urban environments, but also help with air purification and provide habitat; thereby contributing to biodiversity conservation.

Green facades can indeed be used as a greenwashing tactic since, according to my research, they do influence consumer behavior, as people seem to be more attracted and interested in visiting a store with a green facade. The survey also revealed that the majority of people believe a green facade is an indication of a company's proactiveness and consciousness toward environmental protection. Although the City of Vienna, with its initiatives does have an impact on the growing number of green facades in the city by targeting private costumers it does not seem to influence actions of large corporations. Thereby, no association of direct contribution to the ever growing greenwashing issue can be made. According to my research Raiffeisen International Group, as a money-borrowing institution, does not directly contribute to the phenomenon either, due to their rather holistic approach.

9. Future Work

Future research could include investigating whether the general public is willing to pay higher rent and/or sales prices for real estate that provides greenery on the building envelope, whether it be facades, vegetated roofs, etc.

Other research could focus on examining the real ecological impact of certain companies and parallel finding out the general public's opinion and impression of the company's environmental sustainability in order to compare these potentially two very different realities, that would visualize the power and extent of greenwashing.

Additionally, an analysis and summary of green washing tactics assigned to different sectors of our economy could be done as well.

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Figure 16: Photo by Author

Figure 17: Youtube.com: Available online at: https://www.youtube.com/watch?v=iy__yFVI0ZM

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Figure 18: Photos taken from Survey, Available online at: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQmD6ME9BUuXyj2xDJ30w_VB6riR_4zyiNRAg

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10.Appendix

10.1 Green Walls in Urban Environments – Vienna, Questionnaire English

My name is Elena Spallart, I am an Environmental Engineering student at the Czech University of Life Sciences in Prague. As part of my bachelor thesis, I, among other things, deal with the effects of green facades of corporations / institutions / service providers in urban environments on consumer behavior.

Your answers are of course completely anonymous. They can make an essential contribution to forming opinions on this highly contemporary topic and thus to the cityscape of Vienna. Please take approx. 4-5 minutes of your time to fill out this questionnaire.

Thank you a lot,
Elena

* Mandatory

Czech University of Life Sciences

ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

1. Sex *

Mark one

- ◯ Male
- ◯ Female
- ◯ Non-Binary
- ◯ Other

2. Nationality *

3. Age *

Mark one

- 12-25
- 26-40
- 41-99

4. Which supermarket would you rather go to? *

Mark one

Image A

Image B

5. Briefly state why *

_____

6. In which store would you expect to find higher sales prices? *

Mark one

Image C

Image D

7. Briefly state why *

_____

8. Is finding a green facade within a city a rather rare occasion in your experience? *

Yes

No

9. In case you are a homeowner: Are you interested in adding a green facade to your building? *

Mark one

- Yes
- Yes, if I had more information on costs/maintance/benefits etc.
- No
- I am not a homeowner

10. If your answer was no, please briefly state why

_____

11. Do you find green walls to be aesthetically pleasing? *

Markieren Sie nur ein Oval.

- Yes
- No

12. Do you think green facades have a positive impact on the cityscape? *

Mark one

- Yes
- No

11. If you had the chance to easily implement more green walls in Vienna - would you? *

Mark one

- Yes
- No

14. If you chose no, please briefly state why

_____

12. Do you have the impression, that this retail company (image E) is concerned with it's impact on the environment? *

Mark one

- Yes
- No

16. Depending on what you chose, please briefly state why *

13. Does the greenary on the facade of this building (image F) give the impression that the company is trying to maximize it's postive ecological impact? *

Mark one

- Yes
- No

18. Do you have the impression companies / organizations / corporations / etc. with overgrown facades use all means available to them to have the least possible negative impact on the planet? (Image G) *

Mark one

- Yes
- No

19. Would you like a green facade on the building in which you live? *

Mark one

- Yes
- No

20. Would you like to have the view of a green facade from your apartment? *

Mark one

- Yes
- No

21. Do green facades give you the feeling that the world / the economy is developing in a more sustainable direction? *

Mark one

- Yes
- No

22. How often do you visit Ikea/Hornbach/Hotel Harmonie Wien/Haus des Meeres/other institutions with green facades? *

Mark one

- At least once a month
- At least once every 3-6 months
- Once a year or less

23. Has the frequency changed since they changed their exterior design? *

Mark one

- Yes
- No

24. Has the new design sparked new interest in going there? *

Mark one

- Yes
- No

25. Would you prefer to have more green spaces (like overgrown facades) in the city in which you live? *

Mark one

- Yes
- No

26. What would you think of a regulation for corporations of a certain size that obliges them to green a certain percentage of their built-up area? (vertically possible = green facade) *

Mark one

- I would like that
- I would not like that

27. If you would like to receive further information on the results of this research you may add your email below

10.2 Green Walls in Urban Environments – Vienna German Preface

Mein Name ist Elena Spallart, ich bin eine Environmental Engineering Studentin an der Czech University of Life Sciences in Prag. Im Rahmen meiner Bachelor Arbeit befasse ich mich unter Anderem mit den Auswirkungen von begrünten Fassaden von Konzernen/Institutionen/Dienstleistungsanbietern auf das Konsumentenverhalten.

Ihre Antworten sind selbstverständlich vollkommen anonym, können aber essentiell zur Meinungsbildung bei diesem hochaktuellen Thema und somit im weiteren dann zum Stadtbild von Wien beitragen. Bitte nehmen Sie sich die wenigen Minuten um dieses Fragebogen auszufüllen.

Vielen lieben Dank,

Elena

CZECH UNIVERSITY OF LIFE SCIENCES – PRAGUE

Faculty of Environmental Sciences

Green Walls in Urban Environments – Reasons for Installation and their Effect on the General Public

Supervisor: Doc. Peter Kumble, Ph.D.

Author: Elena Spallart

2022