A Cloud Above

a vertically integrated green infrastructure

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A Cloud Above
a vertically integrated green infrastructure

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This design thesis is dedicated to my parents who have given me invaluable educational opportunities and supports.
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ABSTRACT

Even though Manhattan has a lot of green space, it is not sufficient to reduce the urban heat island effect of so much concrete and metal. This thesis proposes a new way to create more green infrastructure in dense urban areas, by utilizing the stack effect through a chimney structure as an air purifier. Additionally, it proposes the widespread use of facades with heliostats to produce and use solar energy within the structures.

This thesis considers a four-storied parking lot that has two entrances on the south and the north. Its walls are merged with those of the adjacent mid-rise buildings. First, chimneys are offset from the merged walls of the adjacent buildings. These chimneys are used as air purifiers with the stack effect. Second, the exterior walls of the parking lot as ventilated facades purify air. Simultaneously, the proposed facade with heliostats operates and maintains the entire design. Third, cores of the adjacent buildings are vertically extended and used with offset chimneys as the foundation of new green infrastructure. Here new green infrastructure consists of various kinds of dense vegetation. Fourth, the void between the parking lot and new green infrastructure is left as a source of clean energy.
1.1. The Thesis Statement of the Study

This thesis proposes the creation of additional green infrastructure by utilizing chimney structure with the stack effect and implementing facades with Heliotat to address the urban heat island effect in Manhattan.

1.2. Glossary

- **Chimney**: Is to serve a specific role in facilitating ventilation and air purification within the parking facility. Its purpose is to utilize the stack effect, a natural ventilation phenomenon, to help improve air quality and circulation.

- **Concrete Jungle**: Is a metaphorical expression used to describe urban areas dominated by concrete buildings, pavement, and infrastructure, often characterized by a lack of greenery or natural elements. Exemplary city of concrete jungle is Manhattan, Hongkong, etc.

- **Exploded Axonometric**: Is a drawing or illustration technique that depicts a three-dimensional object or architectural structure by visually separating and disassembling its individual components, layers, or elements to showcase their relationship and arrangement.

- **Green Infrastructure**: Green infrastructure refers to the strategically planned network of natural and semi-natural elements, such as parks, green spaces, trees, rain gardens, and wetlands, within an urban area.

- **Section**: In architecture and design, a section refers to a drawing or representation that showcases a vertical cut through a building or structure, revealing its interior spaces, structural elements, and relationships between different levels and components.

- **Stack Effect**: Also known as the chimney effect, is a natural ventilation phenomenon that occurs in buildings. It involves the movement of air due to the difference in temperature and pressure between the interior and exterior of a structure.

- **Urban Heat Island (UHI)**: Refers to the phenomenon where urban areas experience higher temperatures compared to surrounding rural areas due to human activities and the built environment.
2.1. Urbanization of Manhattan

Urbanization refers to the process of urban development in the country, as well as the movement of people from rural areas to urban areas. The United States is one of the most urbanized countries in the world, with about 82% of its population living in urban areas as of 2018. The process of urbanization in the United States has been ongoing since the Industrial Revolution of the 19th century.1

Based on data from the United States Census Bureau, the New York-Newark area maintains its position as the most populous urbanized area in the country, surpassing all other regions, with a population of 18,351,295 residents.2

While urbanization can bring many benefits, such as increased access to services and amenities, economic opportunities, diverse cultural opportunities, it can also create challenges such as overcrowding, traffic congestion, and environmental pollution and loss of nature and green spaces.3

The population of Manhattan has reached a historical high and is expected to continue growing. The population of Manhattan has grown significantly over the past several decades, reflecting the ongoing trend of urbanization in the United States. The most densely populated city in the United States is New York City, specifically the borough of Manhattan.1

According to the United States Census Bureau, Manhattan had a population of 1.4 million people in 1950. This number steadily grew over the subsequent decades, peaking at 19.7 million in 2010. Since then, the population has continued to rise and is projected to reach 20.3 million by 2023. Looking ahead, the New York City metropolitan area is expected to surpass 26 million inhabitants by 2050.2

High population density often leads to the construction of tall buildings. When there is limited space available, building vertically allows for accommodating a larger number of people within a smaller footprint. Tall buildings maximize the use of limited land resources, enabling a higher concentration of population and activities in urban areas. In density populated areas, such as Manhattan, tall buildings help meet the demand for residential, commercial, and office spaces.1

Manhattan is an island with a land area of just over 59 square kilometers. This limited land area, combined with dense population means that space in Manhattan is at a premium. As a result, land use in Manhattan is highly concentrated and optimized for efficient use of space. Especially, building tall structures in Manhattan can enhance a company’s prestige and signify its presence in a global city, driving up the value of the land. Thus skyscrapers have become symbols of architectural prowess, economic success, and urban development in Manhattan2. According to the NYC Department of City Planning, as of 2018, there were over 6,000 skyscrapers in Manhattan, with a total of 455 million square feet of office space.3

The Correlation Between Population Density and Skyscrapers in Manhattan

3. NYC Department of City Planning.
Urbanization in Manhattan has both positive and negative impacts. On the positive side, it brings increased access to various services, amenities, and economic opportunities. The vibrant urban environment offers diverse cultural experiences and fosters innovation.

On the other hand, there are negative consequences as well. The high population density has resulted in overcrowding, housing shortages, and rising prices. The bustling cityscape has contributed to traffic congestion, limited open spaces, and the loss of green areas and natural habitats. Furthermore, as urbanization progresses, the concentration of population, vehicles, and industries has led to an increase in air pollution levels.

Impact of Urbanization in Manhattan

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2.2.1. The Present Conditions

Urban Heat Island (UHI) refers to the phenomenon where urban areas experience higher temperatures compared to their surrounding rural areas. In the context of Manhattan, UHI has significant implications for the borough.

According to NYC.gov, on June 30, 2018, at 6:00 PM, the air temperature recorded at the LaGuardia Airport Weather Station stood at 89°F (F). Concurrently, a block in East Harlem experienced a temperature that was approximately 5°F higher than that recorded at the Weather Station. Similarly, a block in Bed-Stuy exhibited a temperature 2.5°F hotter than the Weather Station. These temperature variations illustrate the urban heat island effect, whereby urban areas like East Harlem and Bed-Stuy tend to have significantly higher temperatures compared to the surrounding areas.1

The UHI effects in Manhattan are primarily caused by the combination of factors such as dense urban infrastructure, limited vegetation, anthropogenic heat sources, energy use, restricted natural ventilation, and low surface reflectivity.

The high population density and intense human activities generate additional heat, and energy consumption for cooling systems contributes to the overall thermal load.2


What is Urban Heat Island (UHI)?

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The UHI effect in Manhattan is primarily caused by the combination of factors such as dense urban infrastructure, limited vegetation, anthropogenic heat sources, energy use, restricted natural ventilation, and low surface reflectivity.

Manhattan’s tall buildings, concrete surfaces, and asphalt roads absorb and retain heat, while the scarcity of green spaces reduces shade and cooling through evapotranspiration.

The high population density and intense human activities generate additional heat, and energy consumption for cooling systems contributes to the overall thermal load.2

2.2.2. Impact of Urban Heat Island

The urban heat island effect has various impacts on the environment in Manhattan.

Temperature rise: The urban heat island effect leads to higher temperatures in Manhattan compared to surrounding areas. Elevated temperatures can result in heat stress, heat-related illnesses, and compromised air quality.

Increased energy consumption: The heat island effect increases the demand for air conditioning, leading to higher energy consumption in buildings. This results in increased electricity demand, fossil fuel consumption, and subsequent greenhouse gas emissions.

Increased air pollution: The heat island can exacerbate air pollution levels. The combination of high temperatures and low wind speeds can trap pollutants in the atmosphere for longer periods, worsening air quality.

Increased water demand: The heat island effect can increase water usage. Higher temperatures and increased evaporation rates lead to greater water consumption by plants and increased soil drying, putting pressure on water resources.

Ecological impacts: The heat island effect can have ecological consequences in urban areas. It can lead to decreased plant diversity, habitat destruction, and changes in wildlife distribution.

Urban Heat Island and Health

The urban heat island effect in Manhattan can have several impacts on human health.

Heat-related illnesses: The elevated temperatures associated with the urban heat island effect can increase the risk of heat-related illnesses, such as heat exhaustion and heatstroke. Prolonged exposure to high temperatures without proper cooling and hydration can lead to dehydration, heat cramps, and even life-threatening conditions.

Respiratory problems: The heat island effect can worsen air quality in urban areas, leading to higher concentrations of pollutants such as particulate matter and ozone. Poor air quality can exacerbate respiratory conditions, such as asthma and allergies, and increase the risk of respiratory infections.

Cardiovascular stress: High temperatures can place additional stress on the cardiovascular system. Heat can increase heart rate, blood pressure, and the risk of cardiovascular events, especially in individuals with pre-existing heart conditions.

Vulnerability of vulnerable populations: Certain groups, including the elderly, children, pregnant women, and individuals with chronic illnesses, are more susceptible to the health impacts of the urban heat island effect. They may have reduced heat tolerance and be at a higher risk of heat-related illnesses and complications.

Mental/health impacts: Extreme heat and discomfort can also impact mental health. Heatwaves and prolonged periods of high temperatures can lead to increased stress, irritability, sleep disturbances, and worsen mental health conditions.

References:


It has been shown through various studies that green spaces effectively mitigate the UHI effect in cities.

Based on a study, urban parks are a major blue-green infrastructure in urban ecosystems, and they are widely regarded as being extremely effective in mitigating the UHI effect caused by extensive urbanization and high temperatures associated with climate change. They exert a general cooling effect and can significantly reduce surrounding land surface temperature. Therefore, research on the adaptation and mitigation of the UHI effect by urban parks has become a key research focus to improve human welfare and urban sustainability.

In addition, according to United States Environmental Protection Agency, green infrastructure, such as green roofs and parks, helps to reduce the UHI effect.

The map shows the temperature deviation from the mean in Manhattan. Areas with high building density and low green space are indicating significantly higher temperatures of 2 to 6 degrees above average. In contrast, Central Park, which is filled with greenery, shows significantly cooler temperatures of -6 to -8 degrees below average.
Over the past six years, New York City has dedicated $410 million in capital funding to green infrastructure, and has allocated an additional budget of $1 billion for the next decade. Furthermore, the city will incur an annual expense of $15 million to maintain and support the green infrastructure projects. This significant investment reflects the city’s acknowledgement of the numerous benefits provided by green infrastructure.1

2.3 Green Infrastructure

2.3.2 Difficulty

Role of Green Infrastructure

The amount of green infrastructure in Manhattan may not be sufficient to fully address the air pollution challenges facing the city. While the city has made significant investments in green infrastructure in recent years, the high population density and limited space in Manhattan can make it challenging to create and maintain large amounts of green space.¹


Image 8. AERIAL VIEW CENTRAL PARK

Image 9. Vacant Lots in Manhattan: an indirect measure of fewer opportunities to expand green infrastructure. A large number of vacant lots in some districts of the outer boroughs, with very little vacant public land in Manhattan.
CHAPTER 3: SUSTAINABILITY
While most of public parks are placed on the ground, there are several public parks which are not located on the ground level. One example is the High Line in New York City. The High Line has become a model example of urban regeneration and sustainable city development, providing a unique and enchanting urban park experience for both New York City residents and visitors. Originally, the High Line was an elevated railway in use from the 1930s to the 1980s. However, in the 1980s, the railway fell into disuse, and its elevated structure was abandoned and left to decay. Subsequently, the structure was reborn as a public park, creating green space within Manhattan.

Now, the High Line offers a range of positive impacts on Manhattan. It promotes biodiversity by providing habitats for various plant and animal species, while also serving as a gathering space for social interaction and community engagement. With its sustainable design approach, the High Line showcases the potential of repurposing existing infrastructure to create accessible and enjoyable public spaces, making it a symbol of urban revitalization and environmental stewardship.

The High Line has been popular among people for a long time. According to TheHighLine.org, the High Line attracts millions of visitors each year and is widely known as one of the most popular tourist attractions.

Little Island is a public park constructed by re-purposing Pier 55, which had been abandoned for a long time in New York. Little Island is designed as a small floating island with structures that appear to hover above the water, creating a new green space within Manhattan. As a result, it helps address the lack of green spaces within Manhattan. Additionally, the park features a variety of plants that absorb carbon dioxide, helping to purify the city’s air. Furthermore, the inclusion of diverse plant species and natural elements in Little Island promotes biodiversity, contributing to the support and improvement of the urban ecosystem.

Little Island serves as a space that combines nature and culture, providing the local community and visitors with opportunities to experience the harmony between nature and culture, and promoting sustainable urban living. It offers a platform for people to engage with artistic performances, cultural events, and the natural environment, fostering creativity, cultural exchange, and a sense of community. Little Island’s design and programming aim to create an inclusive and accessible space that encourages interaction, learning, and appreciation of both nature and the arts, ultimately contributing to the promotion of a sustainable and vibrant urban lifestyle.
The Supertree Grove at Garden by the Bay is a project that was initiated to fulfill Singapore's urban development vision of creating a "Garden City". The Supertree Grove is an artificially created vertical garden designed to maximize green spaces within the city while efficiently utilizing land.

The Supertree Grove incorporates a system for planting and maintaining the vegetation. The plants receive water from collected rainwater, and they are illuminated using solar panels that generate electricity. This system enables the Supertree Grove to operate autonomously and contributes to the sustainable maintenance of the city's green environment.

The Supertree Grove is considered an iconic symbol of Singapore's innovative urban development. It enhances the aesthetic value of the city and preserves the urban ecosystem.

The Supertree Grove has a positive impact on the environment in Singapore. The diverse range of plants that make up the Supertree Grove create green spaces, enhancing plant diversity and supporting the urban ecosystem. They emphasize the importance of plant diversity and conservation, showcasing an exemplary case of harmonizing nature within the city.

3.2. Chimney with the Stack Effect

The chimney structure, which can be found in parking lots, is designed to provide a path for the vehicle emissions and other pollutants to escape to the outside atmosphere. The stack effect is a natural phenomenon that occurs in the chimney structure, driven by the difference in air pressure between the base and top of the chimney structure.

The stack effect relies on the principle that hot air rises. In parking lots, as vehicles operate and emit exhaust gases, the warm air tends to rise due to its lower density. This creates an upward flow of air within the parking structure. As the warm air rises and exits through the chimney, it creates negative pressure within the structure. This negative pressure draws fresh air from the outside through the ventilation openings, facilitating the circulation of air and improving indoor air quality.1


Case Study 4. Cristalleries Planell Civic Center, Spain

The architectural drawings showcase the building’s capacity to naturally regulate and manage airflow. During winter, steps are taken to minimize heat loss resulting from air exchange, remove accumulated internal heat from the wall structure, and introduce fresh air from the atrium, which functions as a natural air recycling system. In summer, the focus shifts towards dissipating heat by facilitating the movement of a substantial air volume while ensuring the intake of strictly natural fresh air through solar chimneys and stack effect-enabled caps.1

Solar energy is well known for its sustainability. It is a sustainable and renewable energy source, relying on the continuous supply of sunlight. Solar power is environmentally friendly, emitting no greenhouse gases or pollutants during operation. It contributes to reducing carbon footprint, combating climate change, and improving air quality. Solar energy systems have low maintenance costs and can provide energy independence, especially in remote areas.

The Heliostat is a highly efficient solar thermal collector system that utilizes double-axis tracking to generate extremely high temperatures with optimal thermal efficiency. Its main purpose is to concentrate and redirect sunlight to a specific location, known as the receiver, to maximize the capture and utilization of solar energy. By reflecting the solar light onto the receiver, a working fluid circulates within it to convert the intensity of the sunlight into thermal energy.

The advantages of the Heliostat field collectors lie in their optical collection of solar energy and their ability to transfer it to a central receiver, thus minimizing heat transport requirements. Additionally, the Heliostat has a high concentration ratio, making them exceptionally efficient in capturing the intensity of solar light and converting it into heat.

3. “One Central Park.” AJN.

The design concept of One Central Park aimed to utilize reflected light to mitigate overshadowing and enhance solar access in the retail atrium, podium spaces, and landscaped terraces. The primary objective was to create a “dappled” natural light effect within the building’s five-story retail atrium, achieved as the reflected light passes through running water and a glass roof above this void.

The heliostat system consists of 40 large motorized mirrors on the roof of the western tower, which track the sun’s movement throughout the day and redirect it to 320 smaller fixed mirrors on the cantilever. This arrangement creates an array of reflections evenly distributed across the ground plane. The resulting reflected light is approximately 50-70% as intense as direct sunlight, providing a unique ambiance and lighting experience.
Density populated cities like Manhattan are facing air pollution issues. In particular, the tightly packed high-rise buildings within limited areas disrupt the airflow, leading to the urban heat island effect. This not only compromises air quality but also has negative impacts on human health, including respiratory illnesses.

One simple yet effective way to mitigate the urban heat island effect is through the use of green spaces. The more green spaces we can secure, the better we can alleviate various atmospheric issues, including the urban heat island effect. However, in densely populated cities where the density has already increased, there is a scarcity of land available to create sufficient green spaces.1

Therefore, this design proposal suggests a new approach to incorporate a significant amount of green spaces. This proposal can be effectively implemented in dense cities like Manhattan.

This proposal considers a four-storeyed parking lot in Chelsea area in Manhattan, NY. The parking lot has two entrances on the south (towards W 34th St) and the north (towards W 35th St). Its walls are merged with those of the adjacent mid-rise buildings, one Hammerstein Ballroom towering at a height of 170 feet and another ten-storyed commercial building.

The Transit Outline illustrates the surrounding transportation environment. The site is strategically located at a transportation hub, with proximity to the Moynihan Train Hall, the FDR entrance, and the 1, 2, 3 subway lines. This convenient proximity enables easy access for a large number of people to reach the site.

Madison Square Garden

January 21
Sunrise

January 21
Sunset

June 21
Sunrise

June 21
Sunset

The Circulation explains the scheme of pedestrian traffic and its movement patterns. Adjacent to the site, notable locations such as Madison Square Garden (MSG), Moynihan Train Hall, and Thirty Hudson Yards contribute to a high expected footfall. Furthermore, the presence of a crosswalk at the southern entrance of the site provides smooth accessibility for pedestrians.

The Sunpath showcases the solar access and shadow conditions of the site. As the site is nestled between mid-rise buildings, achieving ample sunlight requires building heights of 15 floors (at a height of 170 feet) or above. By doing so, the site can benefit from abundant sunlight from the southwest direction, ensuring ample solar access. Even during winter, the site would receive a relatively significant amount of natural light.

The Circle Path explains the scheme of pedestrian traffic and its movement patterns. Adjacent to the site, notable locations such as Madison Square Garden (MSG), Moynihan Train Hall, and Thirty Hudson Yards contribute to a high expected footfall. Furthermore, the presence of a crosswalk at the southern entrance of the site provides smooth accessibility for pedestrians.
The diagram illustrates the process of utilizing the existing structures of the parking lot and its adjacent buildings to construct a new floating park. The existing columns, elevators, and ventilation facilities are vertically extended and reinforced to serve as the structural elements and foundations for the new floating park. Particularly, the ventilation facilities of the parking lot undergo a transformation into advanced chimney structures aimed at addressing the urban heat island effect of Manhattan. The park is then constructed on top of these elements. Additionally, the park’s void/façade is designed with Heliosats, which is a smart solar panel to generate eco-friendly energy.
The Concept Form explains the process of shaping the new park. As it is a park within the city and on top of buildings, the design takes inspiration from the city's grid pattern and the forms of the buildings which are considered as the site. Considering the given natural environment—direction of sunlight, shadowlines, views, etc.—I incorporate multiple floors to the new park and divide the area accordingly. Especially, the FLOW is designed to ensure convenient access and smooth circulation within the park for visitors. Additionally, I added various programs, both urban context and nature context to cater to the visitors’ needs.
The drawing depicts the structural composition and design of the new floating park. It provides a detailed description of the park's design and programs. The park is divided into two main contexts: nature context and urban context. Each context offers a variety of programs that are tailored to different seasons and times.

More detailed visualized information and description will be continue.
4.4. Design Development

4.4.1. The New Park

- MESHED COVER FOR CHIMNEYS
- WOODEN FLYOVER (SKY BRIDGE)
- WOODEN CANOPY
- COLUMNS FOR CANOPY
- CHIMNEY STRUCTURE

The exploded axonometric drawing illustrates the park’s structure, the arrangement of supporting structures (chimneys, elevators, columns), and the assembly of solar energy sources.
4.4. Design Development

4.4.1. The New Park

Walking trail presents a vibrant spring adorned with an abundance of cherry blossoms. This picturesque scene is a delightful attraction, appealing not only to individual visitors but also to families seeking a memorable experience amidst nature’s beauty.

The two overlooks and a viewing spur offer a panoramic Jersey City skyline with Hudson River.

Thicket presents a meandering pathway that gently navigates through a diminutive woodland composed of grasses, shrubs, and trees. This enchanting walkway graciously invites visitors to immerse themselves within the lush surroundings, allowing them to tread upon its charming trails.

The seating steps is a space surrounded by seasonal flowers, providing a pleasant spot for resting, reading a book, or taking a momentary break.
The flyover ascends eleven feet above the original structure, guiding visitors through canopies with autumn trees. Along this elevated path, the visitors will discover a viewing spur that offers a breathtaking panorama of the Jersey City skyline along the Hudson River.

The multi-use field is a versatile space that can be adapted to a variety of user needs. It can accommodate activities such as badminton, yoga, art classes, pop-up stores, and more.

The snow-covered grass meadow is a space where you can experience the ambiance of winter. Walking along the piled-up snow and engaging in snow activities are privileges unique to the winter season.

One of the distinctive features of the winter park is strolling along the meadow walk beneath the canopy and enjoying the scenic views.
The Operation Principles and Processes of Chimney and Heliostat

The following visual material explains how chimney structures and Heliostat are configured and how they work to mitigate the urban heat island effect in Manhattan.

More detailed visualized information and description will be continue.
4.4 Design Development

4.4.2 Chimney and Heliostat

**CHIMNEY WITH STACK EFFECT**

The existing four chimneys in the parking building are offset from the merged walls of the adjacent buildings and then vertically extended up to 346 feet (25 floors) in height. With enhanced durability of the four chimneys, they are capable of drawing in a larger volume of air and effectively filtering out pollutants with stack effect.

As a result, the chimneys facilitate the circulation of hot air that accumulates near the ground, contributing to the alleviation of the urban heat island effect in Manhattan.

**HELIOSTAT, KNOWN AS SMART SOLAR PANEL**

Unlike conventional solar panels, the Heliostates maintain a consistent reflection angle regardless of the angle of incidence. This means they are not affected by shadow cast by surrounding tall or low buildings, and they can reflect sunray uniformly from any direction, enabling consistent production of solar energy.

The Heliostates equipped on the facade of the void space generate solar energy. This solar energy will be utilized to maintain the park and power the operation of the chimneys.
4.4. Design Development

4.4.3. Physical Modeling
Link Between A City and Parks

The importance and influence of Green Spaces have become widely recognized, leading to the construction of multiple floating parks in the air space, the only available open space in the city.

Within Manhattan, there are numerous parking lot buildings, along with site, scattered throughout the city. Similar to the site, those parking lot structures are low-rise buildings, occupying open spaces and squeezed into the urban fabric. According to surveys, there are approximately nine or more parking garages in Midtown. Utilizing these spaces, along with the construction of multiple floating parks, can contribute to mitigating the urban heat island effect and improving air quality. By doing so, the future city can become a sustainable urban environment.
4.4. Design Development

4.5. Imagination and Proposal

New Skyline of Manhattan in 2050