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Optimizing Solar Panel Installation Sites in New York City: An ArcGIS-Based Analysis of High-Energy Residential Buildings for Enhanced Carbon Neutrality and Clean Energy Goals

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Abstract

The New York State Research and Development Authority's (NYSERDA) "City of Yes" plan aims to modernize New York City by achieving carbon neutrality and cleaner energy by 2050. The purpose of this research is to determine the optimal locations for solar panel installation by analyzing energy consumption and solar output of potential using ArcGIS. The buildings that met the criteria were assessed for the solar capacity relative to their energy use. The study identified the 7 buildings throughout NYC with the highest solar potential: 120-130 Gale Place, 306 Beach 56th St, 875 Pennsylvania Ave, 845 Schenck Ave, 81-26 150th St, 5901 Palisade Ave, and 625 Atlantic Ave. Each of these buildings have the capacity to be entirely powered by solar with the added potential to produce surplus electricity. The study recommends these 7 buildings be prioritized for solar panel installation, as they maximize the excess energy entering the grid and reduce reliance on fossil fuels. Future research should expand to include both residential and commercial NYC buildings using newly acquired data to support these findings.

Introduction

In December of 2023, the City Council passed The New York State Research and Development Authority's (NYSERDA) "City of Yes for Carbon Neutrality" plan, to modernize the NYC buildings to create a cleaner, cost-effective, more efficient city (Adams, 2023). The increased effects of climate change make a response to CO2 emissions necessary, with many urban areas, including New York City, making it their goal to reduce the emission of greenhouse gasses. NYSERDA's carbon neutrality plan will rework the energy grid, develop greener buildings, and encourage the shift away from diesel vehicles (Adams, 2023).

Currently, the production of energy in the United States is primarily reliant on fossil fuels. Power plants are a major contributor to the energy supply in New York City and Long Island, accounting for approximately 85 percent of all energy production (Dickstein, 2024). These power plants release harmful gasses such as SO2, CO2, and Hg into the atmosphere (EPA, 2024). Fossil fuels power all aspects of daily life, including heating, traveling, and manufacturing. With new advancements in solar technologies, implementing solar panels has become a viable alternative to nonrenewable energy sources (Hall, 2022). The identification of the optimal location to begin the installation of solar panels is an essential component of the implementation of green infrastructure in any city.

Solar panels offer an eco-friendly alternative to fossil fuels. However, the mass implementation of solar panels does have drawbacks. Currently, solar panels are optimized to improve the effectiveness of energy production but pay little attention to the environmental damages caused by the dismantling process (Xu, 2018). Balancing environmentally sustainable panels with a cost-effective model is essential in ensuring the longevity of the “City of Yes” plan. Unlike fossil fuels, solar panels are intended to be used for years after their installation, and it is therefore essential that the quality of the panels ensure long-term energy production.

NYSERDA’s “City of Yes” plan is taking steps to make New York City a cleaner, smarter city. According to the World Bank Group, a smart city is built on four thematic principles: Green, Development, Visionary, and Smart (World Bank Group, 2023). Each of these four factors are emphasized in the “City of Yes” plan in the following ways:

1. Green: will reduce greenhouse gas emissions by converting to cleaner and more sustainable energy.
2. Development: will utilize the newest technology in solar panels, optimizing the energy production.
3. Visionary: will transform New York City into a more effective urban space by encompassing all its critical infrastructures.
4. Smart: will use data driven analysis to create a smarter and more efficient city.

This research integrates these principals by analyzing publicly available NYC data to identify the optimal locations for solar panel installation to reduce carbon emissions in the city. When determining the buildings to be prioritized in NYC, it is important to recognize how solar energy is financed. For buildings that consume less electricity than what is produced by their solar panels during a billing cycle, the excess electricity enters the grid and is used to power other buildings. The building receives a credit for the surplus electricity produced, which may be applied towards future electricity bills (NYSERDA, 2024). The result of this policy is that the solar panels that produce the maximum excess electricity are the most cost-effective panels.

Problem and Hypothesis

Over the past 30 years, the mean annual temperature in NYC has increased by 0.3°F per decade (Janowiak, 2018). Additionally from 2012-2022 the amount of CO2 emissions in NYC has increased by nearly 402k tons, and with the ongoing dependence on fossil fuels, this number continues to rise (NYC Mayor's Office of Climate and Environmental Justice, 2024). Clean energy consumption is essential in reducing the emission of greenhouse gasses, a primary factor of rising temperatures. NYSERDA's "City of Yes" plan, which aims to achieve carbon neutrality in NYC by 2050, requires the effective placement of solar panels to achieve maximum reduction in fossil fuels consumption. NYC locations with the highest potential solar output relative to their energy usage must be prioritized to create a cost effective model. This research uses ArcGIS to map buildings with the highest potential solar energy output relative to energy consumption, utilizing the collected data to determine the residential buildings to be prioritized for the implementation of solar panels.

Materials and Methods

Data Collection

The first dataset, the NYC Energy & Water Performance Map, was examined to determine energy consumption for various buildings/complexes throughout NYC (DOB, 2023). Created by NYU in 2011, this map is updated annually with the data collected from Local Law 84, which requires buildings to provide information regarding energy and water usage. This dataset is verified directly by the Mayor's Office of Climate & Environmental Justice and is available for public use on NYC Open Data. All data collected from NYC Open Data is fair use.

The second dataset, the NY Solar Map, was used to determine the potential solar output for buildings deemed high energy from the NYC

Energy & Water Performance Map. Produced by CARSI Lab in the City University of New York in 2015, this map was designed with the intention of providing support for New York's solar industry. The potential solar production was obtained using light detection and ranging, which was then converted into a digital surface model. Factors such as shading, roof slope, and cost were assigned to each model and included as part of the map (Case, 2015). NY Solar Map falls under fair use for personal, or non-commercial educational or research purposes.

The limited number of team members made mapping all 26,059 available buildings in NYC impractical. Restrictive filters were applied using Excel to reduce this number significantly. The first filter, buildings that required more than 350 kBTU/ft² of energy to operate, generated a result of 504 buildings— a quantity still too large to address. The second filter, residential buildings, produced a more manageable outcome of 43 residential buildings that exceeded the energy threshold of 350 kBTU/ft².

A key consideration while conducting this research was standardizing the units of comparison. To create a proportion of potential output to current consumption, both values were required to be in the same units. This involved converting the data from the NYC Energy and Water Performance Map from kBTU/ft² to kW DC. One kWH of electricity is equivalent to 3.412 kBTU/ft² (Calculator Academy, 2023). For each building/complex selected for this research, the potential energy production was adjusted using this factor.

Data Application

A key element of solar energy production is the exposure to sunlight. The data on individual buildings' exposure to sunlight was gathered from NY Solar Map, but the data did not address the amount of energy used by the buildings. This research utilizes ArcGIS, a geographic data and spatial analysis tool, to establish which buildings most benefit from the installation of solar panels based on the locations with the highest relative energy production. This parameter is determined using relative solar output, calculated by dividing the hypothetical energy output by energy consumption.

This research instituted a two-step process in determining the optimal buildings for solar panel use.

- Step 1: Residential city blocks with the highest energy consumption were identified and mapped onto a basemap of NYC.
- Step 2: The potential solar energy output of these buildings was determined and overlaid on the same map.

This produced a visual representation of the relative solar output of the 43 selected buildings.

Currently available data for NYC’s potential solar energy production is explicitly based on the quantity of electricity that can be generated. For effective solar panel implementation, this data must be analyzed in conjunction with the building’s energy consumption. Identifying the intersection of high consumption and high potential production will produce the most immediate impact on the use of fossil fuels. The research identified buildings with the highest energy consumption using the NYC Water and Energy Performance Map, which indicates buildings/complexes with the greatest energy use and, consequently, the highest reliance on fossil fuels. This data was cross-referenced with the NYC Solar Map, which provides the potential solar energy output per building. By summing the solar capacity of every building in the selected complex, potential solar energy output relative to current consumption rates could be accurately assessed.

The focus on residential properties redefined the scale of this study, allowing for the development of a solution that could be more readily applied. The targeted approach enabled a more practical analysis of the residential buildings that would benefit most from solar panel installation, based on both energy production potential and consumption rates.

Results

ArcGIS was utilized to identify buildings with the maximum relative solar output to be prioritized for solar panel installation. This software also provided data to create a plan for long-term implementation. The urgency for renewable energy has resulted in an increase in the number of buildings required to install solar panels to help reduce the city’s carbon footprint. However, not all buildings can effectively support solar panels. Factors such as continual shading from other buildings, which prevent sunlight from reaching the panels, or unfavorable wind patterns, which create dust buildup at a faster rate, can reduce solar efficiency. In non-self-sufficient buildings, the remaining energy requirement is primarily met with fossil fuels. Therefore, it is crucial to prioritize buildings that can effectively utilize solar panels, as any surplus energy produced by a building goes into the grid and amasses credit.

The solar production and energy consumption data were used to create geospatial maps to identify the optimal locations for solar panel installation in NYC. The potential solar production relative to consumption ($\sum$Potential solar output / $\sum$Energy consumption) for the selected buildings ranged from 0.06813 to 5.504. Of these, only four buildings had a relative solar output more than twice its energy consumption:

- 5901 Palisade Avenue, Bronx: Proportion of 2.562
- 625 Atlantic Avenue, Brooklyn: Proportion of 3.035
- 845 Schenck Avenue, Brooklyn: Proportion of 4.306
- 81-26 150th Street, Queens: Proportion of 5.504 (Fig. 2)

These four buildings produce the greatest surplus of electricity, maximizing energy contributions back to the grid, which translates into greater credits for the buildings. The significant overproduction of electricity will substantially reduce future energy bills, ultimately being more cost effective than fossil fuels. The excess energy will also support neighboring buildings that currently rely on fossil fuels.

3 other buildings were identified as self-sufficient:

- 120-130 Gale Place: Proportion of 1.239
- 875 Pennsylvania Avenue: Proportion of 1.55
- 306 Beach 56th Street: Proportion of 1.825 (Fig. 3)

The energy production at these 3 locations is lower than the top 4. However, their ability to be entirely self-sufficient qualifies them to be included in the first phase of solar panel installation. Buildings with high energy consumption that have the ability to support themselves with solar panels achieve a significant reduction in fossil fuel usage.

In Figure 3, the darker shade of blue represents buildings with greater relative solar capacity and the lighter shades represent buildings that are less beneficial.

Following the installation of solar panels at the 7 initial buildings, the criteria for installation must shift to buildings with solar capacity greater than half of their energy consumption. 7 additional buildings fall into this category, with relative solar capacity between 0.5 and 1:

- 255 Havemeyer Street: Proportion of .5265
- 671 Lincoln Avenue: Proportion of .7407
- 820 Boynton Avenue: Proportion of .7974
- 230 East 123rd Street: Proportion of .7974
- 157-50 17th Avenue: Proportion of .8281
- 2086 2nd Avenue: Proportion of .8489
- 3178 Nostrand Avenue: Proportion of .9154 (Fig. 4)

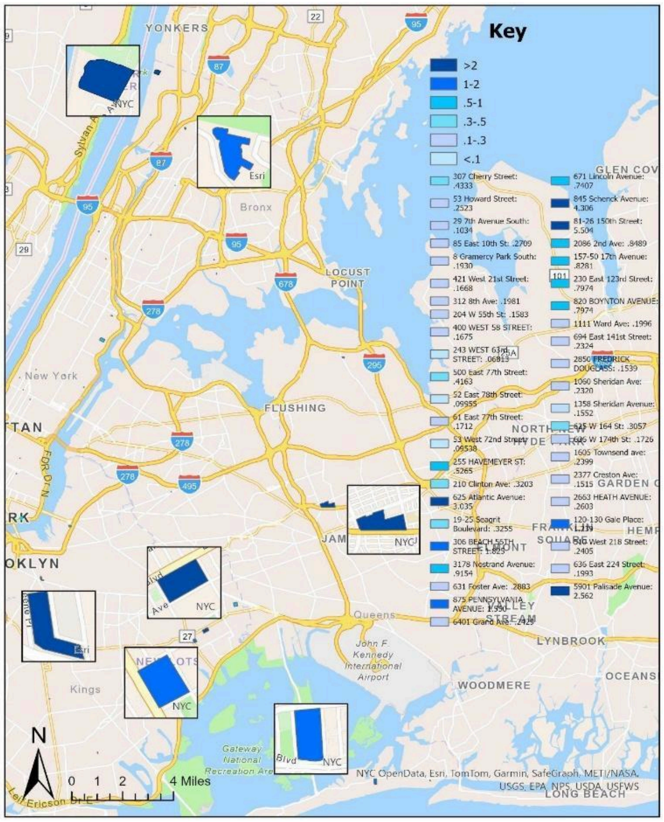

FIGURE 1. City-wide map with labels

Solar panel installations in the 14 residential buildings identified in the study will have the maximum impact on the reduction of CO2 emissions caused by the use of fossil fuels. Once these 14 buildings are fitted with solar panels, focus can shift to buildings with lower relative production values. There are a number of additional buildings in NYC with a relative output greater than .3 that have the ability to contribute to achieving carbon neutrality by 2050 (Fig. 5). This phased approach ensures the most effective use of solar technology and maximizes energy efficiency across the city.

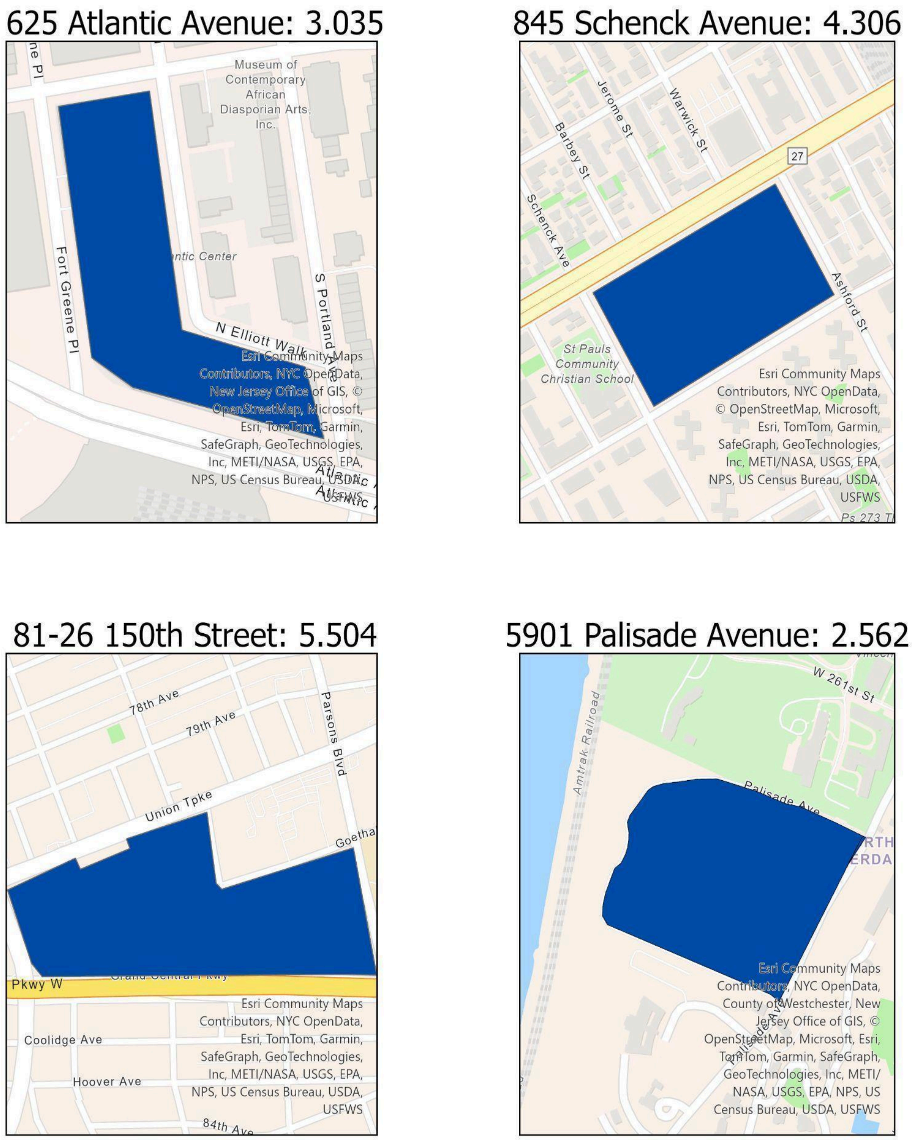

FIGURE 2. Highest relative solar product buildings

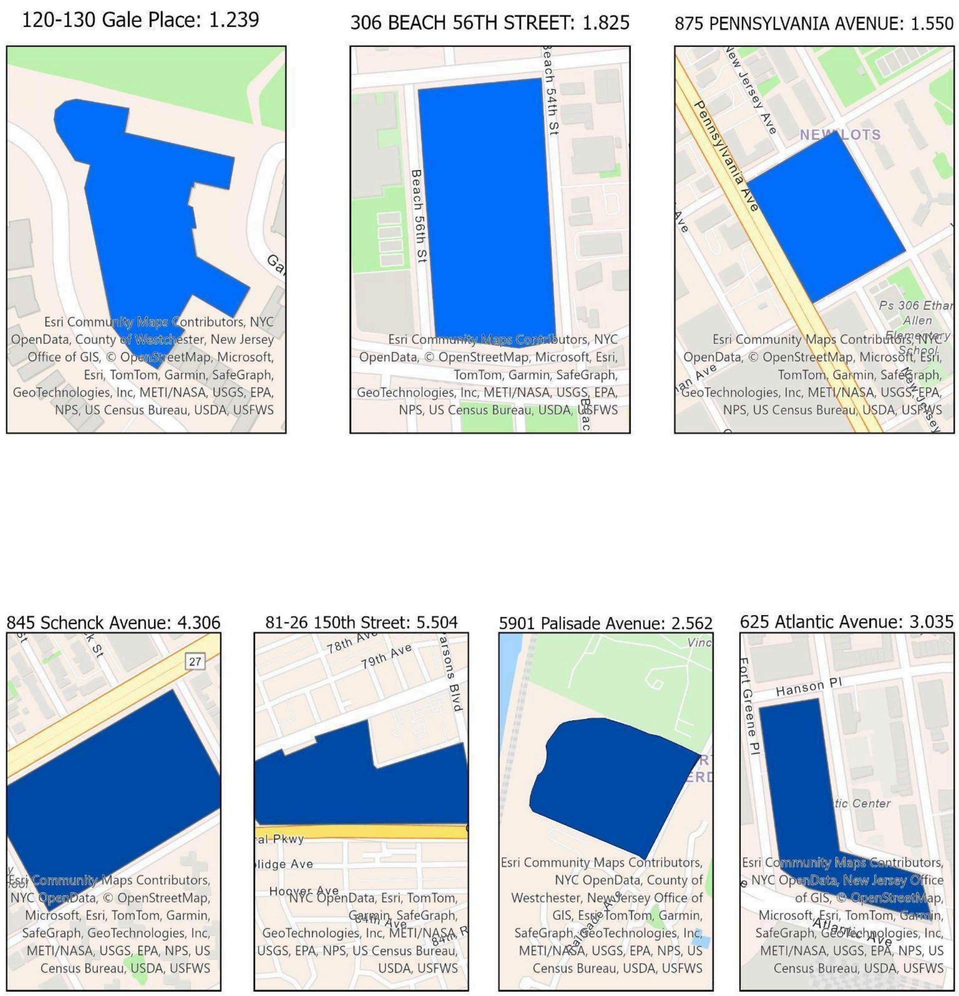

FIGURE 3. Self-sustaining solar product buildings

FIGURE 4. Buildings between 0.5 and 1 relative solar capacity

Location	Relative Output
81-26 150th Street	5.504
845 Schenck Avenue	4.306
625 Atlantic Avenue	3.035
5901 Palisade Avenue	2.562
306 Beach 56TH Street	1.825
875 Pennsylvania Avenue	1.55
120-130 Gale Place	1.239

3178 Nostrand Avenue	0.9154
2086 2nd Ave	0.8489
157-50 17th Avenue	0.8281
230 East 123rd Street	0.7974
820 Boynton Avenue	0.7974
671 Lincoln Avenue	0.7407
255 Havemeyer Street	0.5265
307 Cherry Street	0.4333
500 East 77th Street	0.4163
19-25 Seagirt Boulevard	0.3255
210 Clinton Ave	0.3203
625 W 164 Street	0.3057
631 Foster Ave	0.2883
85 East 10th Street	0.2709
2663 Heath Avenue	0.2603
53 Howard Street	0.2523
6401 Grand Ave	0.2429
510 West 218 Street	0.2405
1605 Townsend ave	0.2399
694 East 141st Street	0.2324
1060 Sheridan Ave	0.232
1111 Ward Ave	0.1996
636 East 224 Street	0.1993
312 8th Ave	0.1981

8 Gramercy Park South	0.193
636 W 174th Street	0.1726
61 East 77th Street	0.1712
400 West 58 Street	0.1675
421 West 21st Street	0.1668
1358 Sheridan Avenue	0.1552
2850 Frederick Douglass	0.1539
2377 Creston Ave	0.1515
29 7th Avenue South	0.1034
52 East 78th Street	0.09955
53 West 72nd Street	0.09538
243 West 63rd Street	0.06813

TABLE 1. Location and relative solar output

Discussion

NYSERDA's carbon neutrality plan may be viewed as a costly endeavor due to the high price of solar panel installation and energy storage. However, not only will this change be beneficial to the environment, but it will also ultimately prove to be cost effective. The payback period for the installation costs will depend on factors such as energy consumption, local incentives, and system efficiency, and it is expected that the initial investment will be recovered within approximately 7 to 10 years for the selected buildings (Case, 2015). The system of accruing credits towards future bills will maintain a relatively constant energy cost, eventually leading to a cheaper alternative to the rising price of fossil fuels. While the cost of solar panel installation is not the primary focus of this study, it is still necessary to consider when addressing a project of this scale.

A 2006 study published by The Center for Sustainable Energy at Bronx Community College highlighted the future of solar development. The study claimed that solar electric systems have the greatest potential for renewable energy in New York City, with potential solar energy production in the city each year being double the city's energy needs. The study stated that the key challenge was effectively capturing and utilizing this abundant sunlight. It also concluded that solar electric systems on rooftops and buildings could provide 18% of the city's electricity by 2022 (Rickerson, 2006). However, according to the U.S. Energy Information Association, solar energy accounted for only 4% of New York's total energy production in 2022 (EIA, 2023). This discrepancy illustrates that past expectations for solar energy development have not been met in recent years. Fossil fuels have been the dominant source of energy until recent discussions on clean energy shifted the focus to what should be used, rather than what can be used. Renewable energy sources, such as solar energy, are now being actively implemented to reduce costs and carbon emissions as a result of NYSERDA's goal for NYC to reach carbon neutrality by 2050. As the emphasis on renewable energy grows, New York City has become better positioned to leverage its abundance of sunlight.

The first step in increasing dependence on solar usage is determining which high-energy consumption buildings have the greatest potential and implementing solar panels at these locations. This research effectively captures which areas produce the most solar energy relative to the energy consumed, thus determining which buildings would benefit most from solar panels. A key strength of this research is its ability to effectively convey solar potential data with the use of GIS programs. ArcGIS was utilized to visualize the data, allowing for the clear representation of buildings based on their solar energy potential. The maps are created using a blue gradient with the darker shades corresponding to higher solar energy potential.

Despite the strengths of this research, there are notable limitations. The data used for determining potential solar production is an older dataset from 2015. While the position of sunlight in the city has not shifted, it is important to recognize that the urban landscape has changed significantly. Due to the age of the dataset, buildings that were constructed or demolished in the past 9 years are not referenced, and therefore the data does not fully represent the present day city. Additionally, data collection is more accurate now than 9 years ago. Newly collected data may have a different outlook, potentially affecting the validity of the findings.

Another limitation of the research is the scope of the study. As a single researcher, exploring every high-energy consumption building in the city was not viable, and thus I was forced to limit my research to only residential buildings. While the initial goal was to assess all high-energy consumption buildings, the practical limits of time and resources required a narrower scale.

The insights gained from this study, in conjunction with updated data and a broader scope, will enhance the effectiveness of solar panel deployment, contributing to NYSERDA's Carbon Neutrality Plan. The ongoing transition to renewable energy sources in New York City will benefit from continued refinement of solar energy strategies and the incorporation of current data.

Conclusions and Future Work

The primary finding of this study is the identification of 7 residential buildings in NYC to be prioritized for solar panel installation. These are buildings with the highest potential solar production compared to the amount of energy they consume. It is important to examine solar production relative to consumption, as buildings get credit for excess energy sent into the grid. The study has identified 7 additional buildings with a relative solar capacity that is not self-sufficient, but high enough to impact the reduction of fossil fuel usage.

The results of this study can be tested by implementing solar panels in the 14 recommended buildings and collecting data on the production and consumption of solar energy. Analyzing the collected data will reveal if the solar output matches the predicted performance. Solar panel installation in these 14 buildings should be implemented as phase one of the "City of Yes" plan and monitored following installation. Many factors may affect the findings presented in this study, and it is important to independently verify that the implications are accurate.

Future research regarding optimal location for solar panel installation should include a review of all buildings— residential and commercial— to ensure that the trends found for residential buildings are applicable to commercial buildings as well. Such a study will ensure that the buildings which contribute to greenhouse gasses are remodeled. A research of this scale is currently outside my capability, as I do not have the resources to map all buildings in NYC.

Given time and resources, my study would have included visiting each area and taking measurements of the potential solar output using a digital solar power meter. This new data would more accurately reflect the current numerical values, increasing the validity of the research. While the data used in this research was verified at the time of collection, it is important to confirm that the data is still accurate, as it was compiled 9 years ago. There is no reason to assume that the data will be vastly different now, but there is no doubt that newer technology can better determine the potential solar output.

References

Adams, E. (2023, December 6). Mayor Adams, speaker Adams celebrate passage of zoning changes that fights climate change. The official website of the City of New York. https://www.nyc.gov/office-of-the-mayor/news/935-23/mayor-adams-speaker-adams-celebrate-passage-zoning-changes-fights-climate-change-by#:~:text=%E2%80%9CCity%20of%20Yes%20for%20Carbon%20Neutrality%E2%80%9D%20is%20the%20first%20component,zoning%20rules%20to%20hinder%20the

Adams, E. (2023b, December 6). City of yes. City of Yes for Carbon Neutrality- DCP. https://www.nyc.gov/site/planning/plans/city-of-yes/city-of-yes-carbon-neutrality.page

Calculator Academy Team. (2023, September 6). Kwh to KBTU Calculator. Calculator Academy. https://calculator.academy/kwh-to-kbtu-calculator/#:~:text=Kbtu%20stands%20for%20kilo%20British,approximately%20equal%20to%203.412%20Kbtu.

City Planning Commission. (2016, March 22). 74-31: Zoning resolution. 74-31 | Zoning Resolution. https://zr.planning.nyc.gov/article-vii/chapter-4/74-31

DATA: Case, T. (2015). Ny Solar Map. NY Solar Map. https://nysolarmap.com

Department of Buildings, (DOB). (2023, August 11). NYC Building Energy and Water Data Disclosure for Local Law 84 (2023-present): NYC Open Data. NYC Building Energy and Water Data Disclosure for Local Law 84 (2023-Present) | NYC Open Data. https://data.cityofnewyork.us/Environment/NYC-Building-Energy-and-Water-Data-Disclosure-for-/5zyy-y8am/about_data

Dickstein, S. (2024, July 24). Bad Data and miscalculations behind NY's lagging green energy goals. Massena Electric. https://www.massenaelectric.com/bad-data-and-miscalculations-behind-ny-s-lagging-green-energy-goals#:~:text=This%20week%2C%20roughly%2085%20percent,is%20from%20gas%20and%20oil.

EIA. (2023, December 21). U.S. Energy Information Administration - EIA - independent statistics and analysis. https://www.eia.gov/state/analysis.php?sid=NY

EPA. (2024, August 20). Power Plants and Neighboring Communities. https://www.epa.gov/power-sector/power-plants-and-neighboring-communities#:~:text=Burning%20fossil%20fuels%20at%20power

Hall, C. (2022, December 13). Systems. NYC Mayor's Office of Climate and Environmental Justice. https://climate.cityofnewyork.us/subtopics/systems/#:~:text=NYC%20relies%20on%2024%20in,are%20over%2050%20years%20old

NYC Mayor's Office of Climate and Environmental Justice. (2024, July 17). Inventory of New York City Greenhouse Gas Emissions. NYC Mayor's Office of Climate and Environmental Justice. https://climate.cityofnewyork.us/initiatives/nyc-greenhouse-gas-inventories/

Janowiak, M. (2018). New York City. New York City | Climate Change Response Framework. https://forestadaptation.org/assess/ecosystem-vulnerability/urban/new-york-city#:~:text=Key%20climate%20change%20impacts%20to,total%20of%203.4%C2%B0F.

NY-Sun. (2024). Solar Program (NY-sun). NYSERDA. https://www.nyserda.ny.gov/All-Programs/NY-Sun/Solar-for-Your-Home/Customer-FAQs#:~:text=You'll%20only%20pay%20for,pay%20other%20charges%20and%20fees).

NYU Marron Institute of Urban Management's Civic Analytics Program. (2017a). NYC Energy and Water Performance Map. NYC Energy & Water Performance Map. https://energy.cusp.nyu.edu/#/

Rickerson, W. (2006, January). New York City's Solar Energy Future, part I: The market for photovoltaic systems in New York City. The City University of New York's Million Solar Roofs Initiative . https://www.researchgate.net/publication/323666027_New_York_City's_Solar_Energy_Future_Part_I_The_Market_for_Photovoltaic_Systems_in_New_York_City

Umit R. (2022). Solar Panels and Political Attitudes. Political studies review, 20(3), 525–533. https://doi.org/10.1177/14789299211044868

World Bank Group. (2023). Smart Cities for Sustainable Development [Online course]. WBGx. https://www.worldbank.org/en/olc/course/58205

Xu, Y., Li, J., Tan, Q., Peters, A. L., & Yang, C. (2018). Global status of recycling waste solar panels: A review. Waste management (New York, N.Y.), 75, 450–458. https://doi.org/10.1016/j.wasman.2018.01.036