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LIVING WALLS: VARIETIES, BENEFITS AND GLOBAL DISTRIBUTION

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ABSTRACT

Today, “going green” has become a salient issue in the United States and across the globe. One of the green initiatives growing in popularity is the practice of green construction. Commercial, educational, and government buildings have increased their use of sustainable construction materials and environmentally-friendly designs with the addition of green roofs and living walls. Green roofs either partially or completely cover the roof of a building with vegetation for environmental and economic benefits. Living walls are similar to the design, construction and function of green roofs, yet these walls exist indoors or outdoors as a vertical arrangement of plants. One example of a living wall is an indoor herb wall constructed by Penn State. In Penn State’s entry to the 2009 Solar Decathlon competition, the Natural Fusion house contains planter boxes with herbs used for cooking that hang in the kitchen on boards of horizontal poplar. This indoor living herb wall receives sunlight from three skylights and water from the house occupants. Despite the green construction efforts in the United States, living walls are more popular and common in Europe than the rest of the globe. To address the lack of accessible information on the locations and benefits of living walls, a customized interface has been designed in Google Earth to display the global, geographic distribution of living walls. This Google Earth file helps to publicize and spread awareness about not only the existence of living walls but their environmental and social benefits. Finally, ideas are proposed as to the construction of an outdoor living wall at the University Park campus of Penn State University.

Keywords: Living walls • Green Roofs • Environmental and Social Benefits • Penn State 2009 Solar Decathlon • Google Earth

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Chapter 1

BACKGROUND AND RESEARCH OBJECTIVES

A common element found with today's green buildings are green roofs and living walls, with green construction and environmental practices predicted to increase in the next decade. It is important to create an awareness of living walls for the general public through technology of the Internet. By spreading awareness about existing living walls, more people across the globe can be aware of their various benefits and ways of implementation in residential and commercial settings. This thesis explores the varieties of indoor and outdoor living walls being constructed across the globe with a discussion of the perceived social and environmental benefits of these green features. A case study is presented with an indoor living herb wall that was part of Penn State University's 2009 Solar Decathlon "Natural Fusion" home.

The Green Movement

The environment is described as "all that surrounds us" (Bechtel, 1997, p. 4), including both the positive and negative aspects. This chapter focuses on the natural and man-made dangers to the environment that were discovered over periods of time that led to the start of the environmental movement, also referred to as the "green movement."

Silent Spring, by writer, scientist and ecologist Rachel Carson in 1962, is often considered to have been the catalyst of the environmental movement. Vice President Al Gore stated the book was "a shaft of light that for the first time illuminated what is arguably the most important issue of our era" (Heines, 2009, p. 1933). The instant bestseller focused on the dangers of pesticide-use. Because the book was heavily focused on the negative impacts of pesticides, the chemical industry threatened to sue Carson's publisher (Mastroni, 2008).

Carson originally published an article in 1945 about pesticides' negative effects, but her statements did not have such a strong influence on readers until she discovered court documents from a Long Island, New York lawsuit against the use of pesticides. She documented concerns that governmental scientists had about pesticide use on farming and food production to support her argument. As a result, the insecticide DDT was banned in 1977. DDT had been spread all over Earth's landscape. It was found in penguins in Antarctica, endangered peregrine falcons in the eastern United States, and had negative effects on several species of fish (Bechtel, 1997). *Silent Spring* was published just as the herbicide Agent Orange was being used in Vietnam for herbicidal warfare. Agent Orange included pounds of dioxin, which was found to cause diseases in those exposed to the substance, such as "soft-tissue sarcoma, non-Hodgkin's lymphoma and chloracne" (Bechtel, 1997, p. 33). Many Americans came back from the war with these conditions. Carson's book helped to make associations between herbicides and disease.

Silent Spring helped launch a variety of regulations and campaigns, including the Wilderness Act in 1964, the National Environmental Policy Act (NEPA) in 1970, and the poster with the words written underneath an image of the Earth: "Love your Mother" (Hopey, 2007).

Decades later, the book is still very relevant; for example, a documentary of the book premiered on PBS's "American Experience" series in 1993. Carson's scientific background, literary skills and resilience as an environmentalist helped bring global environmental issues into mainstream thought.

One of the most widely known environmental events was established in 1970. Senator Gaylord Nelson, a "liberal Wisconsin Democrat," called for a nationwide gathering to preserve and celebrate the Earth, calling it, Earth Day (Hopey, 2007, p. 1). The first Earth Day on April 22, 1970, gathered twenty million people across the United States to support the conservation of the

Earth. Deemed as the “largest public demonstration since World War II,” the “green” grassroots movement had begun (Hopey, p. 1). This day sparked a social and political phenomenon, in which two-thousand colleges and ten-thousand elementary and high schools participated. Many pushed for political action, resulting in the establishment of the Environmental Protection Agency and the Clean Air Act, which set standards for “air quality, auto-emission and anti-pollution” under the presidency of Richard Nixon (Hopey, 2007, p. 1).

Those that choose to “Keep America Beautiful” also found themselves picking up after the “litterbugs” who trashed the Earth with a variety of recyclables like plastic bottles, wrappers, soda cans and cigarette butts, the most common type of litter (Heines, 2009, p. 1936). During The Great Pennsylvania Cleanup in 2005 alone, there was a total of 3,100 tons of trash collected. Annually, there is 176 million pounds of cigarette butts nationwide, in which ninety percent are disposed of ten feet from ash trays or other trash areas (Heines, 2009). As Senator Nelson said in 1980, Earth Day still remains “an effective reminder that management of Earth’s resources will forever be the most fundamental of issues faced by humans” (Heines, 2009, p. 1936). This is evident in this 2010’s expected participation in Earth Day, with 30 states in America planning to turn off lights in public and government buildings. Eight more states are participating this year than last year. Atlanta, Georgia will have 650 buildings go dark. Other areas, such as the Las Vegas Strip, Niagara Falls, and the Willis Tour, formerly the Sears Tower, in Chicago will also be participating (Koch, 2010, p. 8A).

There are other organizations that also contribute to making the Earth a cleaner and healthier place, such as The United Nations Environmental Programme (UNEP). Established in 1972, UNEP “…provide[s] leadership and encourage[s] partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations” (http://www.unep.org, 2010).

One of UNEP's environmental goals is to improve various aspects of water on our planet, as a constant increase in world population, continued industrialization and the illegal or uncontrolled discharge of contaminated water within and outside national borders all negatively impact the quality of water. World Water Day, first enacted on March, 22, 1993, occurs annually to promote more efficient and sustainable water management across the globe. In 2010, World Water Day's theme focused on improving the quality of water. In previous years, water themes have revolved around sanitation, coping with water scarcity, water disasters, and water for the future (World Water Day, 2010).

According to World Water Day (2010), every year, more people die from consequences of unsafe water than all forms of violence, including war. Contaminated water affects food production, fisheries and lead to disease. Water is a vital resource to live for all living organisms on Earth and if it is not clean and properly managed, various species are in danger of surviving and reproducing (World Water Day, 2010). With a constant increase in population, continued industrialization, maximizing food production and with more people migrating to cities, the salience of water as a managed, sustainable resource is an increasing concern (Sick Water?... 2009).

Climate Change

According to Heines (2009), "…all credible scientific research on climate trends shows we have entered a period of potentially devastating warming of the Earth" (p. 1935). Climate change has been a very controversial topic for decades and "…there is little doubt that human produced emissions of greenhouse gases have had a smokestack or tailpipe in causing it" (Heines, 2009, p. 1935). If the human race is responsible for contributing to the effects of climate change, it is important that the human race takes responsibility for "minimizing the effects" too (Heines, 2009, p. 1935).

Evidence for the "little doubt" that Heines states are reports on an increased amount of droughts, floods, heat waves, infectious diseases and extinctions in both the United States and Canada (Heines, 2009). There has not only been an increase in frequency, but these natural weather incidents are also ascending in velocity and impact since the 1970s (Anthes et al., 2006). Recent examples with devastating impacts include Hurricanes Andrew, Floyd, Katrina and Wilma.

Hurricane Andrew was one of the first hurricanes of the 1990s, hitting South Florida on August 24, 1992. Though the hurricane's path was only about 100 km long and only caused 5 cm of rain, winds reached 242 km per hour. This storm caused destruction to three National Parks: Biscayne National Park, Everglades National Park and Big Cypress National Preserve. The hurricane caused long-lasting damage to two parks in two hours. Marine environments and freshwater marshes were affected, causing some fish species to decline (Pimm et al., 1994).

Hurricane Floyd hit in September of 1999. With damage surpassing $6 billion, 7,000 homes were destroyed and 51 people died in Eastern North Carolina. The North Carolina State official stated that this was the worst disaster in the area since the Civil War (McChesney, 2001). Floyd was known for its heavy rainfall, dumping 13 inches of rain onto North Carolina, sometimes receiving up to 19 inches (Hurricane History, n.d.). At the time that Floyd was over North Carolina, it was a Category 2 storm, whereas when it was over the Bahamas earlier, it was a Category 4. Approximately 50-57 deaths occurred because of Floyd with $3-6 billion in damage.

Hurricane Katrina is by the far the most deadly hurricane the United States has experienced since 1928, when the Palm Beach-Lake Okeechobee occurred. Katrina was a Category 5 hurricane on August 28, 2005, before reaching the Louisiana and Mississippi area on

August 29. On that date, it was a Category 4 hurricane. Katrina ultimately resulted in a total of $75 billion in damage costs in New Orleans and Mississippi with a death toll of approximately 1,200 people. Thirty-three tornadoes were reported to have occurred over the storm period with flooding of 25-28 feet over the level of a normal tide along the Mississippi coast (Hurricane History, n.d.). The devastating amounts of destruction from the hurricane still leaves people in the Mississippi and Louisiana states in need of help, years after the hurricane. On September 2, 2009, the first new public school building in New Orleans, the Langston Hughes Academy, was finally established (Maxwell, 2009).

Hurricane Wilma hit the Caribbean Sea two months after Katrina on October 15, 2005, near Jamaica. Winds reaching up to 185 mph, Wilma became a Category 4 hurricane upon its arrival to the Yucatan Peninsula. Wilma caused 22 deaths and caused $16.8 billion in damage in southern Florida (Hurricane History, n.d.).

Hurricanes like Andrew, Floyd, Katrina, and Wilma were all Category 4 or 5 hurricanes, all occurring during the 1990s. Though hurricanes are naturally frequent, they have increased in frequency and intensity over the past three to four decades. Studies have shown that there could be a “relationship between hurricane activity and sea surface temperature,” which has also been rising. From 1970-2004, the sea surface temperature rose 0.5 degrees Celsius. Increased hurricane velocity and frequency has been a trend for the past thirty years. Counting and the doubling of carbon dioxide in the atmosphere, as models have shown, would reflect in more frequent and intense cyclones and hurricanes (Webster et al., 2005). Thus, in this analysis, as many other studies have shown, an increase in carbon dioxide is attributing to the warming environment and intense natural disasters.

A measurable way to know how the human race is impacting global warming is through the carbon footprint, the amount of carbon dioxide emitted by an industry, country, state household or individual (Heines, 2009, p. 1935). Efforts to decrease carbon footprints to reduce greenhouse gases will help contribute to slow the process of global warming. Countries all over the world have signed the Kyoto Protocol in1992, an agreement to reduce greenhouse gas emissions. Though the United States signed the treaty, it was never approved by the Senate during the Clinton Administration. Internationally, the signing of the agreement is symbolic of the United States' efforts to decrease greenhouse gas emissions, and there have already been many advancements in newer technology to meet that goal. Developments in alternative energy sources have been created to reduce these emissions, such as solar, wind, and biofuels made with corn, old French-fry grease and cooking oils (Heines, 2009).

As there have been efforts to reduce greenhouse gasses in the ways in which people travel and use energy, urban cities also contribute heat to the environment that enable climate change to progress. The reason that urban cities contribute to the process is because of an "unprecedented increase in the human population" (Despommier, n.d., p. 1). In 1975, only one-third of the world population lived in cities. By 2025, approximately 59.9% will live in urban areas (Domurath and Schroeder, 2009). It is only natural that an increase in world population will result in an increase in population in urban areas.

More people reside in cities because they are "centres of innovation and economic growth," but they are also "centres of pollution, waste and heat" (Domurath and Schroeder, 2009, p. 249). Heat negatively affects city rooftops and roadways, increasing the surface temperature from 50 to 70 degrees Fahrenheit, which is higher than the surrounding air (Domurath and Schroeder, 2009, p. 249). The increase in temperature occurs from lack of vegetation and green space in urban areas. Less evaporative cooling occurs, which increases the storage of heat in these areas, dubbing these urban climates as "heat islands" (Domurath and Schroeder, 2009, p. 249). Various plant systems, such as living walls, integrated into green buildings can help address this issue in urban areas, which is discussed further in Chapter 3.

The timing of advanced technology and an increase in the expertise of "green" systems have come together to allow for better designed, sustainable building options, thus, increasing their demand. Christine Ervin, president and CEO of the U.S. Green Building Council (USGBC) from 1999-2004, stated, "…market savvy tools, technologies and expertise are converging at just the right time – when the global case for sustainability is undeniably compelling" ('Value' Underlies Green Movement, 2005, p. 8). Since the timing of expertise and technology are advancing at the same time, the green movement has taken such strides in various fields, especially green construction to combat many environmental issues.

Green Roofs

The book Planting Green Roofs and Living Walls, by Nigel Dunnett and Noel Kingsbury, is an excellent and thorough print source of information for green roofs and living walls. Because of the lack of additional comprehensive print material in English on the subject, the Dunnett and Kingsbury book will be used as the primary source throughout most of the next two sections. Many books published on green roofs and living walls are in German, as many green roofs and living walls originated in Europe, particularly Germany.

The Hanging Gardens of Babylon is one of the first examples of roof gardens, dating back to the seventh and eighth centuries B.C. These gardens were developed by ancient civilizations of the Tigris and Euphrates River valleys, as well as the Romans (Dunnett and Kingsbury, 2004). In the mid 1800s and with more modern building materials, flat-roofed buildings with cement and greenery were being constructed all over major cities in Europe and America.

Some of the earliest examples of green roofs include the first of many concrete “nature roofs” during the 1868 World Exhibition in Paris and a roof garden designed by Frank Lloyd Wright on a restaurant located in Chicago in 1914. One of the most famous green roofs is the garden built on the London department store, Derry and Toms, during the 1930s (Dunnett and Kingsbury, 2004). Architect Le Corbusier was responsible for the systematic construction of this green roof in the 1930s. This green roof was over 64,560 square feet and really helped to spread the idea green roof construction to many people because of how elaborate it was.

At first, green roofs were constructed for aesthetic reasons and required expensive materials and much maintenance. In other areas of the world, such as Turkey, Iraq, Iran and other neighboring countries, green roofs have been around for centuries because “mud and earth” have been used for traditional building materials. Scandinavian roofs had a soil and grass mixture to keep the heat inside during the winter and keep the heat out during the warmer seasons. This mixture is very similar to turf, which was also used in Scandinavia with other materials from Mother Nature: twigs, birch bark and straw. These items helped keep the rain outside of the home.

However, the turf and branches needed much maintenance and a full replacement was necessary after twenty years. If vegetation began to grow, the green roofs would become highly flammable. As better technologies and materials were developed and more available, green roofs became less expensive and required less maintenance.

Books about green roofs were written in the early 1970s, which sparked the counter-culture of the green movement. Freidensreich Hundertwasser, an Australian architect, built a green roof in Vienna, the Hundertwassar-Haus with “992 tons of soil and 250 trees and shrubs” (Dunnett and Kingsbury, 2004, p. 13). This green roof was yet another example that magnitudes of people viewed.

The increase in roof-greening, another term for building a green roof, caused people to view “greening the city” as a popular idea. More people were having more libertarian views, people were growing plants in containers, especially in West Berlin, vegetables were growing on rooftops and climbers were growing up the walls of buildings.

The idea of green roofs and walls growing in popularity inspired future research on green construction. In 1977, a green-roof study group within the FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau: the society for research into the development of landscape and landscape construction) was created. This German-based group was responsible for research in landscape construction, specifications and industry standards. This research started two decades earlier because Germany recognized the benefits that urban habitats can provide for both ecological and environmental reasons. Professor Hans-Joachim Liesecke at the Institute for Green Planning and Garden Architecture at the University of Hannover and Dr. Walter Kolb at the Bavarian Institute for Viticulture and Horticulture at Vietochheim explained the benefits of roof greening as conserving energy and minimizing water runoff.

Understanding the benefits that green roofs have on the environment and the economy has allowed countries to invest interest in building more green roofs and façades. Germany is reported as one of the leaders in green roof construction, with one out of every ten flat-roofed building consisting of a green roof. In 1980, the Green Programme for Urban Renewal was established, which provided subsidies for those that constructed green roofs. Forty-three percent of the cities in Germany offer incentives for green roof construction.

Other countries such as Austria and Switzerland have joined the green bandwagon. Switzerland enforces the Swiss Landscape Law that states twenty-five percent of any new commercial building must have green construction in order to “maintain favourable microclimates” (Dunnett and Kingsbury, 2004, p. 17).

The United States has also made steps into green building predominantly because researchers and horticulturists have traveled to Europe, seen their greenery and want to promote the same ideals in North America. President of Green Roofs for Health Cities, Steven Peck, stated that green roof installations have increased at about 30 percent a year over five years (Green Scene, 2009, p. 3). The Pentagon in Washington, D.C., among many structures, has a green roof.

Two cities that are especially known for their green façades are Chicago, Illinois, and Portland, Oregon. Chicago is striving to be the "greenest city" in America by making it a requirement to have every roof replaced by a green roof and "meet minimum standards for solar reflectance and emissivity" (Dunnett and Kingsbury, 2004, p. 19). Even Chicago's City Hall has a green roof.

Figure 1-1: City Hall's Green Roof in Chicago (The Udall Legacy Bus Tour: Views From The Road, July 2, 2007).

Portland is striving to build more green roofs to reduce and prevent polluted urban runoff reaching rivers, which damage the salmon population. (Dunnett and Kingsbury, 2004). In order to increase green roof production in Portland, developers are allotted more building space depending on how much area of green roof is constructed on the building.

Figure 1-2: Ford Motor Company's Green Roof in Dearborn, Michigan (Resedabear, November 11, 2006).

Ford Motor Company was one of the first corporations to install a green roof on their complex in Dearborn, Michigan. Completed in 2003, it was the 'largest green roof on an industrial complex in the world" (Dunnett and Kingsbury, 2004, p. 19). Ford Chairman, Bill Ford, stated that it laid "…the groundwork for a model of sustainable manufacturing…" (Dunnett and Kingsbury, 2004, p. 19). This step helped to increase that adaptation of green roofs to other commercial buildings.

Types of Green Roofs

There are different types of green roofs: extensive, intensive and semi-intensive. Extensive green roofs are thin, light and seem more naturally based in the environment. Intensive green roofs are designed to look, act and be maintained as a garden. Semi-intensive green roofs use the same lightweight technology and growing media as extensive roofs but the medium used is greater in depth, allowing more plants and vegetation to grow (Dunnett and Kingsbury, 2004).

There are various terms that can also be associated with green roofs, such as *ecoroofs*, and *brown roofs.*

Ecoroof is used as a term to substitute for green roof and is associated with ecological function such as plants integrated with photovoltaic cells. Ecoroofs are also associated with roofs that are in very dry climates that cause vegetation to brown, so the term green roofs do not always seem to fit the look of these roofs, which are very popular in Portland, Oregon.

Figure 1-3: Ecoroof in Portland, Oregon (atduskgreg, September 13, 2005).

Brown roofs are roofs that are covered with soil or loose, lightweight growing material that has not been planted (Dunnett and Kingsbury, 2004). These roofs provide an environment for insects and birds and at times can colonize spontaneously with vegetation.

Green roof components involve both “hard” and “soft” aspects. The hard aspects include non-living materials such as the stone or pavement, or geotextiles, as well as substrate material and cabling (Dunnett and Kingsbury, 2004). The soft aspects include the plants used, which differ on various green roofs or façades, as climate and region are big factors. For example, green roofs designed in North America would differ greatly from green roofs designed in Asia, South America and Australia because of their hot and humid tropical climate . Since rainfall is so frequent and of vast amounts in these areas, erosion, saturated substrates and exposure to diseases carried by mosquitoes that swarm around fast growing plants and vegetation are points to consider when building a green roof in these areas.

Green roofs are very different from garden roof tops, which are simply composed of plants in containers on a roof. Green roofs consist of two or more layers, which typically include a substrate layer and the vegetation layer. A drainage layer will sometimes be included, usually for commercial buildings.

When building a green roof, there are many structural considerations, ranging from the weight of the green roof materials, the amount of additional weight moisture, wind, people on the roof for maintenance and other specifications. For example, when calculating the green roofs weight per square foot, it is important to consider the weight capacity of the building's roof that the green materials will be applied to. If the roof itself cannot withstand the weight of the green roof that is being installed, additional costs for further roof construction, such as columns or beams, to support the green roof technology will be necessary.

Green roofs, if constructed properly, will not need any irrigation systems unless they are located in very arid climates There are four different types of irrigation systems: sprinkler systems, drip and tube systems, capillary systems and standing-water systems.

There are four different water systems that can be used to irrigate green roofs: sprinkler systems, drip and tube systems, capillary systems and standing-water systems. Sprinkler systems tend to be wasteful and can cause roots to surface from the soil and may be least desired out of the four.

Drip and tube systems can exist on the exterior of the green roof or within the soil or substrate itself. If the pipes are buried within the soil, they are much more effective and efficient, reducing water evaporation and weed development.

Capillary systems are “porous mats” that deliver water to the very bottom of the substrate material and are only used for shallower green roofs with 8 inches or less of soil and vegetation (Dunnett and Kingsbury, 2004, p. 64).

Standing-water systems keep enough water at the base of the green roof. They can run by themselves or get assistance from rainfall or even be maintained by “float-control devices” (Dunnett and Kingsbury, 2004, p. 64).

With all previous conditions needing to be met for constructing a green roof, there are still many different ways construction can occur. Each roof will all require to have a weatherproof, even surface. This waterproof membrane can be a built-up roof, single-ply membrane or the fluid-applied membrane.

Most common built-up weatherproof membranes are made of asphalt roofing felt or bitumized fabrics and last about twenty years. They do not fair well with extreme temperatures and ultraviolet radiation, which can cause cracks and leaking. Other built-up membranes that are more durable consist of “…SBS modified bitumous membrane sheets set in SEBS polymer modified bitumen and coal tar pitch/polyester built-up systems” (Dunnett and Kingsbury, 2004, p. 67).

Single-ply roof membranes consist of inorganic plastic and synthetic rubber, such as PVC and adhesive. Where they are joined through a heating process may be the weak points on the roof, however, caused by the plant roots interaction with the membrane. To prevent this type of damage, they may contain “root-deterring chemicals or metal foil between the membrane layers” (Dunnett and Kingsbury, 2004, p. 67).

Fluid applied membranes can be sprayed onto the roof, hot or cold, and hardens within time. This especially helps if a membrane is needed for vertical vegetation.

Another layer can be added to further protect the membrane from experiencing damage from the sun's radiation and heat by adding sand, gravel, Styrofoam and other items (Dunnett and Kingsbury, 2004).

A root protection barrier is necessary if the roof contains bitumen, asphalt or other organic material. The roof cannot be exposed to any organisms or items that would encourage growth directly on the roof. PVC is a great root barrier that is usually laid over the weatherproofed surface. It has a multitude of benefits: long lasting, easily recyclable, reduces risk of potential leaks, can be heat steamed, etc. (Dunnett and Kingsbury, 2004).

A drainage layer is also important, as water needs to drain from the roof. Roofs that are flat have a fifty percent chance of getting damaged quicker than sloped roofs because the water from a rainfall will just sit instead of run off the roof. A roof that becomes too wet or whose soil or substrate is too saturated with water will not be able to sustain plant life, nor will the thermal insulating properties of the roof remain. Water is not supposed to run off the surface of the green roof, only to remove excess water. Doubling up on the drainage layer can be a start to irrigation.

Some of the growing mediums or substrates used include natural minerals, lava and pumice, gravel, artificial minerals, perlite, vermiculite, light expanded clay granules (LECA), rockwool, recycled or waste materials, crushed clay brick or tiles, brick rubble, crushed concrete and subsoil. Each type of material has their own characteristics that are best suited for a specific green roof design, depth and function.

Green roofs have increased in popularity because of the green movement to various extents throughout the world. Each region builds green roofs for a different set of benefits than others, which can tend to depend on their geographical location, climate and their economy. These benefits include: aesthetic value, increased roof life, insulation and energy efficiency, serving as a place for wildlife, managing storm runoff, reducing air and noise pollution, minimizing the urban heat island effect, lowering the amount of greenhouse gas emissions from buildings, help slow the spread of fire, serve as medium for food production and increase employment opportunities.

Living Walls

The different green roof designs are very similar to those of living walls, yet living walls contain vertical structures of plants, not horizontal.

Façade greening, in which climbing plants, such as the Virginia Creeper, are naturally growing along a wall or have physical support systems, are very similar to living walls. Vegetation mats and vegetated retaining structures are referred to as “ecotechnology” (Dunnett and Kingsbury, 2004).

Because living walls, like green roofs, are still in its new stages of development and awareness, there are no real definitions or sets of standards that developers use to construct a living wall. Therefore, there are a variety of descriptions and types of living walls. These include: dry stone walls, stacked modular-walls, mortared walls, gabion walls, hydroponic systems, vegetation mats and living fences (Dunnett and Kingsbury, 2004).

Dry stone walls are used to create a living wall. Normally, the stone is native to the landscape. Dry or battered walls are an appropriate type to use for this living wall, as they are not mortared. These battered walls have joints where soil can sit and allow plants to grow. This way, the roots can grow back into the wall itself. Living walls like these can only grow up to one meter and three feet in height before it is unsafe and may collapse. Ideally, to allow for more stability and rain to filter down into the plants on the wall, the stone walls can be constructed at an angle.

Stacked-modular walls are free standing and have stones that interlock with each other in a jigsaw pattern. Similar to the dry stone walls, the stacked-modular walls can only reach a certain height before they become unstable because of the stones being held together by gravity alone. Dutch architect, Louis G. LeRoy, was influential on ecological design in The Netherlands from the 1960s onward. He trademarked this idea of stacked-modular walls by using bricks, rubble and other materials that served as a catalyst for a variety of ideas: playground for children, an area for much vegetation and the “relentless power of nature” (Dunnett and Kingsbury, 2004, p. 177).

The EcoCathedral in Mildam in northern Holland is an example of a stacked-modular wall built by LeRoy. Started in 1974, it is expected to be built by year 3000. Made completely with “demolition materials” like brick and pavers, they colonize naturally by vegetation with some additional, deliberate planting. Small bricks or tiles that are crushed and inserted in-between any of the spaces in the structure further the progress of plant growth (Dunnett and Kingsbury, 2004).

Figure 1-4: EcoCathedral Mildam (Pwouda, June 23, 2007).

Figure 1-5: Louis LeRoy in EcoCathedral (Pwouda, June 24, 2007)

Modular wall systems also use the idea of stacking. Dry-stacked precast concrete blocks interlock have holes inside them. These holes are then filled with gravel and soil. Sometimes, steel rods are inserted into these holds for more stability. There are a variety of purposes this living wall provides, such as a way to reduce noise, retain slopes, and raise land to allow construction to occur.

Since these modular walls are designed by engineers, there is an unknown range of plants and grasses that can be used for the wall. Hardy shrubs, vines and grass mixes have been used. Because these walls are not sealed, there is no build up of hydrostatic pressure behind them. This varies greatly from concrete walls that have living walls on them.

Figure 1-6: Gabions at the Chester Zoo (A. Appleyard, June, 2, 2007).

Gabions are walling units that are made from wire baskets filled with rocks. Egyptians used similar structures, except filled with reed, to stabilize riverbanks. They often replace bricks used to build a wall. Normally, they are without vegetation but in many cases, especially at riverbanks, plants grow around them and sometimes even hide the gabions (Dunnett and Kingsbury, 2004). However, fostering plant growth can be done in two different ways with gabions, inside and on top of the gabion. A mixture of both rocks and soil can fill the gabions in order to further the development of vegetation inside the structure. To grow plants on top of the structure, wire baskets can be filled with various sizes of rocks and soil or another growing medium can fill the top (4-6 inches) of the gabion.

Gabion mattresses are very similar to gabions, only they are more shallow or shorter than the typical gabion size. Besides the difference in height, they allow vegetation to grow more rapidly. Geotextile materials are incorporated in the wire basket with a filter mat on the lid of the gabion. Various grasses, meadow seed mix, … "seedlings or plug plants can be inserted through the fiber mat" (Dunnett and Kingsbury, 2004, p. 179).

Mortared walls made from either natural or manmade stone serve as a sealed surface and barrier to plant establishment and growth. Because mortar exists in-between the bricks and stones, mortared walls can serve as a barrier for a much higher living wall than dry stoned walls can provide. These walls are quite rare as adequate foundations need to be applied in order for the plants to thrive.

One example of a mortared wall is the Grift Park in Urecht, The Netherlands. Measuring 6.6 feet in height, there are gaps between certain sections of bricks to allow plug plants to grow. These plants include "native species (such as lady's bedstraw, *Galium verum),* alpines and succulents (sedums and sempervivums) ad typical wall growing species (for instance, *Antirrhinum* and *Centranthus ruher)*" (Dunnett and Kingsbury, 2004, pp. 180-181).

There is much to be considered when building a living wall with dry stone or mortared walls. It is important that the foundation of the wall, like the roof of a green roof, is protected against moisture and damage from plant roots. This can be done by using a protective waterproof membrane. The retaining wall structure is built then, in front of the wall, and filled with the substrate, soil or medium. The substrate used should be lightweight to allow water draining to occur. If the structure is any more than 3.3 feet in height, other materials for reinforcement will be necessary for stabilization. Irrigation is a must as well, if there are areas of very thin layers of substrate. Irrigation can begin at the top of a structure like this, as to act like rainfall, trickling down the living wall.

Hydroponic Living Walls

Hydroponic systems were first pioneered by the French researcher and designer, Patrick Blanc, who was an internationally celebrated tropical botanist. Blanc researched various ways plants can grow on rock walls and in tropical forests in regions that are very humid. By doing so, he applied this knowledge to create living walls that operate solely on water and without soil (Dunnett and Kingsbury, 2004). Blanc applied hydroponics, growing plants without soil using balanced nutrient solutions to provide all the plant's food and water requirements, to buildings and walls.

Blanc's set up for a hydroponic living wall consists of an outer layer of propagation felt or capillary matting that is fixed over a waterproof PVC sheet. The PVC (polyvinyl chloride) sheet is a thermoplastic polymer, a type of plastic that separates the wall from the propagation felt that supports the plants. Blanc's system is thin, only 13 mm thick. Small holes are cut into the felt, allowing small plants to be inserted into the felt. The plants help to reinforce the structure of the system by rooting themselves into the felt. Water and other nutrients are constantly being provided to these plants through a drip irrigation system. These systems can be free standing or on the exterior or interior of a building.

The façade at the Foundation Cartier seen below is an example of a living wall by Blanc.

Figure 1-7: Jean Nouvel Fondation Cartier, Paris France (R. Hyde, December 11, 2003).

Blanc uses a variety of large-leaved plants, many of which are evergreens to mimic the regions that are very tropical. He uses plants that require a lot of sun exposure while also utilizing ferns that require vast amounts of shade. Species include *Ficus* and *Salix*, and *Buddleja globosa*, a plant that requires a lot of sun. Shade tolerant species include saxifrages, mosses and lichens and are usually placed at the bottom of a living wall, as they can be overshadowed by the plants that require more sun. Maintenance includes clipping the leaves and removing any dead plans yearly.

Vegetation mats that are used for green roofs as a plant layer can also be used within a design on a living wall. Walls that use vegetation mats, however, have many other factors to consider. Walls do not receive a lot of direct rainfall because they may be in the rain shadow of a building. Wind can affect the vegetation mats, there may be a lack of sun on the lower portion of walls that affects the growth of the sedums positioned on the lower portion of the mat, and growing any plants on a thin layer of substrate can be difficult. How the mats are pinned to the wall is also another aspect to consider. Netting that is stretched across the front of the wall will help to hold the vegetation in place.

There are techniques to overcome these obstacles that may prevent a successful living wall using vegetation mats. The vegetation mat can be angled to capture more water as well as acquire more sun for plant growth. However, due to these obstacles, they are commonly used horizontally on the ground in European cities located in-between tramlines or along sidewalks.

Vegetation mats typically consist of sedums, which are almost completely drought-resistant. “Vertical sedum walls” is another term used to describe this type of living wall. During demonstration shows, they’re very lush and work well for the short term. It is questionable if vertical sedum walls can last for the long term without any irrigation.

Living Fences, unlike the other living walls mentioned above, are multi-dimensional. The viewer of living fences sees more than a one-dimensional wall of plants. A living fence, also known as a “fedge,” is a “…sandwich of substrate between vegetation layers” (Dunnett and Kingsbury, 2004, p. 186). They are very much like hedges, which were modeled off of the British Isles’ dry stone walls that enclosed vegetation. Hedges, typically made of stone and is permanently stationary, are similar in the fact that its three-dimensional. Living fences differ in regards to having plants being easily replaced, the structure can be easily moved and stays the same size. Living fences consist of three main parts: a supporting framework, growing medium and vegetation layers. The framework is usually wood or metal and may hold wire grid sections that contain the growing medium on either side of the structure with a geotextile mat to prevent the soil or substrate from spilling through the grid’s holes. Plants can be inserted into the walls if slits are made in the mats. Structures like living fences have been used as noise protection barriers along highways and railway lines.

Plants Used for Living Walls

Most plants used for green roofs are also used for living walls, especially the lower growing and creeping plants. These include the following: mountain pinks (*Dianthus*), harebells (*Campanula*), alpine wall flowers (*Cheiranthus*), toadflax, wall ferns, alpine phloxes, stonecrops, houseleeks, tymes, *Cor¥dalis,* sea thrift (*Armeria*), and cranesbills and storksbills (*Geranium* and *Erodium*).

Other plants that are used are a little lengthier and hang down. These include: *Alyssum, Arabis, Aubretia,* some *Campanula* species, *Cerastium*, and rockroses (*Helianthemum*).

Sedum, a popular medium used in green roofs, is also used in living walls. Sedum is a low-growing, hardy species that can withstand many different weather conditions (Kimberley, 2009). Sedum is a genus that belongs to the family of Crassulaceae, consisting of over 300 species. Many species are frost-hardy and can survive in temperatures as low as -258° Fahrenheit, although a number of species need a minimum of 42° Fahrenheit to survive, which would require them to grow indoors. Types such as *S. acre, S. oreganum,* and *S. album* are used in green roofs by being planted in mats of polyester or hessian in a thin layer of growing medium and can be done just as easily for a living wall, only with different sedums.

Figure 1-8: *Sedum oreganum* (W. Siegmund, August 12, 2008).

For example, the director of Fisher Tomlin in London stated, "[Sedum]…is great to use on living walls… particularly the smaller species such as *S. oreganum* [Oregon stonecrop]… we are currently designing a green wall for a commercial project in which it is included alongside *Heuchera* and *Euphorrbia*" (Dan Bowyer quoted by Kimberely, 2009, p. 17).

There are many other species that can be grown on a living wall. To best discover which plants are most appropriate for a living wall in a specific location, it is recommended that the flora of old walls in the same region is observed and serve as a model. There are many microclimates in one area. A living wall in one area of a country may require different plants than a living wall in another area of the same country if their climates differ.

Food Walls

As the world's population grows exponentially, another problem also arises that contributes to a reason for the "green movement" to take effect: lack of space for food production. As population increases, the diseases farmers encounter will also ascend. Farmers are exposed to a variety of health risks during the agricultural practices of irrigation, plowing, sowing and harvesting, such as schistosmoses, malaria and geohelminths (Despommier, n.d.). Though many people move to cities for economic reasons, the "push" factors for farmers to relocate to urban areas include droughts or exploitation of farmers, which can result in rural destitution (Despommier, n.d.). In fact, the amount of farmers has reduced over the past century. Sixty-nine percent of the labor force was farming in 1840 and declined to 21 percent during the 1930s and in 2008, it dropped to only 2.6 percent (Irwin, 2008).

It is foreseen that the number of farmers will keep declining over the years and the available land for agriculture will also decline as world population increases. The usable farmland is shrinking by 2.2 million acres per year (Irwin, April 2008). Therefore, building greener facilities in urban areas will be necessary. The people of the United States did it once before by designing Victory Gardens during World War II to conserve materials for the war effort. Over 20 million people participated, growing vegetables in their backyard and on rooftops (Irwin, July 2008). Vertical farms will be needed to ensure food production for the ever-increasing population of the future.

Vertical farms are much larger versions of living walls, which can also produce food, herbs and spices. Vertical farms are three-dimensional, multi-story buildings that grow cash crops inside. Farming indoors is not a new concept, as it has existed through greenhouse-based agriculture (Despommier, n.d.). Strawberries, tomatoes, peppers cucumbers, herbs and spices, among other crops, have been grown in greenhouses and sold in supermarkets all over the world for the past fifteen years. Countries that have succeeded in greenhouse agriculture include: Japan, Scandinavia, New Zealand, Canada and the United States. Vertical farms are very much like greenhouses, only they can produce enough food for tens of thousands of people year-round. If more people become aware of living walls and their benefits, vertical farms will be more likely accepted and considered for future building practices to establish other methods of food production for the ever-increasing population of the world.

There are companies that design living walls that can produce food, such as ELT, http://www.eltlivingwalls.com/, and Green Living ™ Technologies, http://www.agreenroof.com/. Both of these companies specialize in green roof and green wall (living wall) construction, among some of the other organizations.

Spreading the Word

Green roofs, a common addition to green buildings, have already been communicated to the public through various technological media. As living walls are very similar to green roofs and can serve as a stepping stone to optimizing the design and construction of vertical farms, it is equally important to spread awareness about living walls to the general public.

Though there is interest in these technologies, there are still barriers to the wider implementation of these structures. There is a lack of awareness on their benefits, low incentives for implementation, and risks of the uncertainties of relatively new technologies, with the overarching problem convincing people that the additional costs associated with green roofs give worthwhile paybacks (Dunnett and Kingsbury, 2004, p. 21).

However, with the progress made thus far, there is an expected increase in production of these systems in the coming decade. "[In ten years], we should be seeing exponential advancements [in green buildings]…," said Ervin. ('Value' Underlies Green Movement, 2005, p.

141). Senior partner Steve McIntyre of Aldingbourne Nurseries, a modular living wall and green roof company, said, “For some situations [green walls] are becoming a requirement. They’re sustainable, they reduce pollution and noise, and support wildlife. They also look more attractive than a plain wall” (Green walls see rising demand… 2008).

If the exponential growth of green buildings is expected to occur within a decade, it is important that living walls are identified as an optional component of an eco-friendly facility and that people understand the valuable benefits they provide. The fastest way to expose people to living walls is through the Internet. “The internet has further democratized and empowered the environmentalism in the information age” (Heines, 2009, p. 1936). Among many options, digital media such as social media (Facebook, Twitter, MySpace), YouTube, iTunes, and GoogleEarth can be used to facilitate an increased recognition and appreciation for living walls.

There have already been other environmental programs that have spread awareness about their efforts and have had much success, such as the 2009 United Nations Seal the Deal campaign and Live Earth.

Seal the Deal 2009 was lead by the United Nations to combat global warming by having a “Seal the Deal” campaign in which online users signed a petition to have leaders around the world seriously consider ways in which a long-term, greener economy can be created. The meeting took place in Copenhagen, Denmark on December 7, 2009. Over 400 business leaders, climate change activists and negotiators attended the summit to see how they can contribute to a greener earth. After the summit, “…a $10 billion a year commitment from the industrialized world to finance” developing countries in adapting to more environmentally conscious methods was a result, with a $100 billion per year goal to reach by 2020 (Dicovitsky, 2010). Though a “binding agreement” was never established and many believed Copenhagen didn’t result in any beneficial legal action, the summit was a start to climate negotiations across the globe. Conferences are planning to take place in 2011 in South Africa and another in 2012 in an undecided location (Dicovitsky, 2010). Through the use of online participants, more awareness about the climate crisis was spread to people across the globe.

Live Earth, founded by former U.S. Vice President Al Gore and Emmy-winning producer Kevin Wall, is an annual event to encourage people to combat the climate issue through entertainment, such as "…events, media and live experiences" (Live Earth, 2010). Live Earth uses a series of videos, a blog, and also print and email communication for the campaign. The for-profit organization partners with corporations and non-governmental organizations (NGOs) in addition to entertainment and political figures. Entertainment in the organization is viewed as a ways to "transcend social and cultural barriers to move the world community to action" (Live Earth, 2010).

Live Earth first started on July 7, 2007. Concerts featuring artists like Bon Jovi, Madonna and the Police, were taking place all over the world, in places like Kyoto, Washington D.C. and Antarctica. These videos were streamed live to the online community, showing the singers and bands perform while also promoting actions individuals can to help solve the environmental crisis.

Concerts also take place during Live Earth's Run for Water event in which people participate in a 6 km run or walk in 24 hours. This distance represents the amount of travel women have to take to get their daily amount of water supply in some third-world countries. The Schreyer Honors College at the Pennsylvania State University had a small event similar to Run for Water, called "Water Walk" on April 10, 2010, using the campus perimeter as the distance in which student volunteers walked and ran. Using the Internet to promote these Live Earth programs definitely spreads the word of their mission to combat the many climate change issues the human race faces.

Nations around the world have taken part in this green movement, which has "evolved into a massive humanitarian endeavor to preserve the planet" (Kent 2008, p. 4). As digital technology can help spread awareness about the movement, it can be used for a variety of other topics, such as the benefits shared by both green roofs and living walls. Further notice of these structures to the public through technology is imperative for people to realize and utilize the benefits to their advantage. With further awareness, it is more likely there will be an increase green construction in the United States and around the world. An employee from the Competitive Enterprise Institute, a non-profit organization that promotes policies of free markets and limited government stated, “We should be looking to technology and innovation to help solve environmental problems” (Michelle Minton quoted by Koch, 2010, p. 8A).

Chapter 2

BENEFITS OF LIVING WALLS

Plants provide many benefits to the physical environment and to humans. By adding plants to walls of buildings, these benefits can reach more places and provide a more positive environment for humans and other species in a variety of ways. Living walls share many of the benefits that green roofs provide because they can be so similar in design and function. Living walls are aesthetic, reduce the carbon footprint and heat island effect, serve as a noise buffer, improve moods and the overall health of those in close proximity.

When people view living walls on buildings or as a freestanding structure, many find them to provide an aesthetic benefit. They are pleasing to the eyes and therefore tend to improve people's moods.

Buildings that have a living wall on the exterior serve another set of benefits, which include reducing carbon footprints and allowing temperatures to be cooler behind the wall than the ambient temperatures (PNC unveils largest …, 2009). Living walls also help to create shade, keeping temperatures cooler around the buildings. The result of having a lower temperature helps to combat the extreme microclimates that are often found in urban areas. These urban climates are also known as the heat island effect. The heat island effect is an area in which high temperatures exist because of multiple buildings' absorption of the sun's heat and the immense pollution of the surrounding air. With these two effects, the amount of energy it takes to keep buildings cool through air conditioning is astronomical. Living walls help to reduce these costs by both providing shade and naturally decontaminating the air.

As plants cool the surrounding area of a building, it also helps to absorb rainfall that runs off these heat-storing surfaces. By improving climates on a small scale, plants can also improve climates at a much larger scale by "…helping to ameliorate the effect of the urban heat island, combat urban flooding…" (Dunnett and Kingsbury, 2004, p. 7).

As a living wall is of a certain thickness, it can almost be considered as extra padding to a wall to help absorb noise. Hence, a living wall can reduce noise, providing a much quieter atmosphere. The plants provide these acoustic benefits on some walls more than others. If the surface of building walls are more reflective and hard, the plants will be more effective in absorbing any noise (Why Plants?, 1995).

Plants are better at absorbing sounds with very high frequencies rather than low, which is beneficial, as sounds with higher frequencies are most irritating. Plant examples that adhere to this are *Spathiphyllum wallisli* (Peace Lily), *Philodendron scandens* (Sweetheart Plant), *Dracaena marginata* (Madagascan Dragon Tree) and *Ficus benjamina* (Weeping Fig) (Why Plants? 1995).

Absorption of noise depends a lot on what is surrounding the plants. If a plant is located in the middle of a room that consists of marble, stone and of hard material, the plant will reduce reverberation time. If places where there are carpets and soft furniture, it will not be "noticeable," as these items already absorb sound (Why Plants? 1995). If an occupant wants an interior living wall to absorb noise in a room, the room should be in an open, marble or stone area, not surrounded by carpet or soft furniture.

To better absorb sound in a home, plants or living walls are best in corners or against the wall, which suits the needs of a living wall. Sound is easily able to reflect from the wall into the plants. Also increasing the area in which the plants cover would help to reduce the noise.

If a living wall is incorporated inside the work place, it is more salubrious for the occupants. Scientists state "…indoor plants can clean the air, reduce illness and improve people's moods" (Appleby, 2009, p. 17). For example, many research studies have shown they are therapeutic, with many patients in hospitals who see trees outside their window recover more quickly than those who do not (Dunnett and Kingsbury, 2004). The aesthetic value alone can help one's health. NASA scientist Wolverton discovered that airborne moulds that cause sick building illnesses in sealed offices can be reduced by 50 percent by incorporating plants into the workspace (Appleby, 2009). According to Norwegian professor Fjeld, headaches, coughs, and sore throats fall by 30 to 45 percent in offices, hospitals and schools with plants (Appleby, 2009).

In fact, with the combined benefits of being aesthetic, reducing noise and airborne illnesses, plants actually reduce absenteeism by one percent as well as increase productivity (Appleby, 2009). Studies have shown that productivity has increased by 12 percent (The Benefits of Interior Plants, n.d.). The reduction in noise makes a contribution to the reduced feelings of stress as well.

These benefits listed above are very similar to green roofs, however, living walls have some reduced benefits compared to green roofs. For example, though green roofs and living walls both retain water, green roofs tend to retain more water than living walls because of how they are typically constructed. Green roofs tend to have more depth to the vegetation and soil while some living walls tend to be thinner in material and are usually at a 90-degree angle, opposed to being flat or on an angle like green roofs. These aspects allow for green roofs to retain more water (Dunnett and Kingsbury, 2004).

Green roofs are also considered to be a part of the Best Management Practice (BMP), a project started in 1996 with multiple environmental organizations that partner with the program. According to the BMP, green roofs are one of the most influential constructions to fight global warming, which is directly associated with the heat island effect (Irwin, March 2008).

Living walls also have their advantages over green roofs as well. Living walls can be grown in closer proximity to occupants of a building, enabling them to benefit more directly from the living walls purifying the air. Occupants can also enjoy the expelling scents that are pleasing to the olfactory nerves if appropriate plants are used.

The proximity of the living wall to the occupants also enables viewers of a living wall to enjoy the aesthetics properties. Living walls, with its many different types, give the creator more flexibility to design a living wall with artistic expression incorporate an appealing architectural design. This is not so for green roofs, as there are stricter standards to green roof construction (Irwin, April 2008).

Occupants also experience greater accessibility to food production with living walls. According to George Irwin, the fact that the structure of a living wall is vertical makes it more ergonomic, an advantage over green roofs (October 2008). This means there is less of a chance in experiencing stress or injury in maintaining the living walls.

Ultimately, however, the benefits derived from green roofs and living walls can be very much equal if they are designed and constructed in the same way. For example, a green roof that has 3 inches of soil can provide the same benefits, more or less, of a living wall that has 3 inches of soil in its construction, especially when using the same vegetation (Irwin, March 2008).

Because of the multitude of benefits both green roofs and living walls provide, the industry of green construction is growing. According to Ervin, green buildings add "…positive value – enhanced health and productivity, operational savings, increased property values, environmental protection, stronger communities and more. It's no wonder that industry interest is accelerating" ('Value Underlies Green Movement,' 2005, p. 8).

As the industry continues to expand grow in a variety of green building spectrums, it is important that standards are agreed upon in design and construction of living walls. Ian Drummond is the Creative Director of Indoor Garden Design, an independent landscaping company based in London. Drummond wants to see plants "appear on a checklist of essentials for architects to be included in BREEAM ratings for offices" instead of being considered an extra cleaning or maintenance task (Appleby, 2009, p. 17). BREEAM is an environmental assessment method for green building, developed in the UK by BRE, Building Research Establishment.

The United States operates under the U.S. Green Building Council (USGBC). Living walls and green roofs already count for a multitude of Leadership in Energy in Environmental Design (LEED) points under this organization. LEED rating systems are specific to a variety of buildings, from hospitals to retail stores and from homes to school buildings. Some of the categories that LEED rates a building that uses green-construction include the following: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality (LEED rating systems, 2010).

Chapter 3

METHODOLOGY

To assist in promoting the social and environmental awareness and benefits of living walls, two projects will be highlighted: the documentation of the indoor herb living wall that was part of the Penn State 2009 Solar Decathlon House “Natural Fusion,” and a Google Earth interface that documents the global distribution of the existence of living walls.

The Penn State 2009 Solar Decathlon Living Wall

The Solar Decathlon competition is a biannual international competition between twenty universities to inspire students, faculty and staff to design, build and operate an entirely solar-powered home. Penn State had an entry in the October 2009 competition, which took place on the National Mall in Washington, D.C.

The Natural Fusion home had three living walls incorporated into its design and construction: an exterior living wall on the north façade, an interior living wall in the bathroom and an interior kitchen living wall. This thesis focuses on the interior kitchen living wall.

As a member of the Penn State 2009 Solar Decathlon – Natural Fusion – team, it was easy for me to absorb and learn information about living walls from other members on the team who already did research on living walls and sustainable design. All team members, with the exception of the Faculty Director, were students. Most of these students were pursuing a bachelors or masters degree in a specified area of Engineering or Architecture. The faculty director, Dr. Jeffrey R. S. Brownson, Assistant Professor of Energy and Mineral Engineering, served as a guide for the project. As the only major in Communications on the Penn State team, I was not involved with the decisions made in regards to sustainability and construction, as these decisions fell on the rest of the team that had background knowledge on these matters.

By learning how to best communicate Natural Fusion's idea of intertwining the natural environment (living walls being one example) with the built environment to various publics through the Internet, press materials, and face-to-face interaction, the interest in living walls and spreading awareness about their benefits reached new heights. When the solar-powered houses were open to the public, I had the opportunity to give house tours during two weeks of the competition, which allowed me to discuss the various benefits of the interior kitchen living wall. The amazement and interest on the faces of the people visiting the home lingered on the mind. From my experiences at the Solar Decathlon, a desire emerged to continue spreading an awareness about living walls in order to continue to expand upon those astonished reactions and interests of the house visitors.

As the Videographer and Communications Assistant for the Penn State Solar Decathlon team, my responsibilities included recording video footage and taking photographs of the many systems within the house, including all three living walls. A short video of the construction of the interior kitchen living wall was created and uploaded onto You Tube and the Web site for the house: http://www.naturalfusion.org under the Construction tab. The knowledge I obtained and work I completed as a member of the team served as a basis for this thesis.

Digital media was recorded using video cameras, tripods and digital SLR cameras that were rented from Media and Technology Support Services (MTSS), located in the Willard Building on campus. This footage was taken during the summer and fall of 2009, when work was done as a ten week, full-time job for the team. This media was saved onto a personal one terabyte external hard drive.

Programs such as Adobe Photoshop and Final Cut Pro were used to edit photographs and create videos for the team's Web site and for this thesis. These photographs and more information on the living wall can also be found on the Web site and detailed in Chapter 4.

Documenting Living Walls in Google Earth

After working to disseminate information about the Penn State 2009 Solar Decathlon living wall, curiosity set in about the existence of living walls around the globe. Google Earth is a program that can plot placemarks at various locations on Earth with descriptions. It can be used for professional, educational, outreach, or personal purposes. In order to make a Google Earth file, there was a series of steps that needed to be completed.

First, I had to locate where living walls exist by searching online with YouTube, Wikimedia, Flickr, Google and other search engines. Since living walls are not as well known or as numerous as green roofs, various searches on related words were used, such as "green walls," "vertical gardens," "biowalls," "vertical landscapes," "plant walls," "green façades," "vertical farms," and "vertical walls." The URL links to articles, videos and photographs I found on various living walls were saved in .RTF files, which are Text Edit documents on a Mac that require less space than Microsoft Word Documents. These .RTF files were saved by the name of the building where a living wall was constructed. These .RTF files were then placed into a folder that specified their location, as in city or state. These folders were placed into other folders that specified their region, such as country and continent. This method was used to make the implementation of this information into Google Earth more efficient and organized. All of this information was saved on an eight gigabyte flash drive.

Once information about where living walls existed around the globe was collected, learning the Google Earth application came next. The addresses of the buildings where the living walls exist were placed into the “Search” area of the Google Earth application. Once Google Earth locates the building, it takes the viewer to the area. From there, a placemark can be created and added to a personal Google Earth file. Within the placemark is where all of the information is inserted. This information requires basic html codes in order for the information to be properly displayed in Google Earth.

The information displayed in the popup window for each placemark includes: the name of the building, an image or video (pending online availability), a short description about the living wall, and any related articles to the construction of the living wall. All images were obtained through Wikimedia (http://commons.wikimedia.org/wiki/Main_Page) or Flickr Creative Commons (http://www.flickr.com/creativecommons/) Web sites, which are free of copyright and may have some rights reserved. Image sources were given credit by using links that take the viewer to where the image was found. No copyrighted material was used within these placemarks.

Living walls were found in Australia, Canada, France, Japan, Mexico, Spain, Singapore, Thailand and the United States. These areas do not represent an exhaustive list, as there were living walls found in other areas, such as Germany and Sweden. However, the information about the German and Swedish walls was not located properly because of a difficulty in translating the Web site text to English. The living walls that were successfully located are documented further in Chapter 4, where screenshots of each placemark have been taken.

The Google Earth file on living walls serves as a tour to those interested and has potential to be used by K-12 teachers in the United States and abroad for educational use. The Google Earth file is placed on Penn State Brandywine’s Google Earth QUEST blog (http://tinyurl.com/googleearthquest/), where QUEST stands for Questioning and Understanding Earth Science Themes. An entire page on the blog has been created to assist in the dissemination of my collected living wall resources.

Chapter 4

INTERNATIONAL TOUR

Solar Decathlon Living Wall

In the fall of 2009, The Pennsylvania State University participated in the U.S. Department of Energy's Solar Decathlon competition. As mentioned in Chapter 3, the Solar Decathlon is a biannual international competition between twenty universities to inspire students, faculty and staff to design, build and operate an entirely solar-powered home.

Figure 4-1: Rendering of the Natural Fusion home (Penn State 2009 Solar Decathlon: Renderings, Image 3, 2009).

The Penn State team, comprised of over 130 active members, implemented eco-friendly designs into their home dubbed Natural Fusion. The Penn State team embodied the idea that nature and the built environment did not have to be separated, but fused together in a living environment. Hence, the team incorporated a green roof and three living walls.

The following diagram depicts the green roof on the Natural Fusion home:

Figure 4-2: Penn State 2009 Solar Decathlon green roof (Penn State 2009 Solar Decathlon: Landscape Snapshot, 2009).

The three living walls include an exterior living wall on the north façade, and two interior living ones: one in the bathroom for aromatherapy and one in the kitchen that provided herbs and spices.

Figure 4-3: Rendering of north façade (Penn State 2009 Solar Decathlon: Renderings, Image 2, 2009).

Figure 4-4: Rendering of bathroom living wall (Penn State 2009 Solar Decathlon: Renderings, Image 6, 2009).

Figure 4-5: Rendering of kitchen and south doors (Penn State 2009 Solar Decathlon: Renderings, Image 4, 2009).

Figure 4-6: Rendering of kitchen with living wall (Penn State 2009 Solar Decathlon: Renderings, Image 5, 2009).

The indoor kitchen living wall will be the focus of this chapter. The living wall, dubbed "Life Well" by the team, extended across the entire countertop area against the wall that separated the kitchen from the bathroom. First, Cambria heat-treated poplar was cut to appropriate lengths and was horizontally nailed into the wall. From there, after they were stained to enrich their color, the planter boxes were inserted into the spacing between some of the boards. This action enabled the planter boxes to hang on the wall.

The text created on the Natural Fusion Web site states the following about the three living walls:

> *"Extending across part of the north wall and into the home on a north-south axis, living walls carry natural landscape into the built environment. A variety of leaf shapes and hues create an intriguing visual on the walls both inside and outside the home. The exterior living wall camouflages the Nexus doors and creates an interesting visual feature on the north wall. The interior living wall, located in both the kitchen and the bathroom, provides a customizable interior garden space that brings nature into the home."*

The following snapshot, viewable on www.naturalfusion.org under Landscape, displays the design of the Natural Fusion home. The green area is the exterior living wall on the north façade as well as the interior living wall that separates the kitchen from the bathroom. The idea was to make the interior living wall seem to extend outside into the exterior living wall.

Figure 4-7: Penn State 2009 Solar Decathlon living walls (Penn State 2009 Solar Decathlon: Landscape Snapshot, 2009).

The plants selected for these living walls include the following:

Adiantum pedatum – “Maidenhair Fern”

Dryopteris marginalis – “Eastern Wood Fern”

Polystichum acrostichoides – “Christmas Fern”

Tiarella cardifolia – “Foamflower”

Sedum ternatum – “Woodland stonecrop”

Carex pensylvanica – “Pennsylvania Sedge”

The *Sedum ternatum* (Woodland stonecrop) was the only *Sedum* species that was used on both the interior kitchen living wall and the green roof. In addition to using ferns and a type of sedum, herbs were also used on the bottom two rows of the living wall. These herbs included a variety of basil, chives, potato and parsley. With the plants adding an aesthetic appeal and filtering the air, the herbs add a benefit while cooking. As they are close to the countertop, it is easy to simply pluck the herbs from the plants and use in a meal. Having the herbs fresh and local tastes better and saves the occupant money in the long run on store bought herbs and spices.

Figure 4-8: Natural Fusion's Interior living wall (photo taken by A. DiLauro, October 2009).

Figure 4-9: Natural Fusion's living wall - Close Up (photo taken by A. DiLauro, October 2009).

These plants and herbs have to be manually watered, as this interior living wall does not have an irrigation system. If not maintained correctly, irrigation systems tend to cause mold. In addition, the rules and parameters of the Solar Decathlon competition made it difficult to include an irrigation system.

Originally, the team wanted to incorporate a gray water facility but with the limited amount of water each team was allowed to use, it would have been difficult to incorporate a gray water facility using the kitchen’s living wall when water was needed for other tasks. Gray water is considered sink water,

Water was needed for laundry, running the shower at very high temperatures and similar tasks that measured water and energy usage within the home. Since irrigation systems also use energy, it just made more sense for the Penn State team to have the living wall be manually watered. It required less water and only human energy to maintain it.

The living wall was approximately $1,700 dollars to construct. This number involved buying the plants fully grown, however, which is a lot more expensive than simply buying the seeds and growing them from its immature stages. A living wall with a similar and much smaller design with the use of seeds can be constructed for a few hundred dollars.

Many people that took a tour of the Natural Fusion home while the solar-powered home was situated on the National Mall in Washington D.C. was amazed by the interior kitchen living wall's beauty and function of growing herbs.

Bayer MaterialScience, a main corporate sponsor of the Penn State 2009 Solar Decathlon team, bought the Natural Fusion home. The house resides on Bayer's Pittsburgh campus location and is being used for education, to host meetings and to conduct further research on sustainability.

Figure 4-10: Bayer MaterialScience, Natural Fusion home, Pittsburgh, PA.

(Google Earth Snapshot, April 2010).

Google Earth: Living Walls Documented

The following living walls have been found through the Internet or from talking with others about their various locations. No resource currently exists that acts as a clearinghouse that documents the existence of completed living walls or walls under development. There were many living walls that were found in Sweden and Germany on various Web sites. However, because some pages had to be translated to English, it was difficult to locate the exact location in which these living walls exist in Google Earth. Therefore, they are not documented in the file and in the below descriptions. The living walls that were located are all documented on the Living Wall Google Earth page. They are categorized by country and region in alphabetical order. The original Google Earth file can be found on this web page: http://www.personal.psu.edu/uxg3/blogs/googleearthquest/livingwall.html

AUSTRALIA:

Sydney:

Sydney International Airport

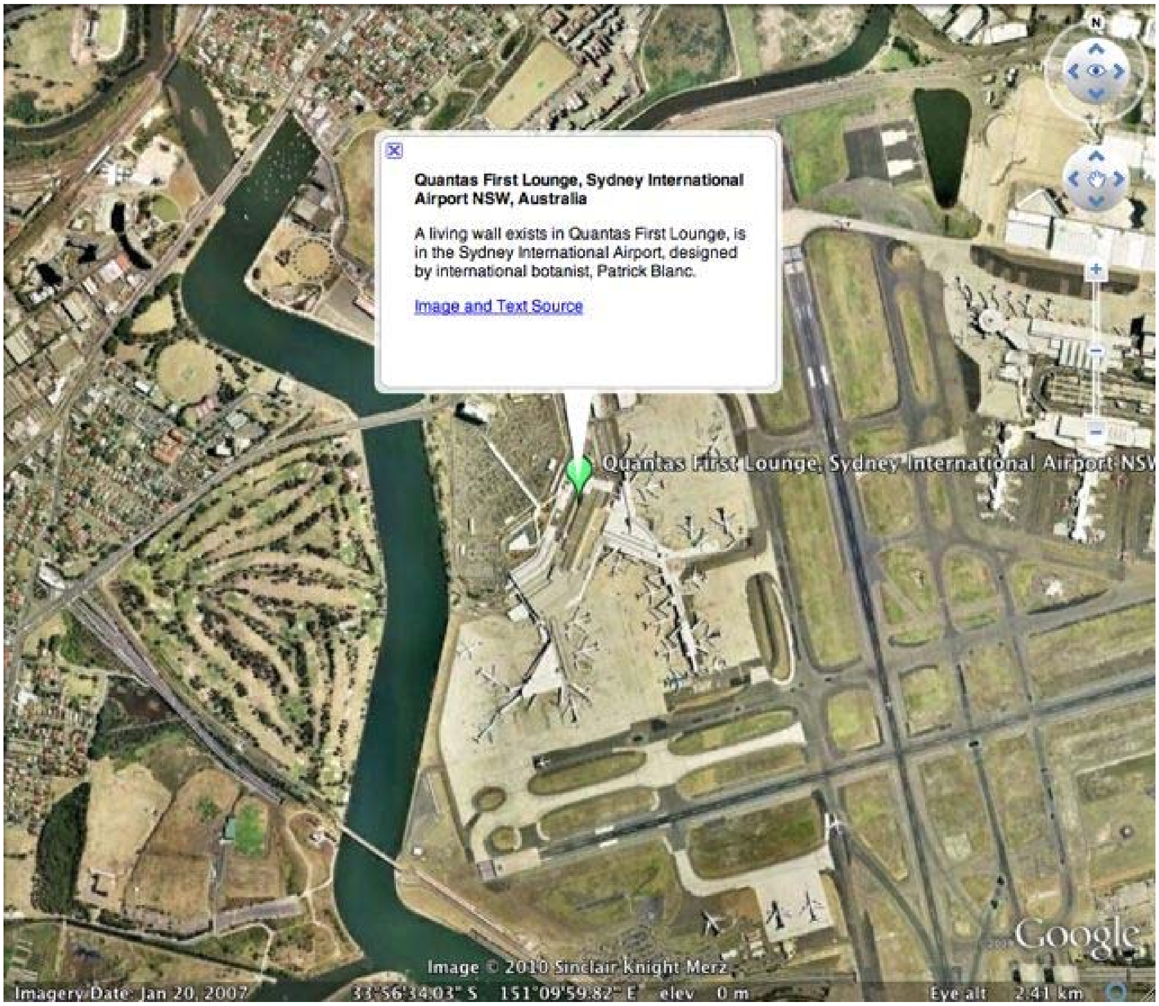

Figure 4-11: Sydney International Airport, (Google Earth Snapshot, April 2010).

Quantas First Lounge at the Sydney International Airport is designed by Patrick Blanc, an international botanist.

CANADA:

Ontario:

University of Windsor's Medical Building

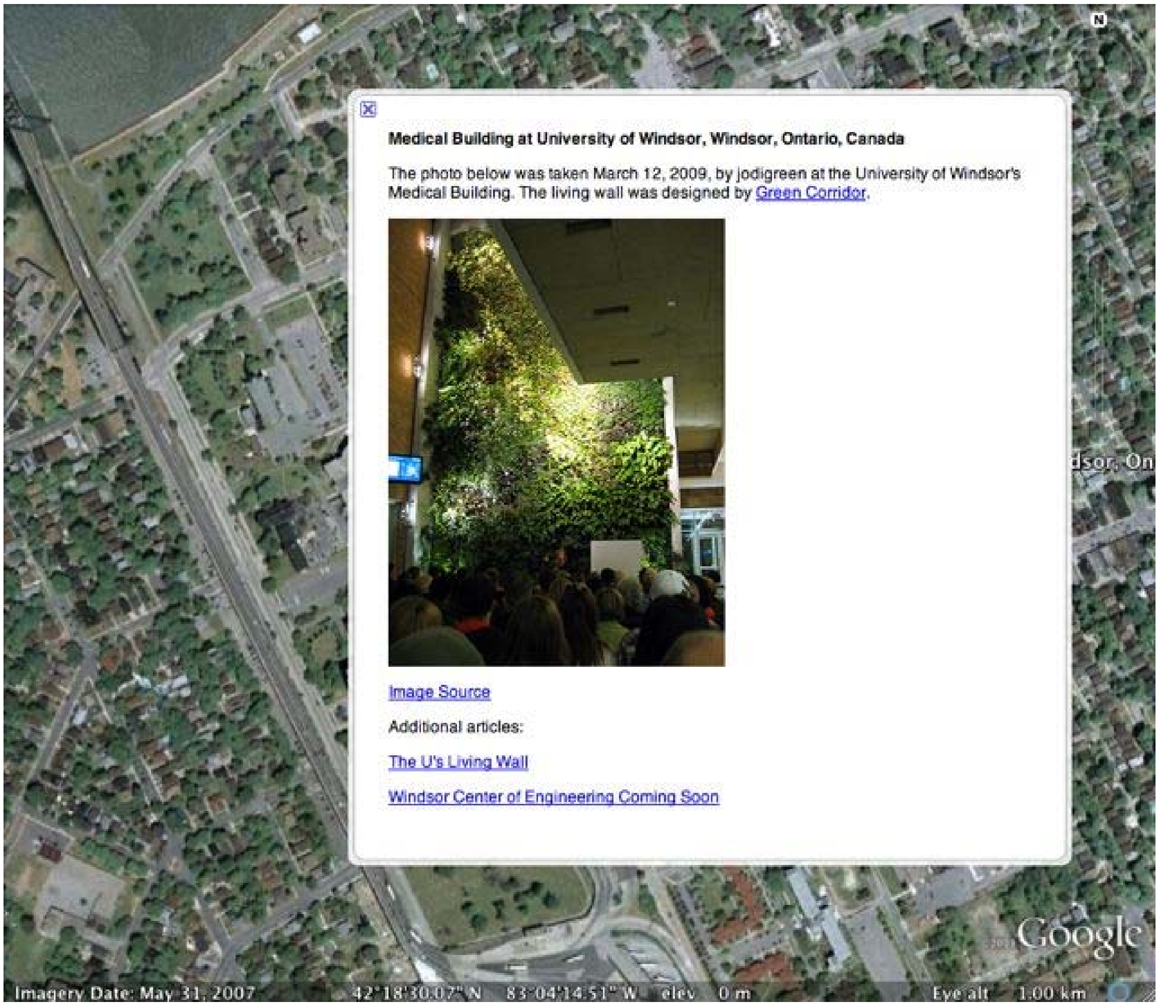

Figure 4-12: Medical Building at the University of Windsor (Google Earth, April 2010).

There is a living wall that measures twelve meters high and seven meters wide. The hydroponic system sustains twenty varieties of plants. This living wall runs on the building's HVAC system to decontaminate the air. The living wall was designed by Green Corridor, a green construction company based in Canada that does a variety of projects.

Brantford Chiropractor

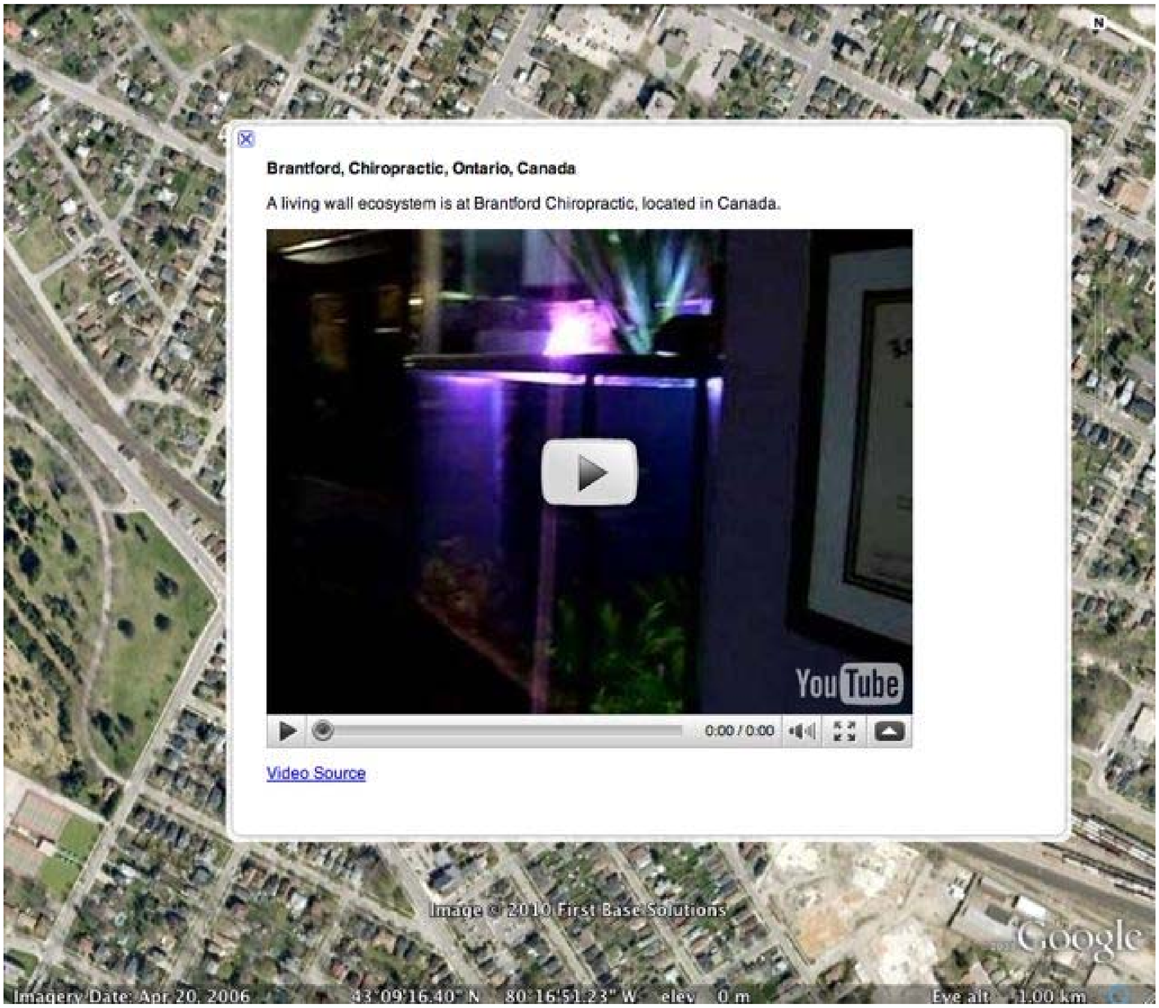

Figure 4-13: Brantford Chiropractic, Canada (Google Earth Snapsnot, April 2010).

A living wall ecosystem is at Brantford Chiropractic, located in Canada.

Toronto:

University of Guelph-Humber Building

Figure 4-14: University of Guelph-Humber, (Google Earth Snapshot, April 2010).

University of Guelph-Humber Building in Toronto, Ontario has a living wall in their Atrium, a four story biofilter.

Vancouver:

Vancouver Aquarium

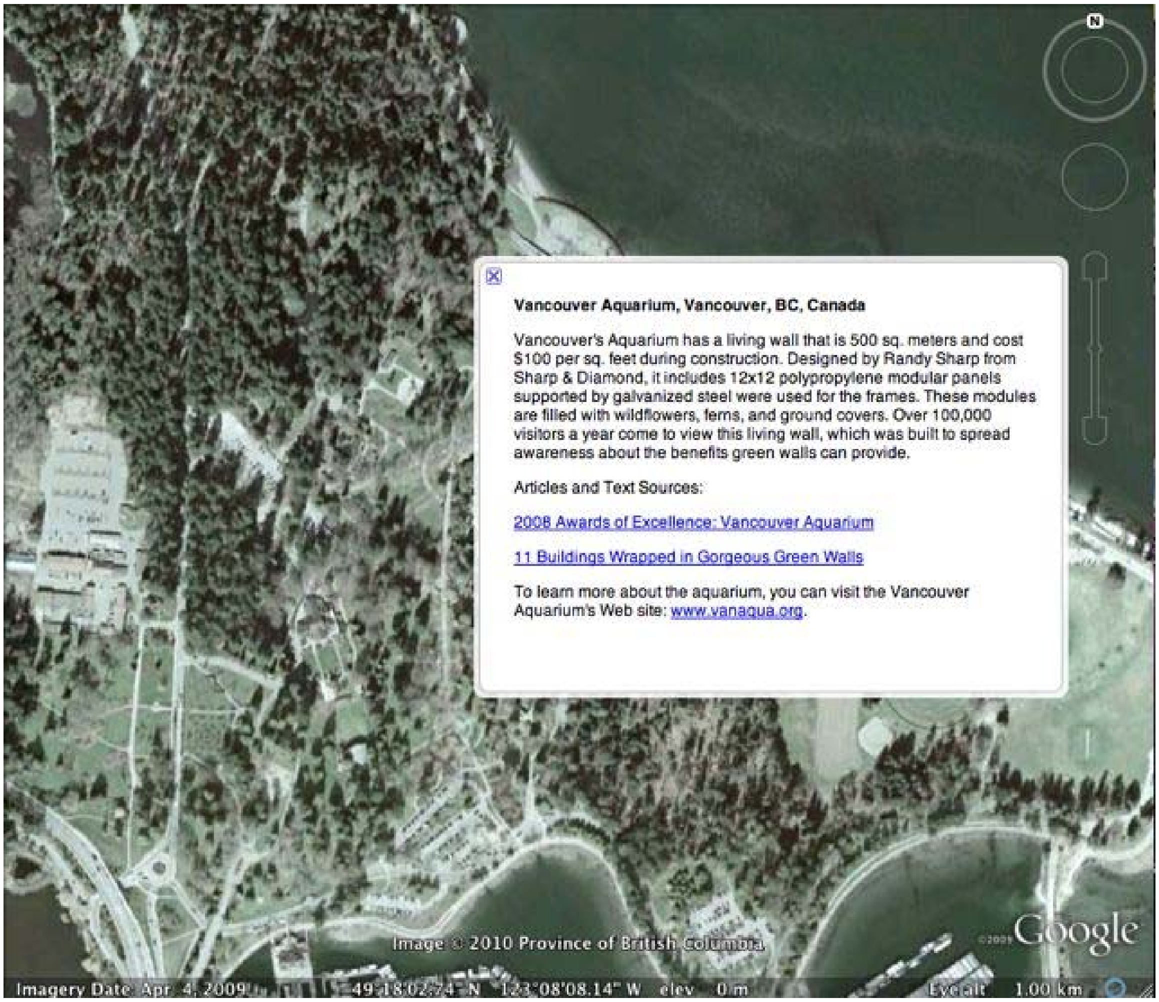

Figure 4-15: Vancouver Aquarium, (Google Earth Snapshot, April 2010).

Vancouver's Aquarium has a living wall that is 500 sq. meters and costs $100 per sq. feet. Designed by Randy Sharp from Sharp & Diamond, it includes 12x12 polypropylene modular panels supported by galvanized steel were used for the frames. These modules are filled with wildflowers, ferns, and ground covers. Over 100,000 visitors a year come to view this living wall, which was built to spread awareness about the benefits green walls can provide.

FRANCE:

Paris:

BHV Homme

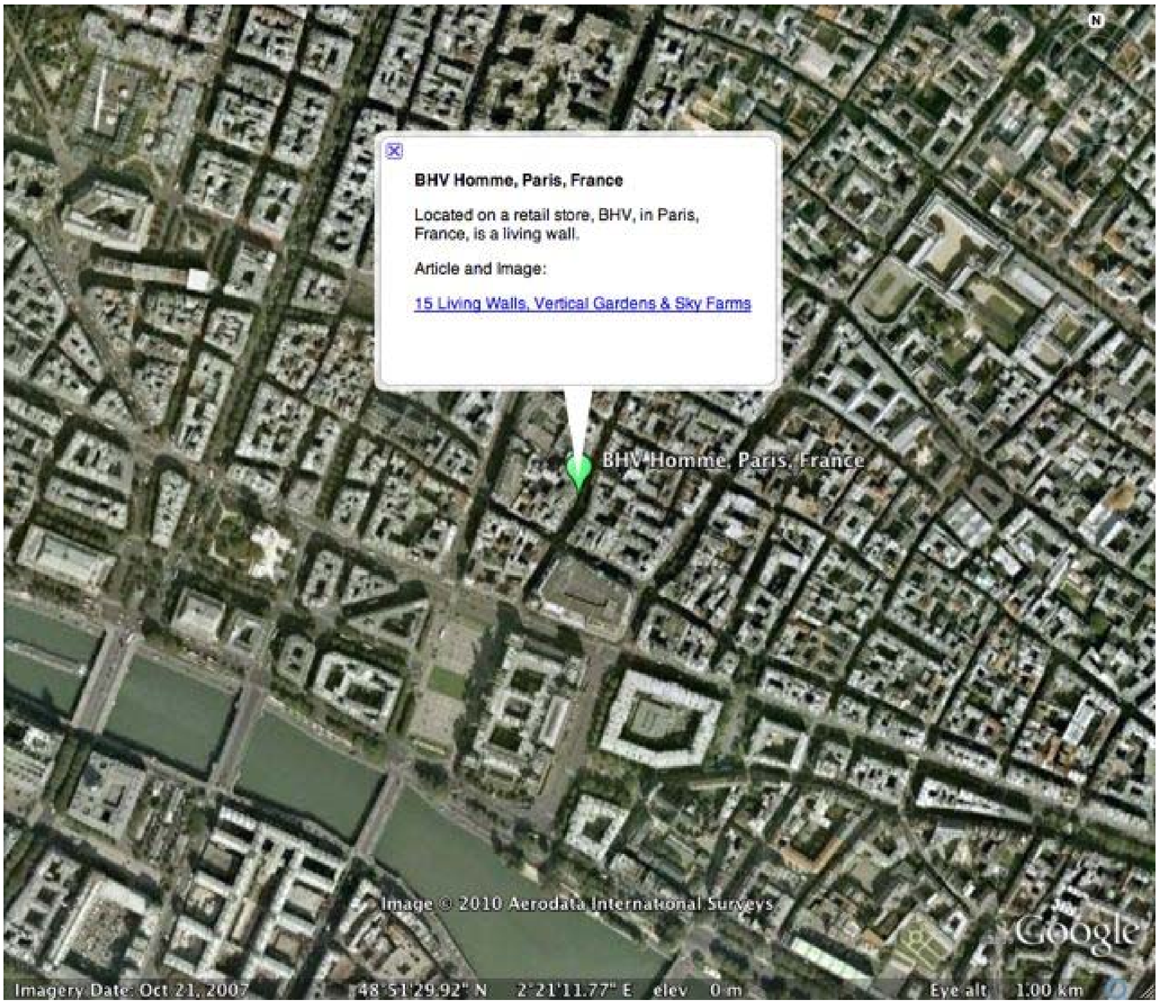

Figure 4-16: BHV Homme in Paris, France (Google Earth Snapshot, April 2010).

Located on a retail store, BHV, in Paris, France, is a living wall.

Flower Tower

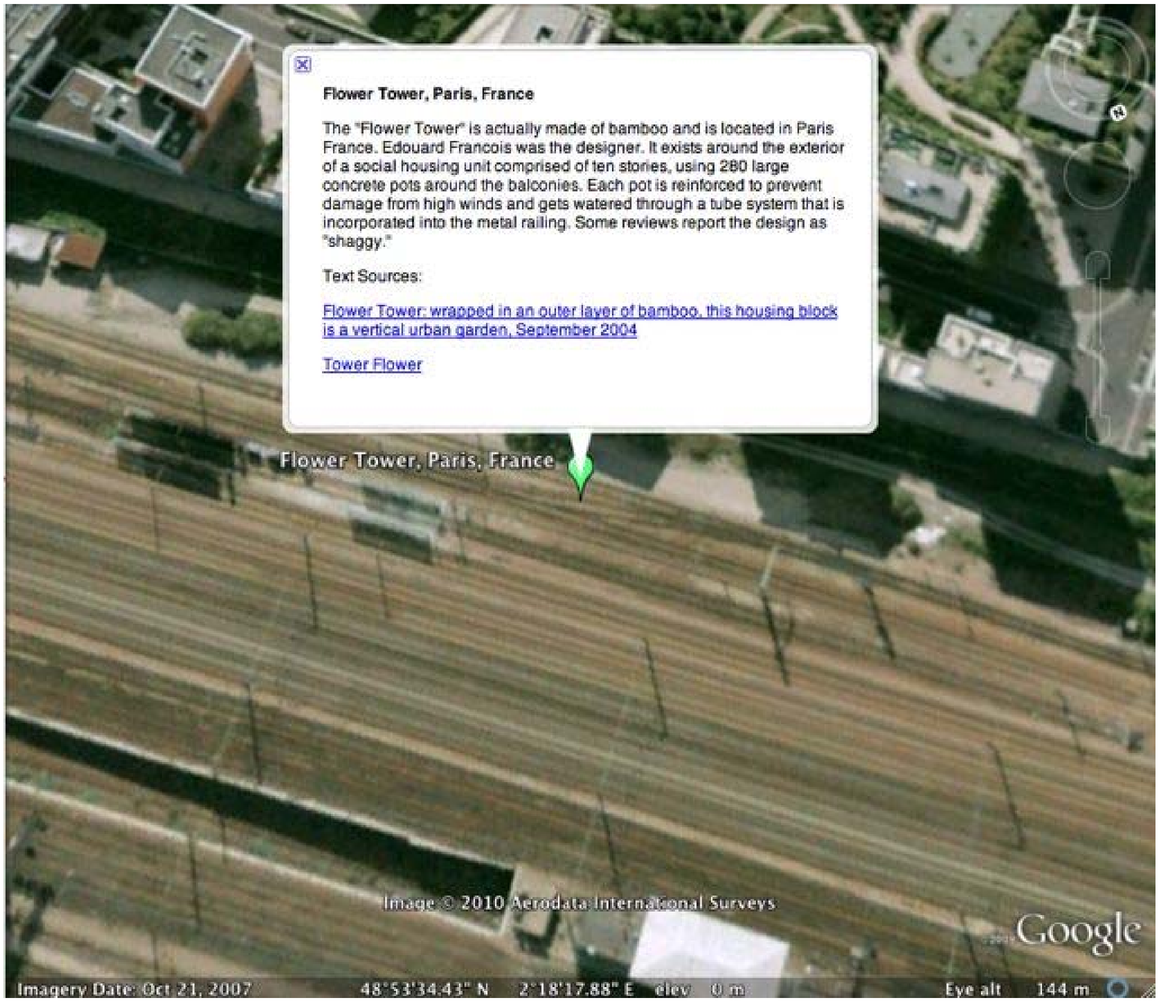

Figure 4-17: Flower Tower, Paris, France (Google Snapshot, April 2010).

The "Flower Tower" is actually made of bamboo and is located in Paris France. Edouard Francois was the designer of this monstrosity. It consists around the exterior of a social housing unit comprised of ten stories, using 280 large concrete pots around the balconies. Each pot is reinforced to prevent damage from high winds and gets watered through a tube system that is incorporated into the metal railing. Some reviews say the design looks quite shaggy.

Jean Nouvel Fondation Cartier

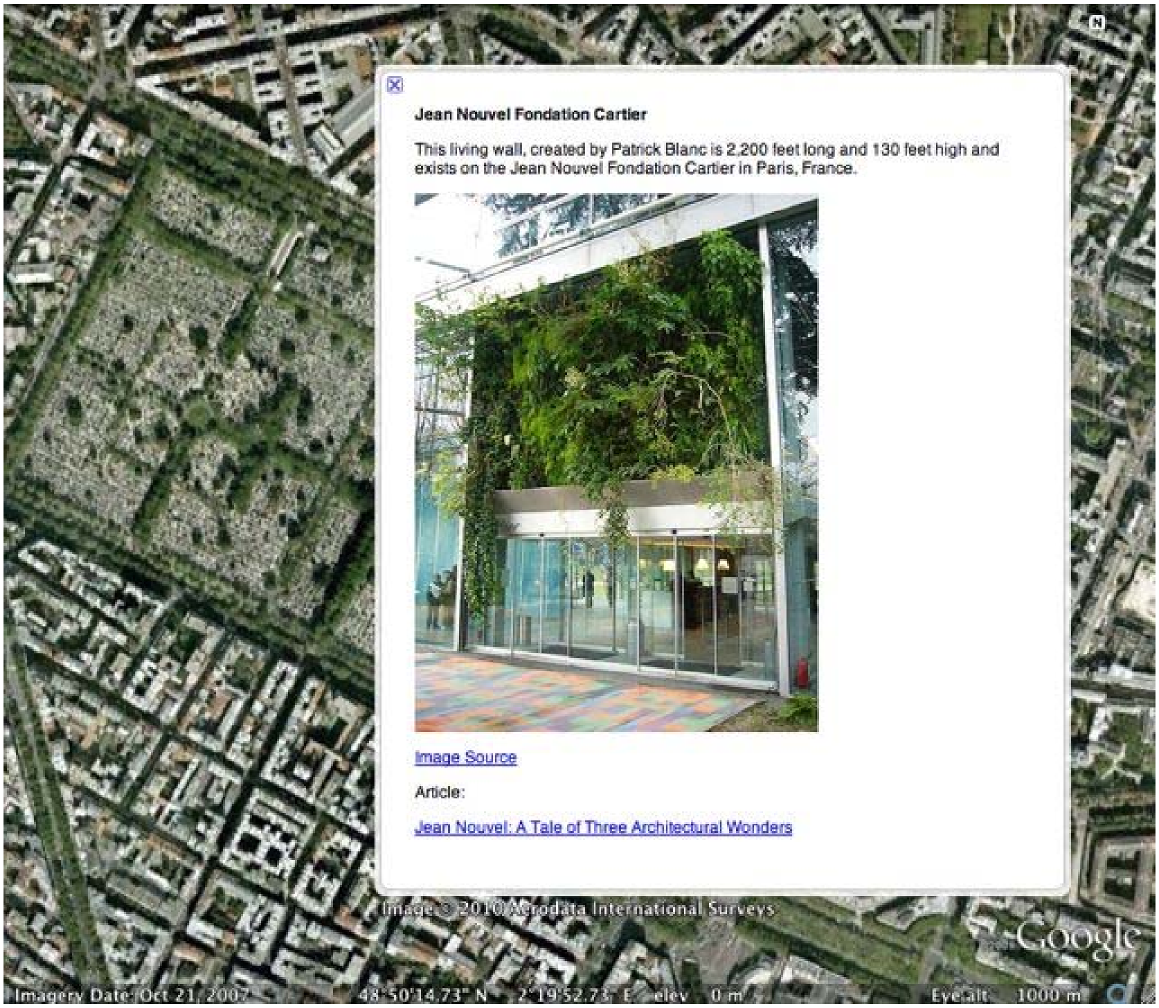

Figure 4-18: Jean Nouvel Fondation Cartier, Paris France (Google Earth Snapshot April 2010).

This living wall, created by Patrick Blanc is 2,200 feet long and 130 feet high and exists on the Jean Nouvel Fondation Cartier in Paris, France.

Musee du Quai Branly

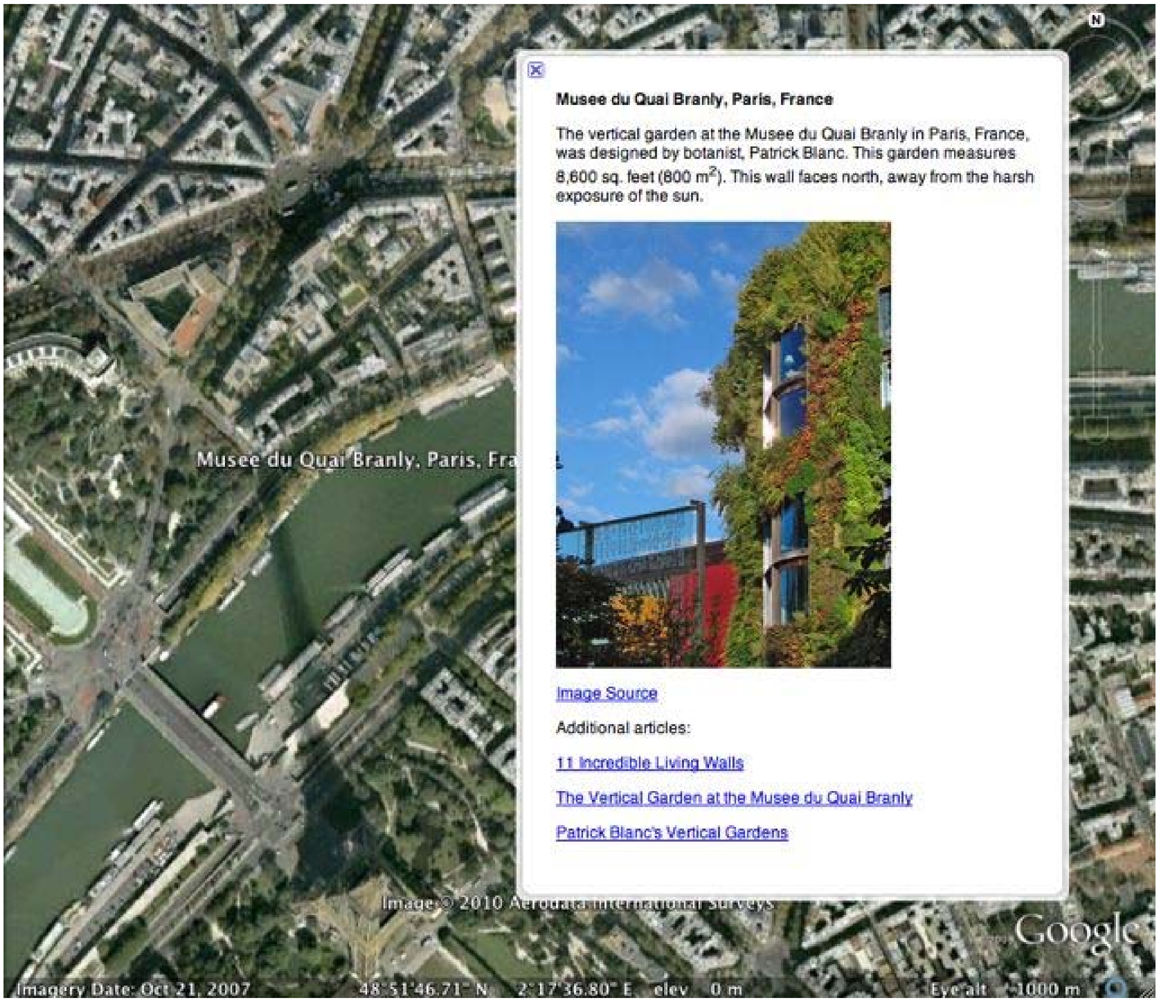

Figure 4-19: Musee du Quai Branly, Paris, France (Google Earth Snapshot, April 2010).

The vertical garden at the Musee du Quai Branly in Paris, France was designed by botanist, Patrick Blanc. This garden measures 8,600 sq. feet (800 m^2).This wall faces north, away from the harsh exposure of the sun.

Pershing Hall Hotel

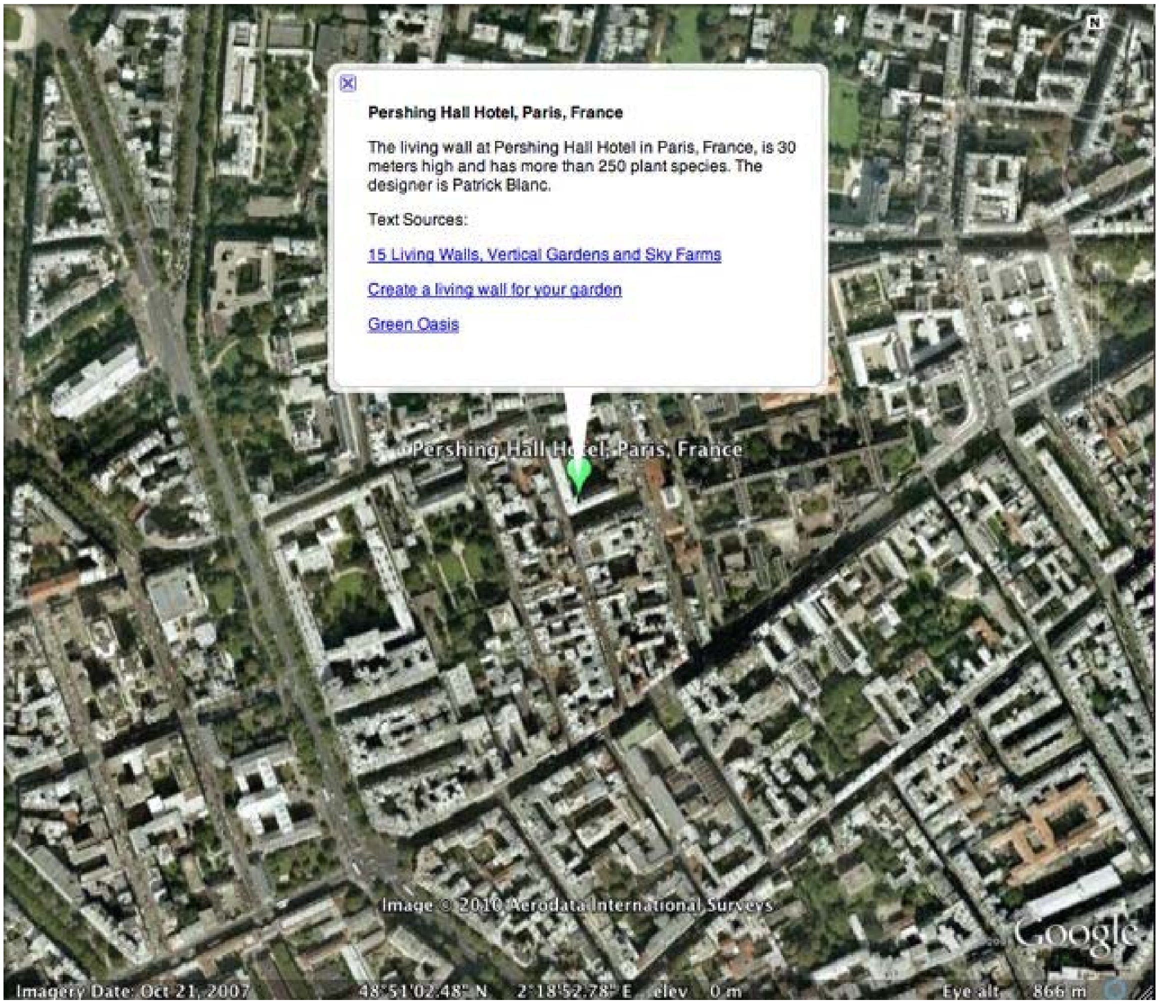

Figure 4-20: Pershing Hall Hotel in Paris, France (Google Earth Snapshot, April 2010).

The living wall at Pershing Hall Hotel in Paris, France is 30 meters high and has more than 250 plant species. Designer is Patrick Blanc.

Avignon:

Vertical Garden in Marche de Halles on Place Pie

Figure 4-21: Marche de Halles in Avignon, France (Google Earth Snapshot, April 2010).

Patrick Blanc's vertical garden in Marche de Halles, on Place Pie in Avignon, France uses a hydroponic system, so no soil is required to maintain this artistic vegetation.

JAPAN:

ACROS Fukuoka Prefectural International Hall

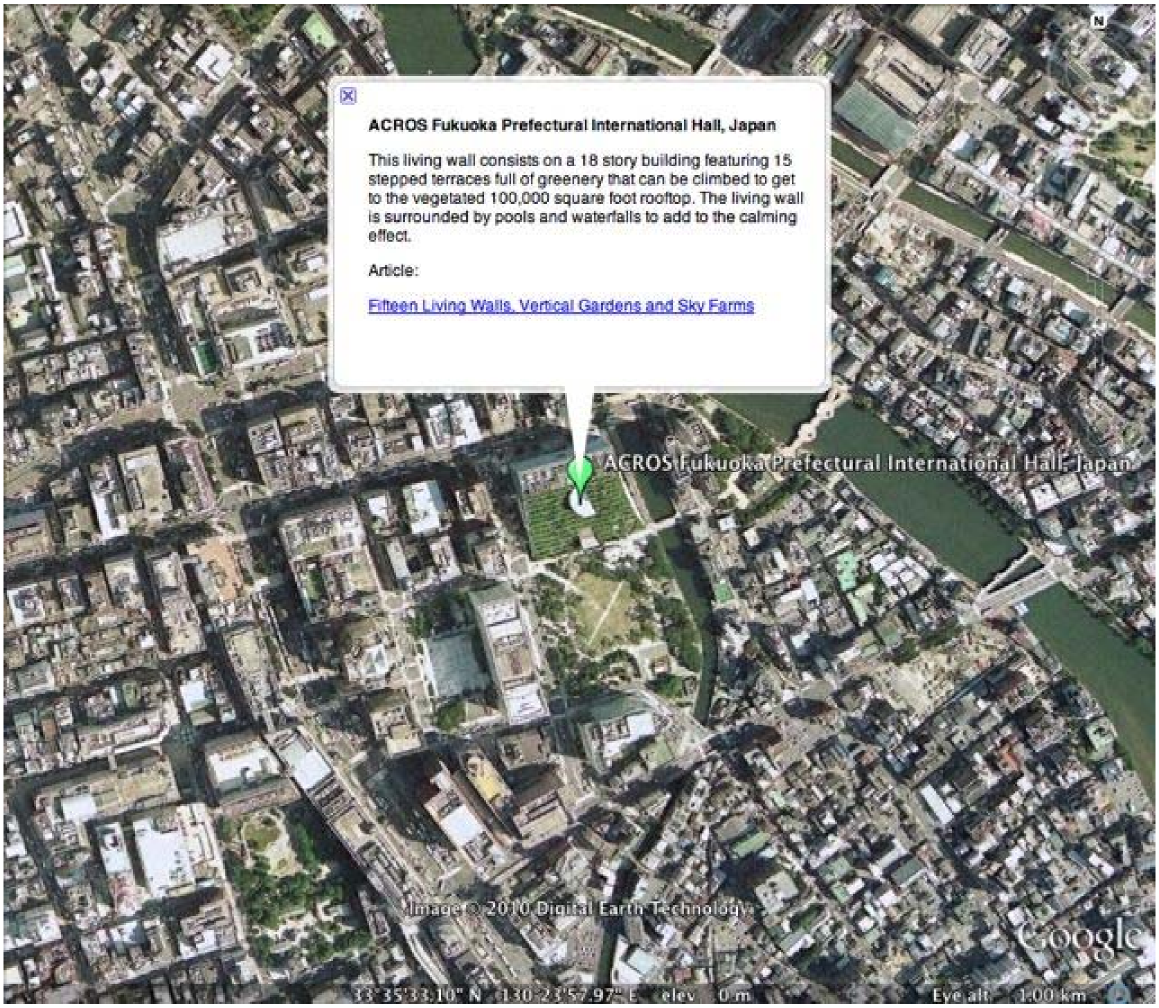

Figure 4-22: ACROS Fukuoka Prefecctural International Hall, Japan (Google Snapshot, April 2010).

The living wall consists on an 18 story building featuring 15 stepped terraces full of greenery that can be climbed to get to the vegetated 100,000 square foot rooftop. Pools and waterfalls add to the calming effect surrounding this living wall.

Marui department store

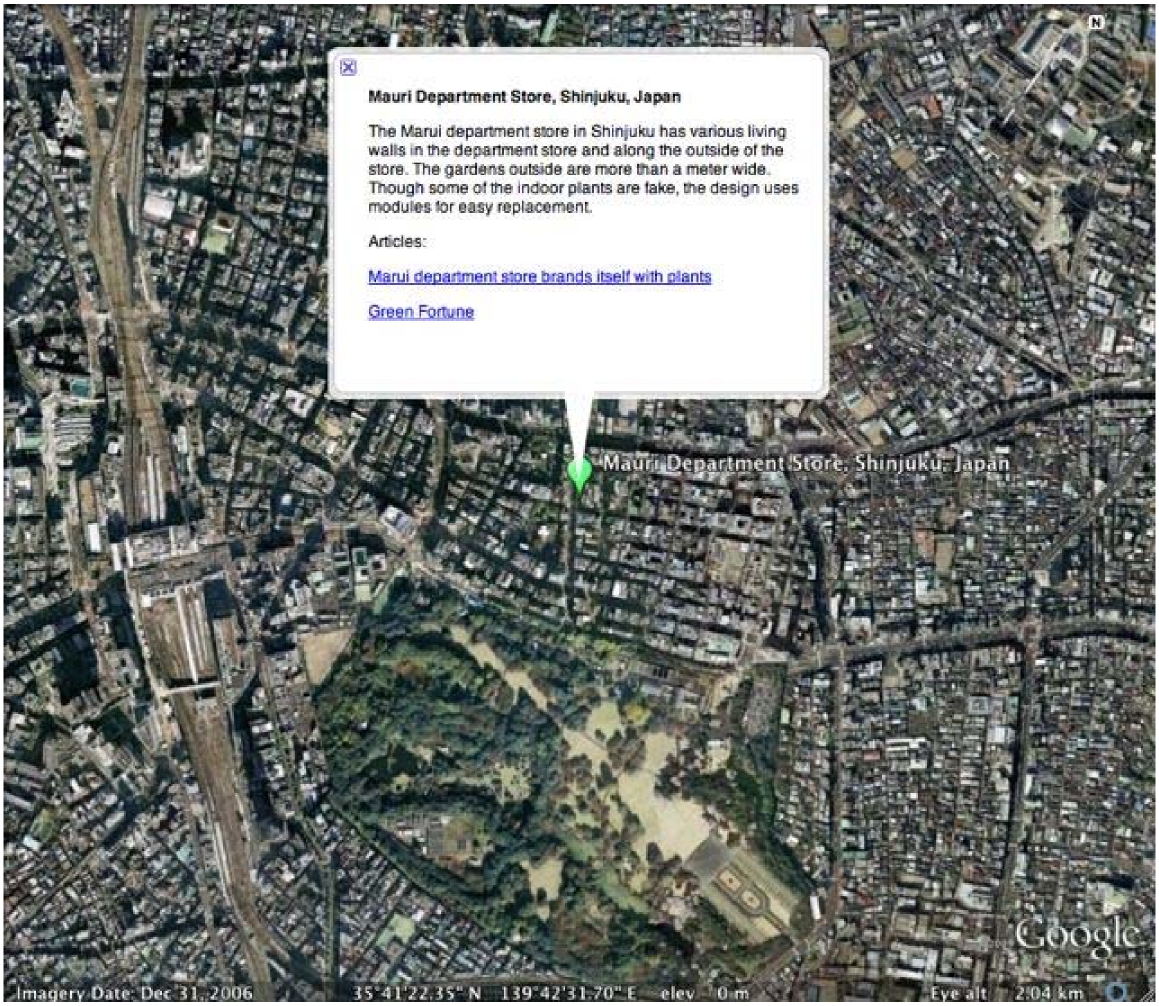

Figure 4-23: Marui department store in Shinjuku, Japan (Google Earth Snapshot, April 2010).

Marui department store in Shinjuku has various living walls in the department store and along the outside of their store. Gardens outside are more than a meter wide. Though some of the indoor plants are artificial, they do use modules for easy replacement.

MEXICO

Mexico City

El Japonez

Figure 4-24: El Japonez restaurant in Mexico (Google Earth Snapshot, April 2010).

Serrano Cherrem Architects designed the living wall that uses wood and a glass enclosure. Seating in this restaurant is right in front of the living wall, located in Mexico City, Mexico.

SINGAPORE:

Changi International Airport

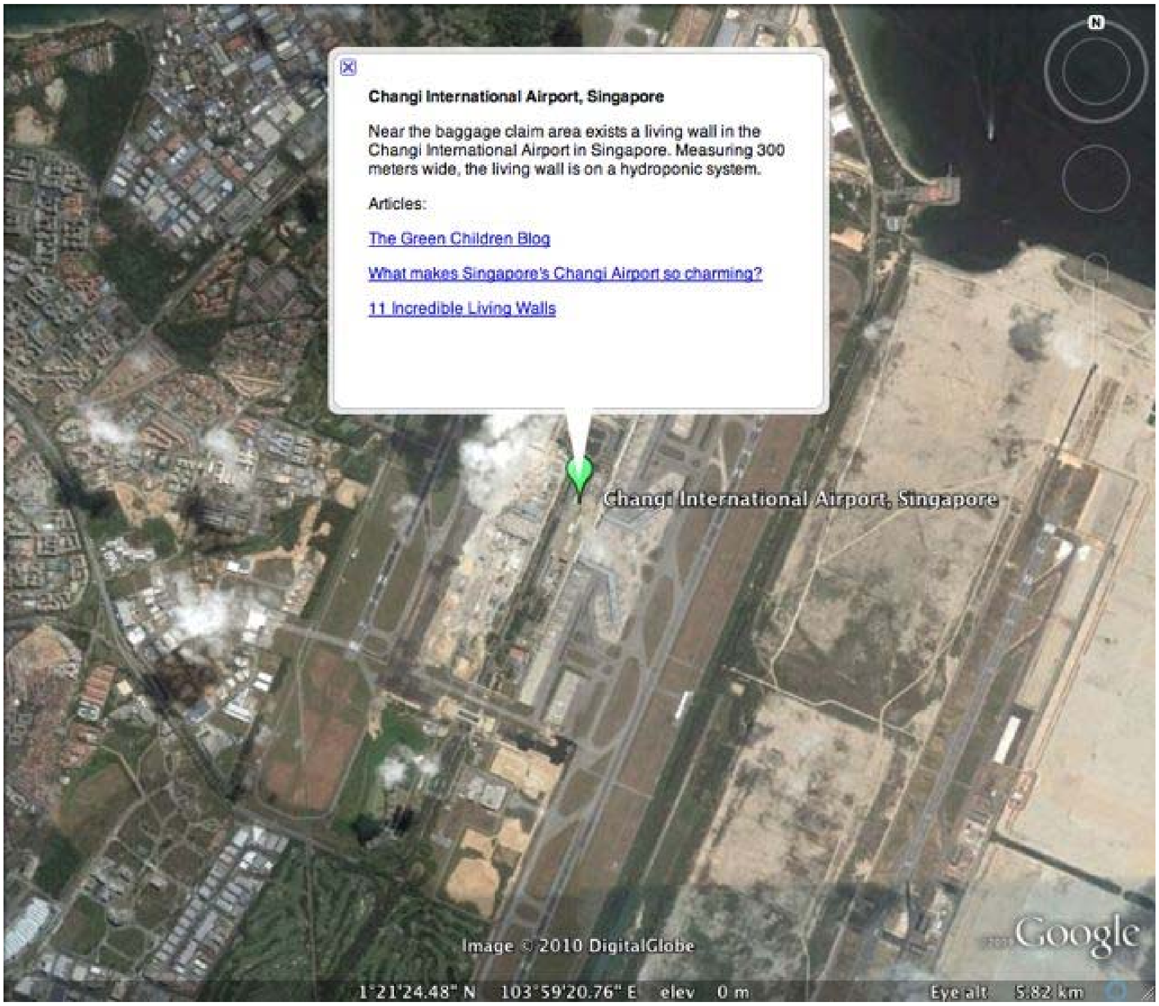

Figure 4-25: Changi International Airport, Singapore (Google Earth Snapshot, April 2010).

Right near the baggage claim area in the Changi International Airport in Singapore exists a living wall. Measuring 300 meters wide, the living wall is on a hydroponic system.

Horticulture Park

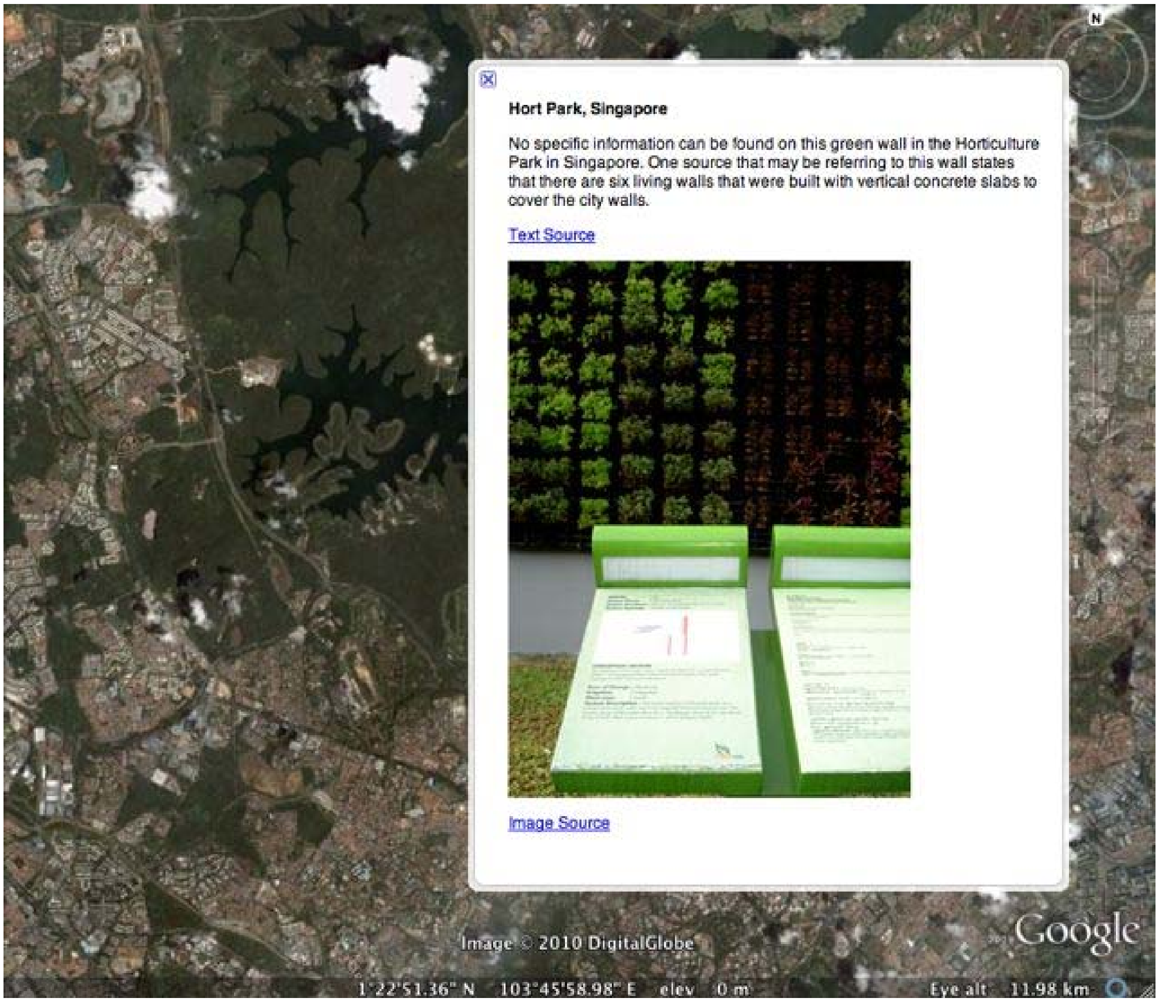

Figure 4-26: Horticulture Park, Singapore (Google Earth Snapshot, April 2010).

No specific information can be found on this green wall in the Horticulture Park in Singapore. One source that refers to this wall states that there are six living walls that were built with vertical concrete slabs to cover the city walls.

SPAIN:

Madrid:

Caixa Forum Museum

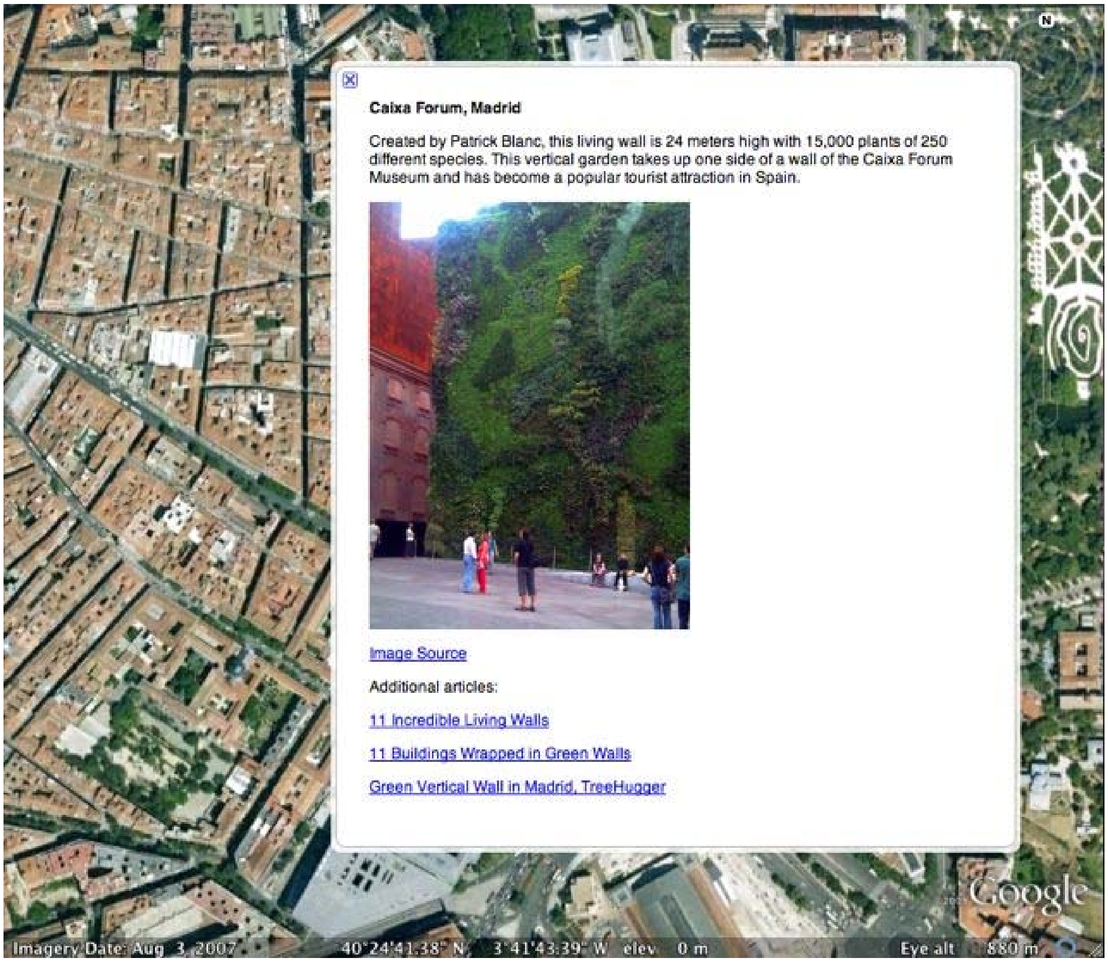

Figure 4-27: Ciaxa Forum Museum, Madrid, Spain (Google Earth Snapshot, April 2010).

Created by Patrick Blanc, this living wall is 24 meters high with 15,000 plants of 250 different species. This vertical garden takes up one side of a wall of the Caixa Forum Museum and has become a popular tourist attraction in Spain.

THAILAND:

Bangkok:

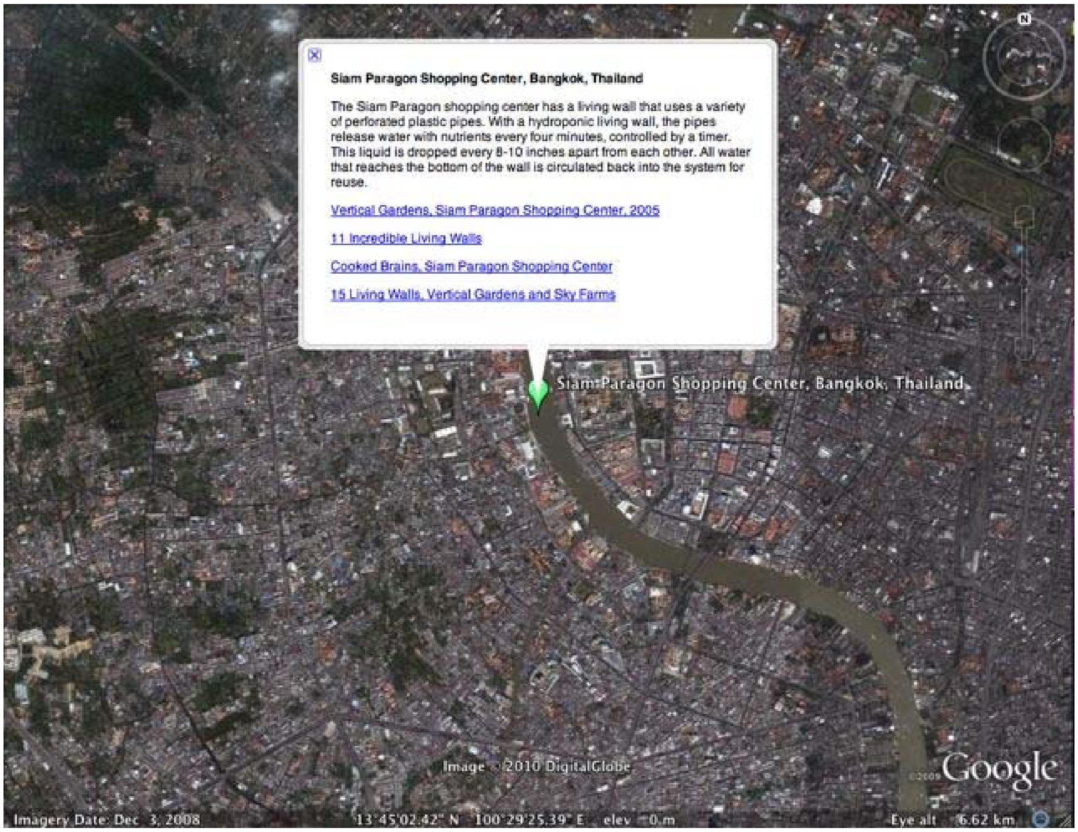

Figure 4-28: Siam Paragon Shopping Center, Bangkok, Thailand

(Google Earth Snapshot, April 2010).

The Siam Paragon shopping center has a living wall that uses a plethora of perforated plastic pipes. A hydroponic living wall, the pipes release water with nutrients every four minutes, controlled by a timer. This liquid is dropped every 8-10 inches apart from each other. All water that reaches the bottom of the wall is circulated back into the system for reuse.

UNITED STATES:

New York:

Oulu Bar & Ecolounge

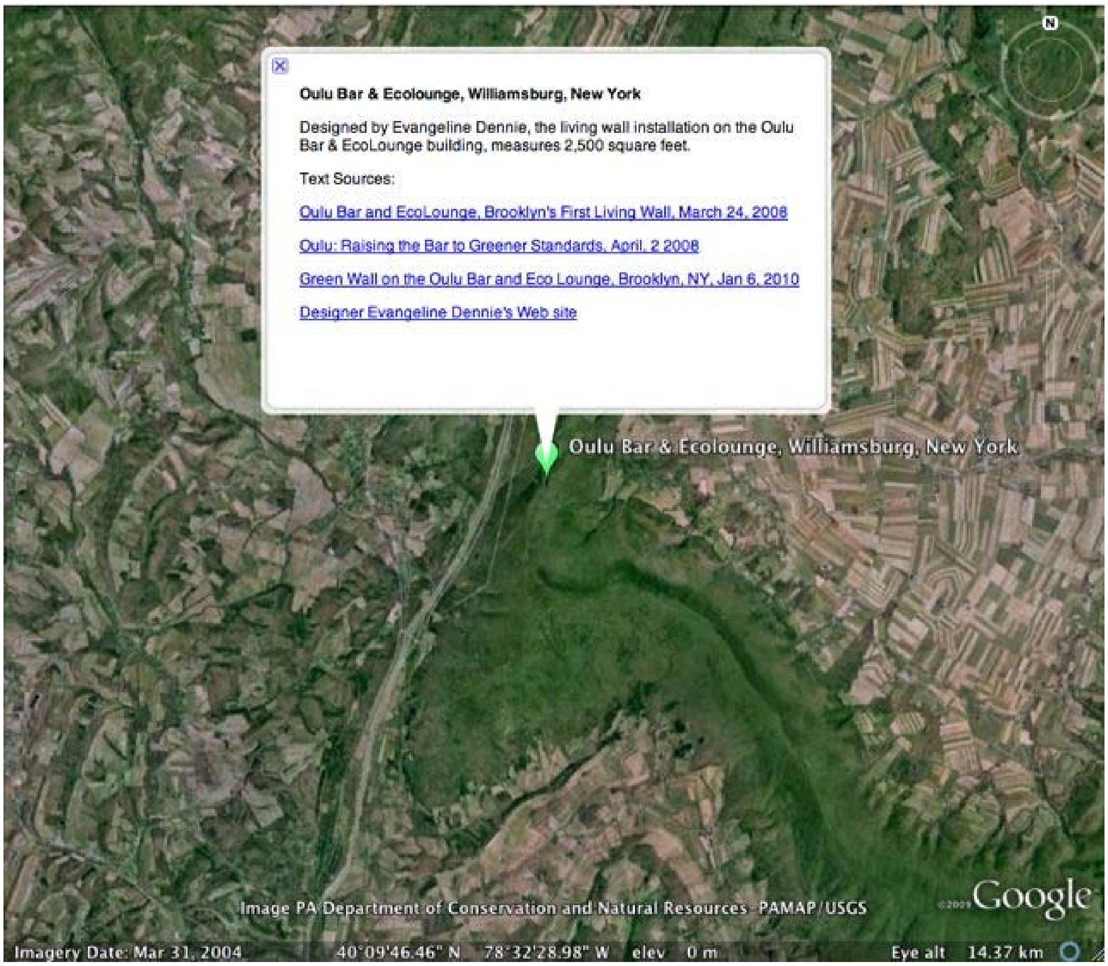

Figure 4-29: Oulu Bar & EcoLounge, New York, USA (Google Earth Snapshot, April 2010).

Oulu Bar & EcoLounge, located on 160 North 4th St in Brooklyn, has a living wall designed by Evangeline Dennie. It measures across the exterior of the 2,500 square foot building.

Pennsylvania:

Drexel University

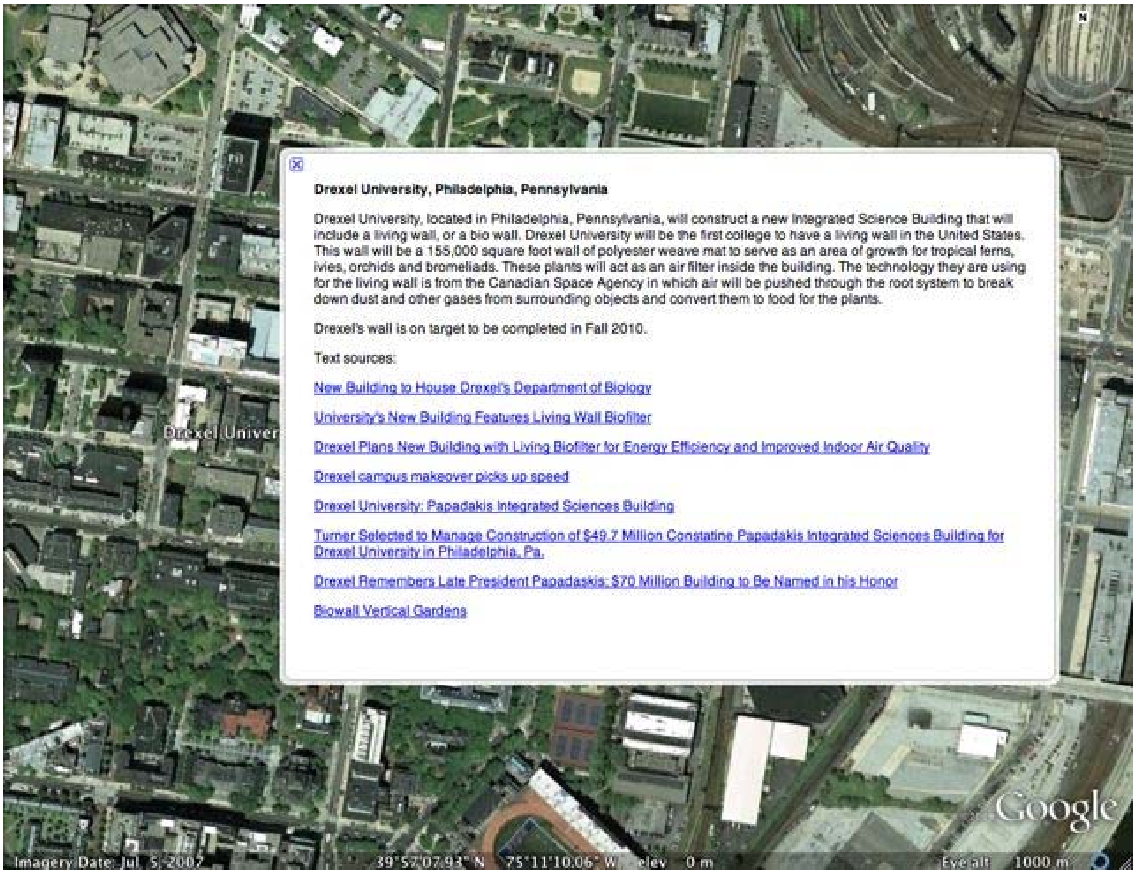

Figure 4-30: Drexel University, Philadelphia, Pennsylvania, USA

(Google Earth Snapshot, April 2010).

Drexel University, located in Philadelphia, Pennsylvania, will construct a new Integrated Science Building that will include a living wall, or a bio wall. Drexel University will be the first college to have a living wall in the United States. This wall will be a 155,000 square foot wall of polyester weave mat to serve as an area of growth for tropical ferns, ivies, orchids and bromeliads. These plants will act as an air filter inside the building. The technology they are using for the living wall is from the Canadian Space Agency in which air will be pushed through the root system to break down dust and other gases from surrounding objects and convert them to food for the plants.

Pittsburgh:

One PNC Plaza

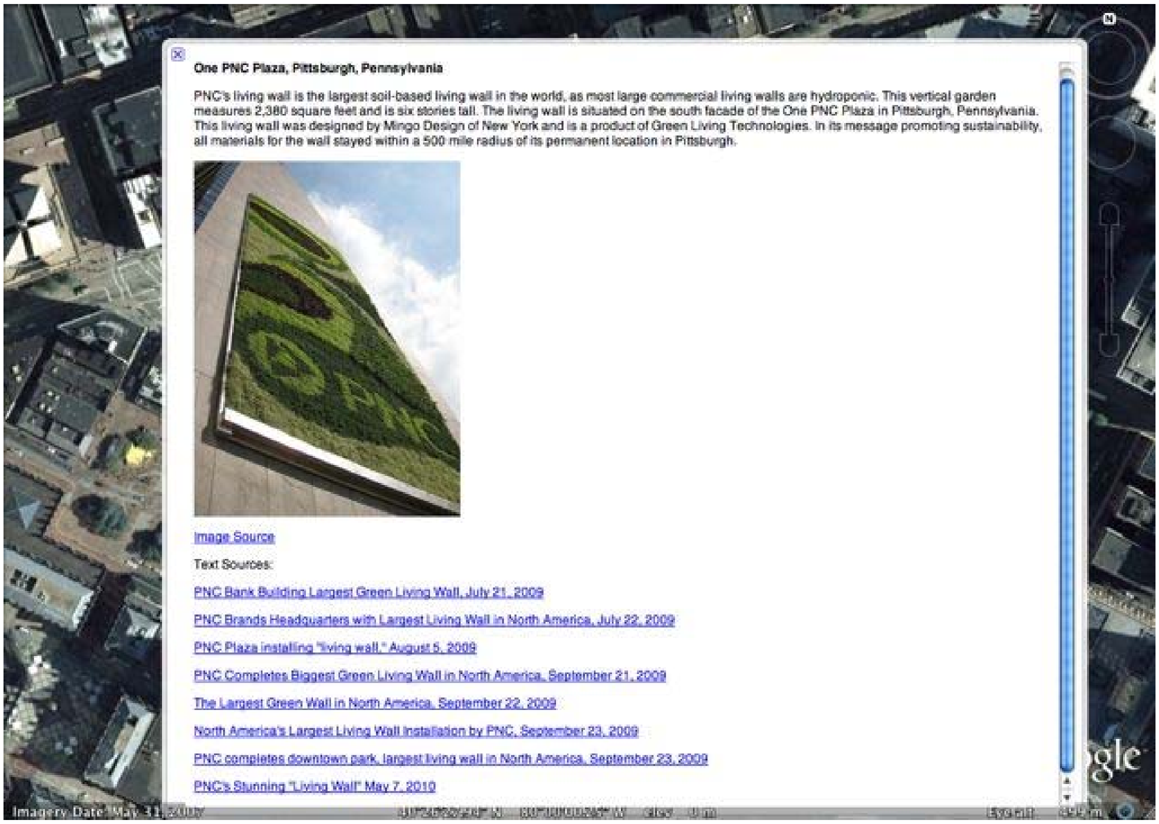

Figure 4-31: One PNC Plaza, Pittsburgh, Pennsylvania, USA (Google Earth Snapshot, April 2010).

PNC's living wall is the largest soil-based living wall in the world, as most large commercial living walls are hydroponic. This vertical garden measures 2,380 square feet and is six stories tall. The living wall is situated on the south façade of the One PNC Plaza in Pittsburgh, Pennsylvania. This living wall was designed by Mingo Design of New York and is a product of Green Living Technologies. In its message promoting sustainability, all materials for the wall stayed within a 500 mile radius of its permanent location in Pittsburgh.

Chapter 5

PENN STATE LANDSCAPES AND LIVING WALLS

The Pennsylvania State University, including all 24 campuses, has over 30 million square feet of land. Many buildings are constructed on these lands. All buildings that are newly built are required to be LEED (Leadership in Energy and Environmental Design) certified. LEED is a certification that measures sustainable building development. There are four different levels: platinum, gold, silver and certified, and Penn State has surpassed all national standards (Greening PSU, 2009).

The Penn State Baseball Stadium, named Medlar Field, is the first certified stadium in the United States. It consists of waterless urinals, gray water recycling , shared parking and convenient access to public transportation (Greening PSU, 2009).

There has been much progress in green construction and developments at Penn State, with flourishing landscapes, green roofs, greenhouse living walls and areas that may serve as prominent foundations for future sustainable, green construction projects.

Gardens and Green Façades at Penn State

There are many locations around Penn State's campus that display various types of greenery. Images of four green areas on campus will be shown: Recreational Hall (Rec Hall), the Hetzel Union Building, the Visual Arts Building the West Electrical Engineering Building.

Figure 5-1: Celebration Garden at Rec Hall (photo taken by A. DiLauro, April 2010).

Figure 5-2: Celebration Garden at Rec Hall (2) (photo taken by A. DiLauro, April 2010).

At Rec Hall, there is the Celebration Garden, a gift from the senior class of 2007.

Figure 5-3: Peace Garden (photo taken by A. DiLauro, April 2010).

Figure 5-4: Flowers at the Peace Garden (photo taken by A. DiLauro, April 2010).

Near the Hetzel Union Building is the Peace Garden, a gift from the senior class of 1997.

Figure 5-5: Tree at Visual Arts Building (photo taken by A. DiLauro, April 2010).

At the Visual Arts building exists a tree that is up against a brick wall. The closeness of the tree to the building promotes a fusion of the build and natural environments.

Figure 5-6: Green façade at the West Electrical Engineering Building (photo taken by A. DiLauro, April 2010).

Figure 5-7: Plants climbing up the façade (photo taken by A. DiLauro, April 2010).

Near the West Electrical Engineering Building is an area to sit where there are plants that climb up the surrounding exterior façades. These “climbers,” as we can call the plants, really depict a living wall. Though this may be more on the lines of façade greening, it is giving way to the idea of living walls.

Penn State Greenhouse Living Walls

Penn State is one of the leaders in Green Roof technology, with four green roofs already on the Penn State University Park's campus. And living walls are similar to green roofs and they are also being researched on Penn State's campus. Some of these living walls can be seen in some of Penn State's greenhouses.

Figure 5-8: Penn State greenhouses (photo taken by A. DiLauro, April 2010).

Inside the greenhouse consists of a variety of various types of living walls. The following images display a gabion-designed living wall, and two hydroponic living walls:

Figure 5-9: Gabions in greenhouse (photo taken by A. DiLauro, January 2010).

Figure 5-10: Gabions - Close up (photo taken by A. DiLauro, January 2010).

The gabions consist of concrete blocks. In between this substrate is where vegetation grows.

Figure 5-11: Hydroponic living wall with orchids (photo taken by A. DiLauro, January 2010).

Figure 5-12: Hydroponic living wall with orchids (2) (photo taken by A. DiLauro, January 2010).

The hydroponic living wall with orchids has a polyester mat. Slits are cut into the mat to leave room for the orchids to grow. The roots grow into the polyester and water is cycled through an irrigation system.

Figure 5-13: Hydroponic living wall (photo taken by A. DiLauro, Janaury 2010).

Figure 5-14: Hydroponic living wall (2) (photo taken by A. DiLauro, January 2010).

The hydroponic living wall with tubing is a biofilter that can be used to filter greywater and blackwater.

Possibility of Implementing a Living Wall on Penn State's Campus

One area where students tend to congregate and pass through frequently is the Hetzel Union Building (HUB) on campus. The facility is used to host events, club meetings, and is also used as a place to eat meals or study.

Figure 5-15: Hetzel Union Building (HUB) (photo taken by A. DiLauro, April 2010).

On the side of the building is an area where students can sit under a trestle and either study or work. The sitting area is up against the windows that are attached to one of the restaurants inside the HUB. This restaurant overlooks the benches and a bare, brick wall.

Figure 5-16: Outside the HUB, sitting area (photo taken by A. DiLauro, April 2010).

Figure 5-17: Windows of restaurant, Outside of HUB (photo taken by A. DiLauro, April 2010).

Figure 5-18: Brick wall outside of the HUB (photo taken by A. DiLauro, April 2010).

Figure 5-19: Alternate view of brick wall (photo taken by A. DiLauro, April 2010).

An idea posed by Derek Kalp, a Landscape Designer at Penn State, is to create an outdoor living wall on the brick wall. One method is to use gabions, as mentioned in Chapter 1, to prevent erosion. Gabions, in this instance, can be used to create a greener area as well as providing an additional place to sit. These gabions can be placed along the bottom, up and across the wall.

Many questions arise as Penn State designs its living wall. Where else has it been done before? Was it successful? Who is going to maintain it? Will students get involved? How much is it going to cost? How often will it be watered? Is it going to be indoor or outdoor? What plants are we going to use? The list of questions goes on with the answers necessary before construction can begin.

CONCLUSION

Although this thesis explores a case study of an indoor living herb wall and compiles a geographic database of existing living walls across the globe, further research will continue to be done to spread awareness about living walls. Videos will be recorded and uploaded onto YouTube that will feature the interviews with Penn State administrative employees and students on living walls. The interviewees will be asked what they believe to be the benefits of these systems and to share their own opinions on having a living wall implemented on Penn State's campus. Documenting various living walls around the globe through Google Earth was one way to spread awareness. In order to have a bigger impact, multiple technological media need to be applied to continue the dissemination of this green construction.

Ultimately, as there is evidence of human-imposed climate change, there is an urgency felt by many to incorporate green technologies that allow for more sustainable-living. The environmental and social benefits that are derived from green roofs and living walls will improve the health and moods of individuals, increase productivity at the workplace, provide a means of food production and benefit the economy through reducing the heat island effect and greenhouse gas emissions. Any cost or maintenance needed to maintain these walls are balanced out when considering the many benefits of these systems. In time, as green roofs and living walls increase in popularity and acknowledged necessity with help from spreading awareness through the Internet, an increase in these technologies will help combat some of the environmental issues we face today and will continue to face in the future.

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Alyce DiLauro

Academic Vitae

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EDUCATION

The Pennsylvania State University, University Park Campus, State College, PA May 2010

Schreyer Honors College (and Cooper Honors Program at Penn State Brandywine)
Bachelors of Arts in Advertising/Public Relations, option in Public Relations
Minor in Civic and Community Engagement
Minor in Environmental Inquiry

Honors in Science, Technology, and Society

HONORS THESIS Spring 2010

Living Walls: Varieties, Benefits and Global Distribution
Thesis Supervisor and Honors Adviser: Dr. Laura Guertin, Associate Professor of Earth Sciences
Thesis Reader: Dr. Andrew Lau, Associate Professor of Engineering Design

WORK EXPERIENCE

Scholar Assistant, Schreyer Honors College, Penn State University Park Fall 2009 – Spring 2010

Served as a liaison between staff and students
Coordinated student programming for the Schreyer Honors College

Orientation Leader, Penn State Brandywine, Media, PA Summer 2007

Discussed various Penn State resources with incoming students
Provided tours for students

Lion Ambassadors, Penn State Brandywine September 2006 – Spring 2008

Served as an official campus tour guide to prospective students
Prepped for campus networking events and ushered at graduation ceremonies

INTERNSHIP EXPERIENCE

Events Coordinator, Penn State Solar Decathlon, State College, PA Fall 2008 – Fall 2010

Planned events for the Penn State community and sponsors at Penn State and on the National Mall in Washington D.C. for the Solar Decathlon competition
Created videos for the Penn State Solar Decathlon team using Final Cut Studio
Acted as an Assistant to the Communications Project Manager by writing public relations materials, such as fact sheets, press releases, media alerts, and creating advertisements

GRANTS RECEIVED

Honors Undergraduate Research Grant, Penn State Brandywine, Amount: $600 Fall 2009

AWARDS

Eric A. and Josephine S. Walker Award, Penn State Brandywine — Spring 2008

SCHOLARSHIPS

Davis Award, Davis Program in Ethical Leadership — Spring 2010
Amount: $2,500

Chancellor Award — Fall 2007 – Spring 2008
Amount: $2,750

PRESENTATIONS

DiLauro, A. 2010. *An indoor living wall: How and why a home can have a fresh, local, sustainable supply of herbs.* Presented at the Northeast Regional Honors Conference, Hilton Hotel, Harrisburg, PA. April 10, 2010.

DiLauro, A. Meyers, T. & Guertin, L.A. 2008. *Smithsonian "classic" dinosaur specimens*. Presented at the Sigma Xi (The Scientific Research Society) Research Symposium, Saint Joseph's University, Philadelphia, PA, April 18, 2008. Presented by undergraduate authors A. DiLauro & T. Meyers.

DiLauro, A. Meyers, T. & Guertin, L.A. 2008. *Smithsonian "classic" dinosaur specimens*. Presented at the Penn State Brandywine EURECA! Symposium, April 17, 2008. Presented by undergraduate authors A. DiLauro & T. Meyers.

PUBLICATION

DiLauro, A., Meyers, T., Guertin, L.A. 2010. The value of extending the honors contract beyond one semester: a case study with Smithsonian Dinosaurs. *Honors in Practice*, 6: 109-115. Undergraduate student lead authors.

PRESS RELEASES

Bayer Foundation Sponsors Natural Fusion. February 17, 2009. "Not peer reviewed."

Natural Fusion Local Day of Tours and Bon Voyage Event featuring special guest Ed Begley Jr. August 24, 2009. "Not peer reviewed."

Phase Change Energy Solutions Donates Material to Penn State. August 31, 2009.

Professional Building Systems Constructed Natural Fusion's Frame of Home. (n.d.).

MEDIA ALERT

The Penn State Solar Decathlon Team Presents Ed Begley, Jr. (n.d.).

MEDIA KIT

Media Kit: Natural Fusion Team and Home Facts, Newsletters.

VIDEOS

2009:

Penn State 2009 Solar Decathlon Videos:
Penn State SD2009: Bayer MaterialScience Sponsorship Presentation
Penn State SD2009: Blitz Build I
Penn State SD2009: Blitz Build II
Penn State SD2009: Bloopers
Penn State SD2009: Completes Siding
Penn State SD2009: Jim Explains the Solar Hot Water System
Penn State SD2009: Natural Fusion Assembles Life Well
Penn State SD2009: Natural Fusion's Cabinetry
Penn State SD2009: Natural Fusion's Interior Technologies
Penn State SD2009: Natural Fusion Installs Cylindrical PVs
Penn State SD2009: Natural Fusion Installs South Doors
Penn State SD2009: Natural Fusion Installs Windows
Penn State SD2009: Natural Fusion Team and Model
Penn State SD2009: Natural Fusion Works on the Floor
Penn State SD2009: PBS Builds Frame of House
Penn State SD2009: Solar Electric Discussion
Penn State SD2009: Solar Hot Water System
Penn State SD2009: Solar Producing Material or Appliance?
Penn State SD2009: Sponsors' Testimonials
Penn State SD2009: Thermal Mass System
Penn State SD2009: Virtual Tour
Penn State SD2009: We are Natural Fusion
Penn State SD2009: What is the Solar Decathlon?

Other:
American Indian Housing Initiative, Lame Deer, Montana
Rally in the Rotunda 2009 Promo

2008:

Smithsonian Dinosaur Type Specimens

PROFESSIONAL MEMBERSHIPS

Northeast Regional Honors Council	Spring 2009
Alliance for Women in Media	Fall 2009
Mortar Board Honors Society	Spring 2009 – Spring 2010

A national honors society recognizing college seniors for their exemplary scholarship, leadership and service.

Public Relations Student Society of America	Fall 2008 – Spring 2010
Omicron Delta Kappa, National leadership honors society	Fall 2008 – Spring 2010

EXTRACURRICULAR ACTIVITIES AND SERVICE

Council of Commonwealth Student Governments (CCSG)
Community Service Director & Public Relations Director, Fall 2008 – Spring 2009

- Encouraged the Commonwealth to take part in community service around their local communities and participate in the themed service-based fundraisers during Council weekends
- Facilitated networking discussions between the Commonwealth campuses regarding advertising, marketing and publicizing events and information on each of their campuses
- Communicated with University Park's campus newspaper, the Collegian, through press releases about upcoming Council plans and agendas

Penn State Dance Marathon (THON), the largest student-run philanthropy in the world that raises funds for pediatric cancer, Penn State Brandywine
Overall Chair, Fall 2007- Spring 2008 and Member, Fall 2006-Spring 2007

- Met biweekly to conduct general meetings to prepare communication materials and plan for fundraising events

Presbyterian Disaster Assistance, Gulfport, MS
Volunteer, May 9-15, 2008

- Rebuilt a roof on a home destroyed by Hurricane Katrina
- Fixed other destructed areas of homes in the area

WHYY Membership Drive, Penn State Brandywine, September 15, 2007

- Volunteered to document phone pledges through an online web form

Philabundance, the largest hunger relief organization in the Delaware Valley in Pennsylvania.
Warehouse Volunteer, July 2006

- Sorted donated food items as they arrived at the Philabundance warehouse
- Basic sweeping and cleaning of warehouse floor

INTERNATIONAL EDUCATION

Penn State Brandywine's International Program in Florence, Italy
January 2-12, 2009

Enrolled in CAMS 045H – Classical Mythology (3 credits)
Traveled throughout Florence, Venice and Rome
Visited the Uffizi Art Gallery & Pitti Palace in Florence, St. Mark's Square in Venice and St. Peter's Square in Vatican City and the Coliseum.

LANGUAGE SKILLS

Spanish, basic skills in spoken and written