

Improving In Place:
**A Passive Solar Design Approach
to Public Housing Redevelopment**

by

Jeffrey Geisinger

Bachelor of Architecture
Rice University, 2004

Submitted to the Department of Architecture in partial
fulfillment of the requirements for the degree of
Master of Science in Architecture Studies

at the

Massachusetts Institute of Technology

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Abstract

For the New York City Housing Authority, or NYCHA, sustaining the city's 178,000 units of public housing for future generations is a significant and increasingly difficult task. Faced with aging infrastructure and cuts in federal funding, the city has turned to private sector partnerships for new ways to finance the upkeep of its buildings. The 2013 Land Lease Initiative, NYCHA's unrealized plan to generate funds by renting underutilized open space to residential developers, demonstrated economic potential but overlooked opportunities to repair critical deficiencies in the urban design and energy-efficiency of its public housing developments.

This thesis suggests that passive-solar design strategies can influence a more sustainable approach to public housing revitalization, integrating site-sensitive infill development with existing building upgrades. Focusing on the Douglass Houses in the Upper West Side of Manhattan, I analyze how the Land Lease Initiative's high-rise massing would worsen existing buildings' access to natural sunlight, and I suggest an infill development model that preserves solar access to existing facades while connecting the superblocks to the surrounding urban fabric. My research then explores the application of sunspace additions to existing public housing to expand living spaces while simultaneously reducing heating demand. I conclude with a discussion of financial plausibility and large-scale impact on NYCHA's overall housing portfolio. This investigation aims to create an integrated process that links new development and public housing upgrades across site, building, and dwelling scales.

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Figure 1-1: Map of New York showing NYCHA properties in red.

01 Introduction

New York City stands apart from other major urban centers in the United States when it comes to public housing. Whereas the prevailing redevelopment model—demolition of distressed buildings and replacement with private, mixed income developments—has eradicated thousands of affordable units in Atlanta, Detroit, and Chicago, New York has kept intact virtually all of its public housing stock. Good management by the New York City Housing Authority (NYCHA), and a long waiting list are some of the factors that explain the city’s decision to avoid demolition.¹

However, maintaining the upkeep of the city’s 178,000 units of public housing for decades to come is an increasingly difficult challenge. Most of NYCHA’s building stock is over 40 years old and in a state of disrepair. Diminishing federal support has led to \$18 billion dollars in unmet capital needs, stranding developments with deficient elevators, damaged facades, and harmful indoor air quality. Antiquated boilers and steam distribution systems, many in need of critical upgrades or replacement, have exceeded their life expectancies and are extremely energy inefficient. The “chronic underfunding” of these necessary capital improvements is only expected to worsen.²

In an attempt to close the financing gap, the housing authority proposed leasing open space for private market-rate developments in a 2013 plan called

1. Bloom, Nicholas Dagen. *Public Housing That Worked*, 1-10.

2. New York City Housing Authority (NYCHA). “Adopted Budget for FY 2015,” 16.

the Land Lease Initiative.³ Although supporters praised the plan's dual benefits of funding an ailing authority and contributing to the city's housing supply, many elected officials and housing advocates argued that the proposed high-rise developments would cause more harm than good, overshadowing the existing "towers in the park" with even taller structures.⁴

Informed by both building technology and urban planning questions, this thesis explores how energy-efficiency strategies, which have been until recently largely under-prioritized by NYCHA and left out of the 2013 infill proposal, can inform a more holistic approach to public housing revitalization. Specifically, by combining infill development with passive solar retrofits, the proposed redevelopment model suggests mutually beneficial outcomes for existing and new buildings, including vital energy-efficiency upgrades and greater connections to the surrounding urban fabric.

My research begins in section two by looking broadly at energy-efficiency in the context of New York's public housing, including its relationship to citywide carbon reduction goals and obstacles to implementation. I then describe and analyze the Land Lease Initiative. Focusing on one of the proposed infill development sites, Douglass Houses in the Upper West Side of Manhattan, I argue in section three that the Land Lease Initiative's as-of-right high-rise massing would worsen existing buildings' access to natural sunlight. This overshadowing effect would be detrimental to the heating load management and daylight environment within the affected buildings.

In reaction to the environmental problems associated with the 2013 plan, section four suggests an alternative approach to infill development that preserves solar access to existing public housing while connecting the super-blocks to the surrounding urban fabric. Using a zoning technique called the "solar envelope," my case study within the Douglass Houses site explores a more distributed and lower-rise infill development that directly responds to the site's latitude, orientation, and preservation of desired sun angles. This section also argues that my proposed massing, in its spatial relationship to the scale and location of the street, repairs existing urban design deficiencies within the

3. NYCHA. "Submissions for Development on Public Housing Property"

4. Angotti, Tom, and Sylvia Morse. "Keeping the Public in Public Housing," 20.

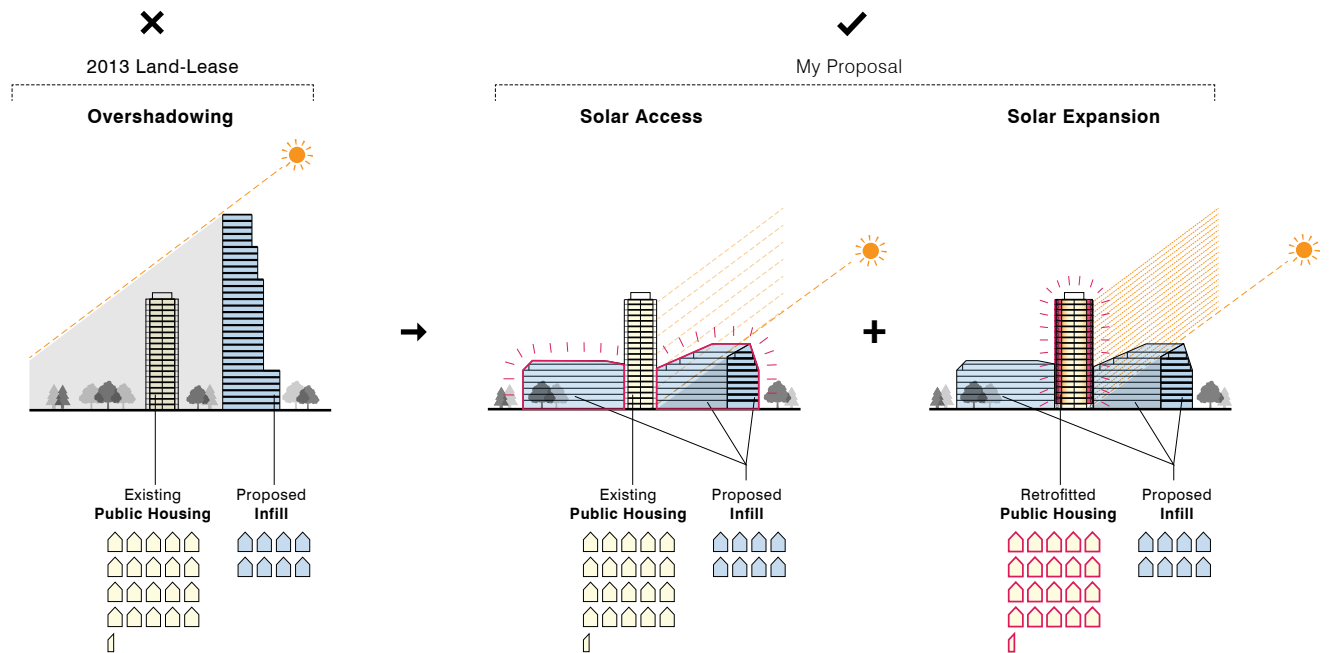


Figure 1-2: Diagram of the main components of my thesis. First, I analyze the Land Lease Initiative's shortcomings regarding access to sunlight. Next, I offer an alternative way of defining infill development that is sensitive to solar access. With solar access preserved, I propose how existing buildings can harness sunlight in a way that reduces heating demand and expands living spaces.

existing Douglass Houses superblock and engenders a greater connection to the surrounding urban fabric.

Then, once solar access is preserved, section four explores the retrofitting of existing public housing to take advantage of the sun for passive solar heating. This section of my research is influenced by my recent travel to France through the MIT Toda Fund to visit three social housing rehabilitation projects by the architects Lacaton, Vassal, and Druot. Through the addition of modular sunspaces to existing building facades, I investigate how to enhance the daylight and energy-efficiency of existing public housing (Figure 1-2).

Lastly, the thesis concludes with a discussion of the financial plausibility of this approach and its potential replicability across a greater number of public housing sites in New York.

02 Background

NYCHA's funding gap and the Land Lease Initiative

Federal funding for NYCHA's capital needs has been in decline for over a decade. Since 2001, the city has accumulated a deficit of over \$1 billion dollars.⁵ In 2006, former Mayor Michael Bloomberg's administration had indicated short-term plans to sell or transfer unused public housing development rights as a means for generating revenue for the worsening deficit. A report issued in 2008 by then Manhattan Borough President Scott Stringer called for a more systematic, long term plan for NYCHA's unused land assets, in order to ensure optimal benefit to the city's affordable housing needs, NYCHA's budget, and public housing residents.⁶

In 2013, NYCHA announced an infill development plan with the purpose of accomplishing the dual goals of alleviating the authority's financial burden and the city's high demand for housing. The Land Lease Initiative, commonly referred to as "The Infill Plan," involved renting parking lots and other underutilized public housing areas to private developers for mostly market-rate high-rise housing. The plan estimated an annual income of \$30 to \$50 million through 99-year ground leases within eight of NYCHA's Manhattan developments. City officials, housing advocates, and resident associations opposed the plan, criticizing the disproportionate scale of many of the proposed as-of-right developments and the overall lack of resident involvement in the planning process.⁷

5. NYCHA. "Adopted Budget for FY 2015," 7.

6. Manhattan Borough President Scott M. Stringer. "Land Rich, Pocket Poor," 2-3.

7. Angotti, Tom, and Sylvia Morse. "Keeping the Public in Public Housing," 20.

Even though it was canceled by the De Blasio administration, the Land Lease Initiative still remains a strong reference in New York’s public housing policy and planning debate. In his recent call for a “total reset” to the approach to public housing, De Blasio indicated that such a plan, if modified to better incorporate resident voices and include a higher proportion of permanently affordable units, would not be off the table.⁸ Through the lenses of energy efficiency and urban design, my thesis expands the ways to modify an infill plan, and therefore its potential benefits, offering a timely and valid response to current debates.

NYCHA and energy consumption

One area that has been overlooked in the discussion on public housing redevelopment is the poor energy performance of NYCHA’s building stock. The typical public housing high-rise in New York consumes about 1.7 times more energy than the median area multifamily residential building, over half of which is due to heating (Figures 2-2 and 2-3).⁹ This poor energy performance owes to outdated central boilers and highly inefficient steam distribution systems, little apartment-level temperature monitoring, and an energy-inefficient building envelope including no insulation in walls and leaky window and wall enclosures.

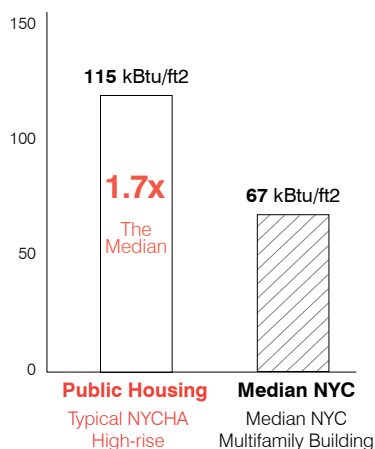


Figure 2-2: Site energy use intensity of public housing vs. Median multifamily housing.

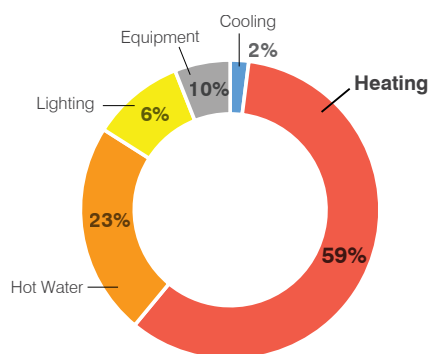


Figure 2-3: Energy use characterization of a typical NYCHA high-rise.

8. The City of New York, and Bill De Blasio. “Housing New York,” 10.

9. Terrapin Bright Green. “Cultivating Community Resiliency,” 25.

This is occurring at the same time that Mayor De Blasio announced a city-wide goal to achieve an 80% reduction in carbon emissions by the year 2050.¹⁰ In addition to improvements in emissions by transportation and infrastructure, De Blasio's initiative explicitly address buildings in New York, which are responsible for almost three-quarters of the city's carbon footprint. As a means to contribute to the city's carbon reduction goal, the administration committed to performing energy upgrades to all city-owned buildings by the year 2025. A recent announcement by the mayor and his NYCHA cabinet made clear that public housing is to be included in this target.¹¹

Public-private partnerships for energy efficiency

Financing these upgrades will have to come from partnerships between the city and private entities. Even before NYCHA's financial shortfall, challenges existed to achieving energy-efficiency upgrades for New York's public housing. Paradoxically, the traditional federal funding model offers little incentive for public housing energy efficiency upgrades. As it does with other local housing authorities, the U.S. Department of Housing and Urban Development (HUD) reimburses NYCHA for three-year average utility spending; if utility spending goes down because of energy efficiency, so will HUD's reimbursement.¹² Any federal funds allocated to energy-related improvements are therefore typically used for lower cost improvements, or repairs that are critical or that have a quick payback period.¹³ NYCHA and other public housing authorities have increasingly engaged in private-sector partnerships such as Energy Performance Contracts (EPCs), which are agreements between a housing authority and a private energy services company, to carry out larger scale energy upgrades. In successful cases, energy cost savings are re-invested back into the original development for future upkeep.¹⁴

10. City of New York. "One City Built to Last," 3.

11. Office of the Mayor of New York City. "Nation's Largest Energy Savings Program for a Public Housing Authority."

12. Dastrup, Samuel, Simon McDonnell, and Vincent Reina. "Household Energy Bills and Subsidized Housing." 127-48.

13. Navigant Consulting Inc. "Con Edison's Multi-Family Low-Income Program," 37.

14. U.S. Department of Housing and Urban Development. "Affordable Green," 19-20.

Given this changing landscape of financing public housing energy upgrades, there is an opportunity to city officials and planners to think more holistically about incorporating energy efficiency into future public housing redevelopment plans, such as infill development and public-private partnerships.

03 Land Lease Analysis

I will explore a passive solar design redevelopment framework by beginning with an analysis of one of the eight proposed Land Lease development sites: Douglass Houses in the Upper West Side of Manhattan (figure 3-1). The goal of this section is to demonstrate the environmental problems associated with as-of-right infill development when carried out without sensitivity to adjacent existing public housing.

Spread out over two large superblocks, Douglass Houses is made up of 17 buildings built in 1958. The buildings range from five to 20 stories in height,

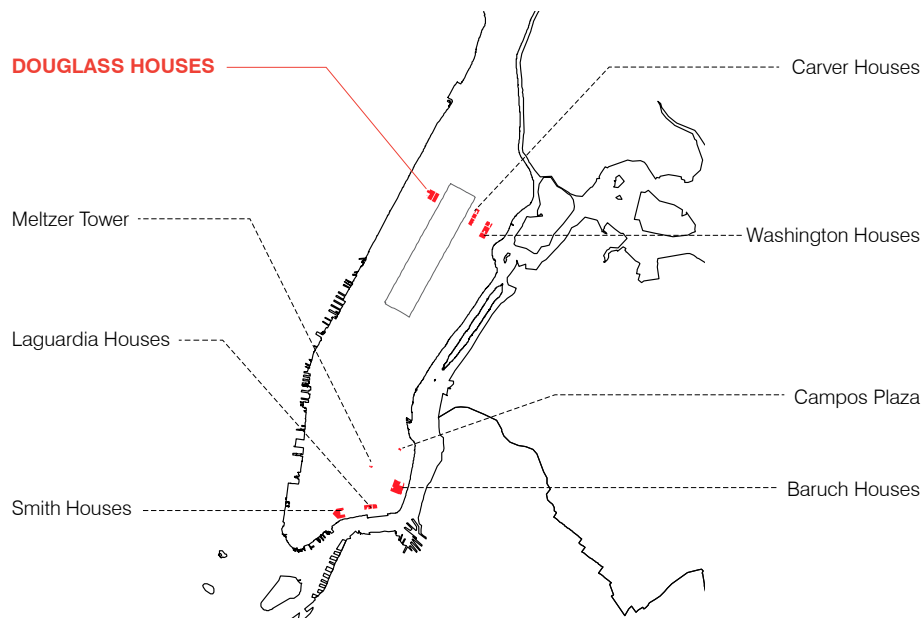


Figure 3-1. The eight proposed Land Lease developments with Douglass Houses highlighted.

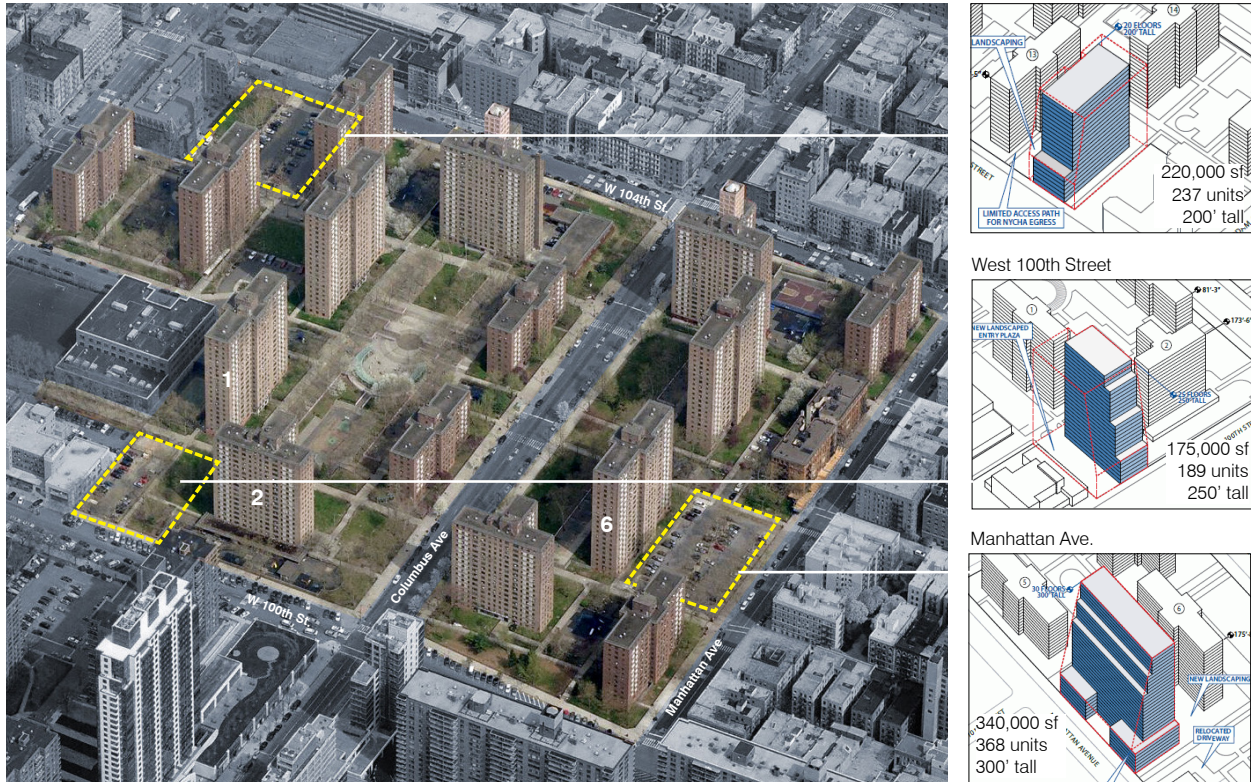


Figure 3-2. (left:) NYCHA's proposed 2013 infill sites with existing buildings one, two, and six indicated; (right:) massing proposals at Douglass Houses (Source: Bing maps, www.theelectricwebnetwork.blogspot.com)

with over 4,500 residents living in its 2,058 apartments. Douglass Houses is underdeveloped in terms of allowable floor area ratio (FAR); the 1.43 built FAR is well under half of the allowable FAR of 3.44 for the R7-2 zoning district. The Land Lease Initiative identified three development sites and associated as-of-right massing proposals within the Douglass Houses complex (figure 3-2): one at West 104th Street, a 200' tall tower housing 237 units; another at Manhattan Ave topping out at 300' tall and housing 368 units, and a third at West 100th Street, a 250' tall tower with 189 units. In total, NYCHA's infill plan proposed 794 new units at Douglass Houses.¹⁵

The maximum as-of-right zoning allows for high rise buildings, as long as they comply with a 60-foot maximum base height and subsequent sky-exposure

15. Rhea, John B. "NYCHA's Land Lease Plan." 7–10.

setbacks. As a result, all three proposed infill developments are out of scale with the surrounding neighborhood and adjacent public housing. The location and orientation of the West 100th St. and Manhattan Ave. proposals, moreover, suggest that these developments may cast long shadows onto the adjacent public housing facades. This overshadowing would limit certain existing buildings' access to natural light, one of the core benefits of the original tower-in-the-park typology that led to its mass adoption in places like New York.¹⁶

In order to properly quantify the negative effect that the Douglass housing infill proposals' overshadowing has on the existing housing, I needed to first establish when having the sun would be "useful" for heating (figure 3-4). Therefore, I determined the heating period for the existing apartments and use that period of time to analyze solar access. To do this, I created a multi-zone energy model of the affected public housing high-rise in the energy simulation software, Archsim, which runs on an Energy Plus simulation engine.¹⁷

I calibrated this energy model according to a typical high-rise energy end-use characterization.¹⁸ As figure 2-3 indicated, heating accounts for over one-half of the annual energy consumed. Model inputs such as lack of existing wall insulation, high air infiltration rates at the building perimeter, and low heating plant efficiencies can be found in appendix 01.

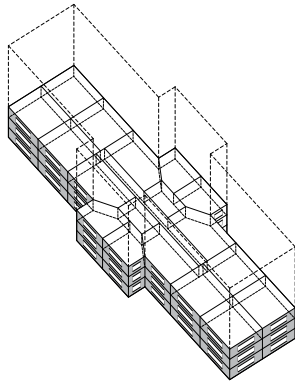
With the energy model calibrated, I ran a monthly energy simulation to find the crossover between heating and cooling consumption. The results identify the dates between October 1st and April 15th as the heating period. Then, using the Cumulative Sky and Radiance analysis method within DIVA-for-Rhino's "radiation map" function, I simulated the cumulative surface irradiation falling onto the facades of the existing Douglass Houses for the heating period.

I used this workflow to test the overshadowing on existing building six at the Manhattan Ave. site, and buildings one and two at the West 100th St. sites.

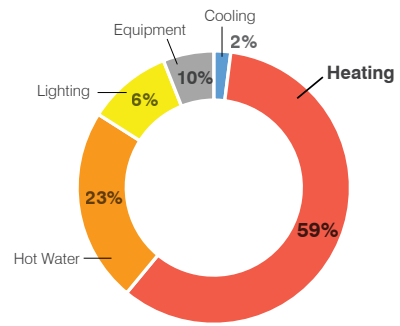
16. Gropius, Walter. *The New Architecture and the Bauhaus*.

17. Archsim. <http://archsim.com/>

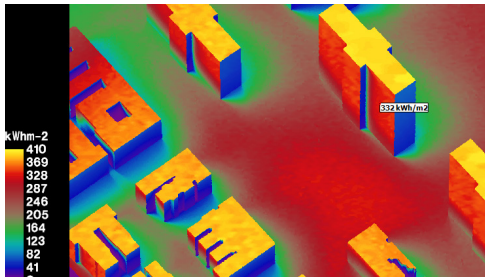
18. Terrapin Bright Green. "Cultivating Community Resiliency."



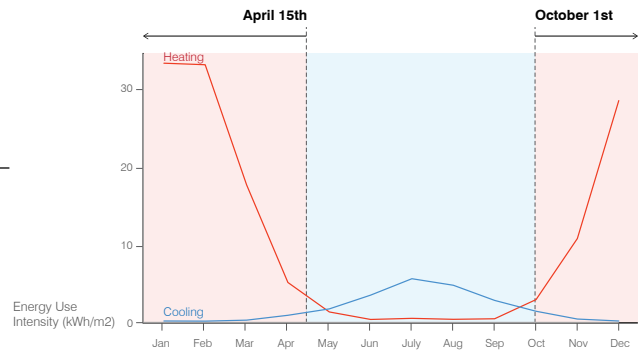
1. Create a multi-zone energy model



2. Calibrate according to typical NYC public housing energy use characterization



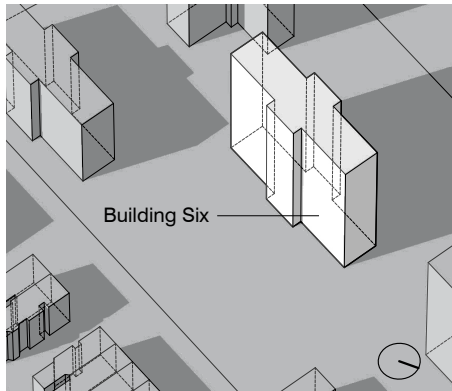
4. Create a radiation map to visualize solar radiation on building surfaces during the determined heating period.



3. Determine heating period by finding crossover between heating and cooling loads

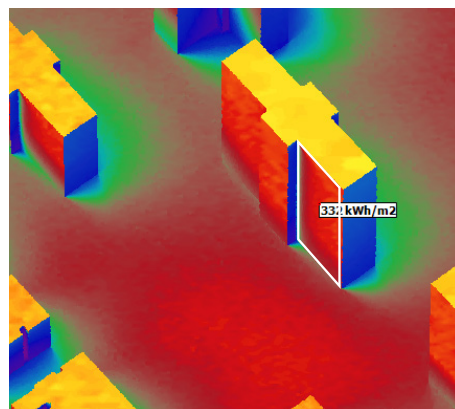
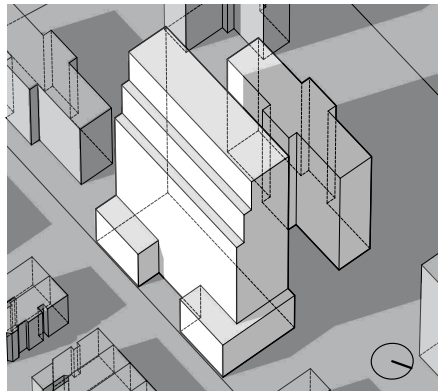
Figure 3-4: Workflow for determining useful solar radiation on building surfaces.

EXISTING PUBLIC HOUSING



Shadows on March 21, 10am

2013 LAND LEASE PROPOSAL



Solar Radiation on Surfaces Oct. 1 to April 15

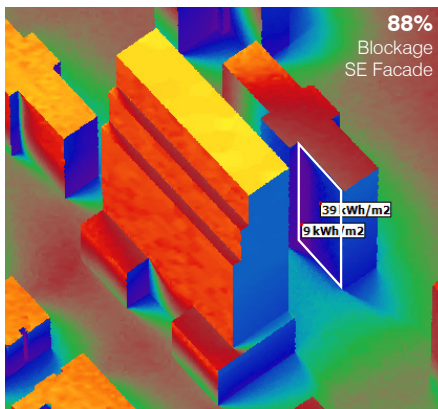


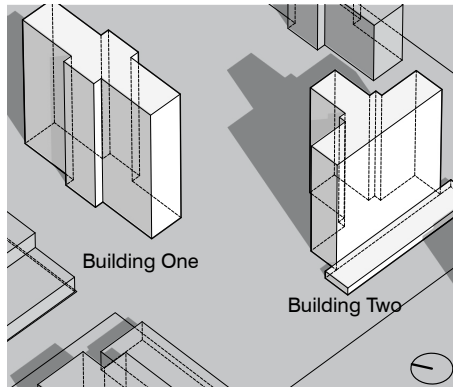
Figure 3-5: Overshadowing at the Manhattan Ave site.

Manhattan Ave. Site

Building Six - Baseline: For the heating period between October 1st and April 15th, the baseline (unshaded) southeast facade of existing building six receives a more or less consistent 330 kWh/m² of solar radiation.

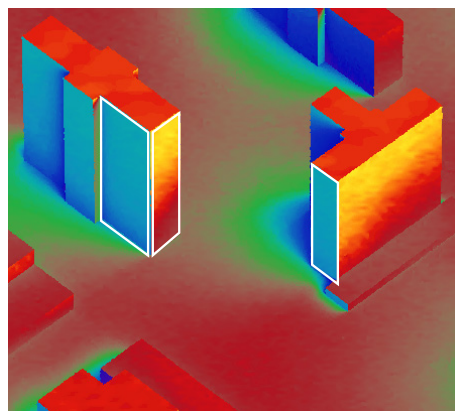
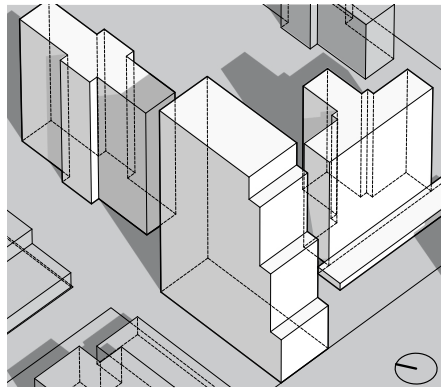
Building Six - Overshadowed: The same facade only receives about 39 kWh/m² when overshadowed by the 300-foot tall Manhattan Ave. infill tower; in other words, the proposed tower would block 88% of the useful surface irradiation during the year.

EXISTING PUBLIC HOUSING



Shadows on March 21, 2:30pm

2013 LAND LEASE PROPOSAL



Solar Radiation on Surfaces Oct. 15 to April 1

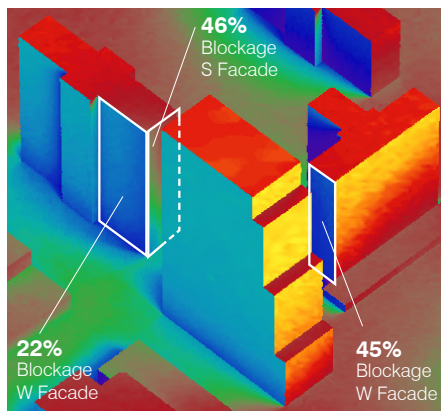


Figure 3-6: Overshadowing at the West 100th St. site.

West 100th St. Site

Building One - Baseline: The west facade receives about 119 kWh/m² of solar radiation, while the south receives about 432 kWh/m² halfway up the facade.

Building One - Overshadowed: The west elevation receives about 93 kWh/m² when overshadowed by the infill tower, blocking 22% of the useful surface irradiation on that facade during the year. The overshadowed south facade receives about 198 kWh/m² at its midpoint, which equates to about 54% blockage.

Building Two – Baseline: The west facade of building two receives about 121 kWh/m² of radiation during the heating period.

Building Two – Overshadowed: The overshadowed west facade receives about 66 kWh/m² of solar radiation, which equates to about 45% blockage.

Effect on Energy

The southeast facade of building six, which is adjacent to the proposed 300-foot tall Manhattan Ave infill tower, receives the most overshadowing out of the facades examined. For this worst-case scenario, I simulated the whole building energy consumption of the existing public housing tower using a multi-zone thermal model, to evaluate heating energy consumption before and after overshadowing. The results of this model showed that the existing building would consume 11% more gas heating energy because of the blockage of solar radiation (figure 3-7). While a worst case scenario, the analysis demonstrates that, when scaled and configured without sensitivity to surroundings, infill development can have a detrimental effect on the energy consumption of existing buildings.

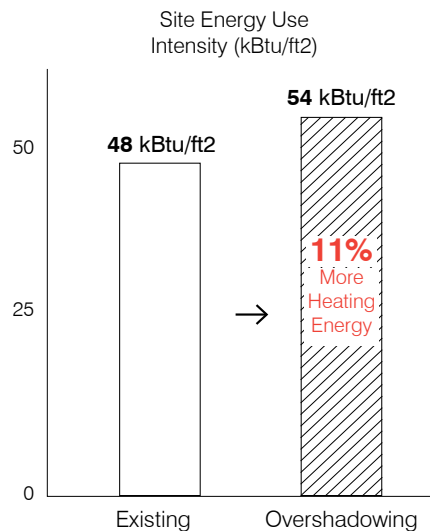


Figure 3-7: Graph showing the existing building's heating energy increase as a result of overshadowing

Effect on Daylight

Overshadowing presents liabilities other than the quantitative effects of energy. The light environment of a space can be greatly altered by the presence of neighboring construction. To evaluate the effect on daylighting for the southeast facade of building six, I created and analyzed a digital model of a living

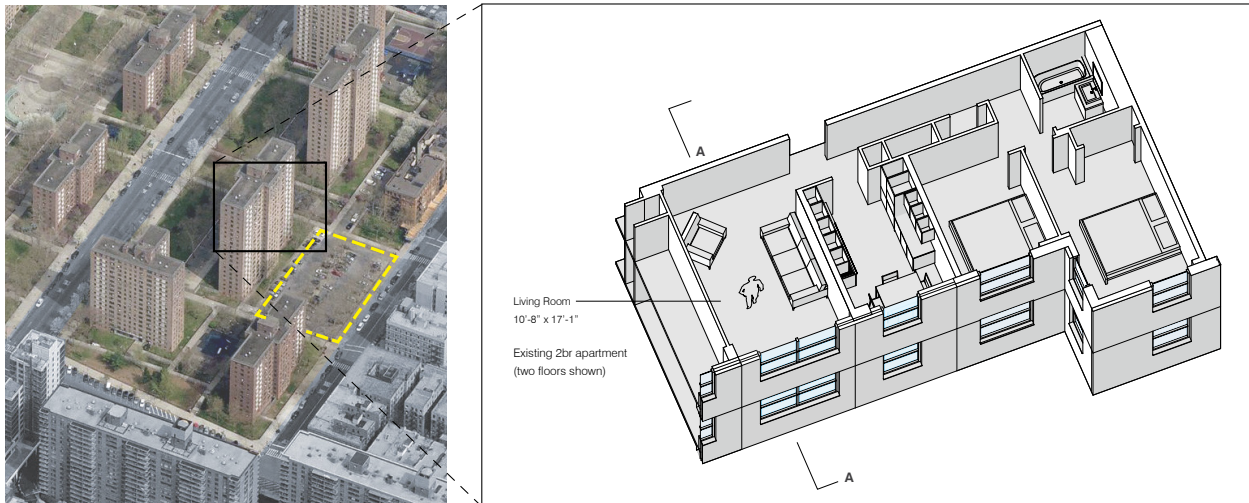


Figure 3-8. A typical southeast-facing apartment within Douglass Houses

room space at about 40 feet from ground level (figure 3-8). Using DIVA,¹⁹ I generated two daylight analyses: a *high-dynamic range, point-in-time* simulation to visualize the overshadowing effect on space brightness, and a *daylight autonomy* simulation to evaluate the overshadowing effect on annual daylight levels (see appendix 01 for inputs and assumptions).

The results of the point-in-time simulation, which gives the viewer a sense of the brightness of a space at a given hour, shows a drop in mean luminance (scene brightness) of about 79% as a result of the overshadowing (figure 3-9). For the annual daylight autonomy metric,²⁰ there is a noticeable dropoff in daylight autonomy further back into the living room as a result of the overshadowing. I also use the daylight autonomy data to inform a comparison of “daylit area,” or the percentage of floor area that has a daylight autonomy of at least 50%.²¹ The DIVA simulation indicates that the overshadowing results in 22% less daylit area within the living space when compared to the existing case (figure 3-10).

19. www.diva4rhino.com

20. Daylight Autonomy is defined as the percentage of occupied hours for which a point on the task plane meets a target illuminance by daylight alone.

21. IESNA, “IES LM-83-12.”

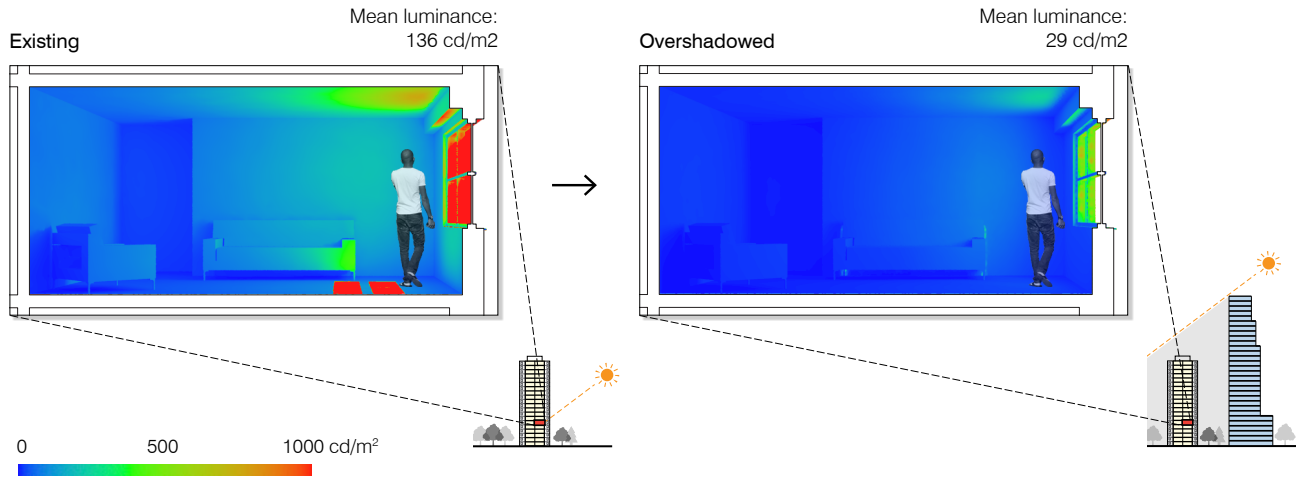


Figure 3-9. Luminance visualizations at noon, Sept. 21st under clear skies show that the typical living room will be 79% less bright at this point in time as a result of the overshadowing.

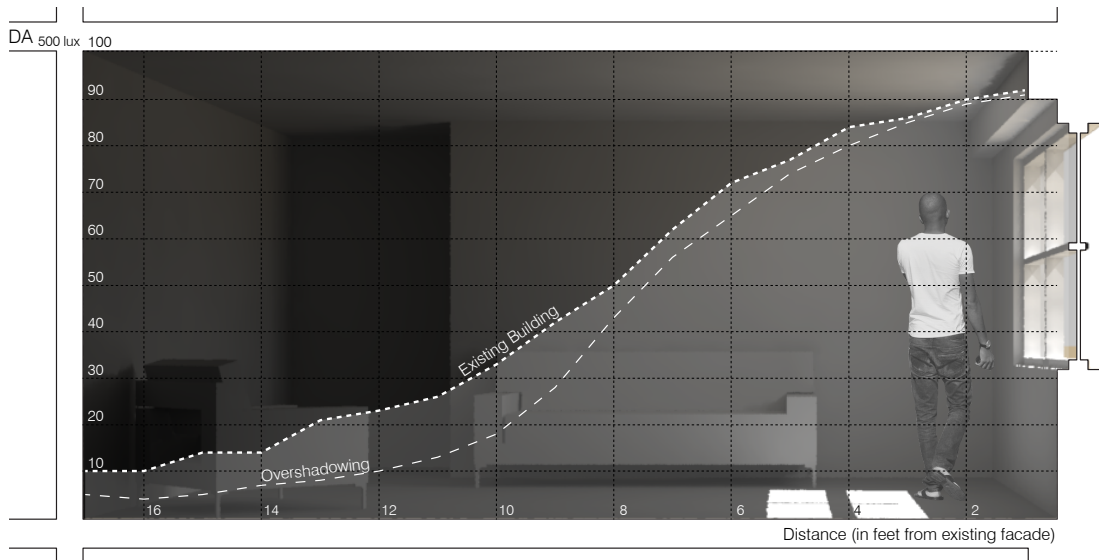


Figure 3-10. A section perspective with an overlay of annual daylight autonomy, showing a reduction in daylight autonomy deeper into the space as a result of the overshadowing.

The as-of-right infill massing proposed by NYCHA in its 2013 Land Lease Initiative would restrict certain buildings' access to natural light and solar energy. While the most adverse environmental impact would apply to a small selection of buildings within the overall campus, an approach to infill that considers these environmental effects would ensure that all buildings receive the benefit of access to light and air. In the next section, I will explore a more site-sensitive work flow for determining maximum infill development.

04 Solar Access

Following the analysis of the Land Lease massing, this section investigates how an environment-driven process for infill development can unfold on the Douglass Houses site. Through this process, I expanded the development area by considering a larger set of perimeter sites, and constrain buildable volume by combining New York City zoning requirements with a more restrictive, sun-angle-based method. For the purposes of this study, I confined the investigation to include 11 of the 17 buildings at Douglass Houses (the area of study is bordered by West 100th St. to the south, Manhattan Ave to the east, West 103rd St. to the north, and a midway point between Amsterdam Ave and Columbus Ave to the west). I use the results of this study to compare new unit count and overshadowing between the proposed solar envelope massing and 2013 Land Lease proposals for the Manhattan Ave and West 100th St. sites.

To define perimeter areas for potential development, I studied the introduction of new streets into the Douglass Houses superblock. I proposed re-introducing West 102nd St. where, before the construction of Douglass Houses, the street originally ran, as well as a new north-south street west of Columbus Ave. By penetrating the superblock, these streets connect the existing public housing to the adjacent urban fabric, and also contribute to creating a hierarchy of open space between the buildings. With the areas of potential development identified, I then raised these zones 60' according to the maximum street wall height for Douglass Houses' zoning district (figure 4-1).

To define a maximum buildable envelope that respects the solar access of adjacent public housing, I used a method called "the solar envelope" developed

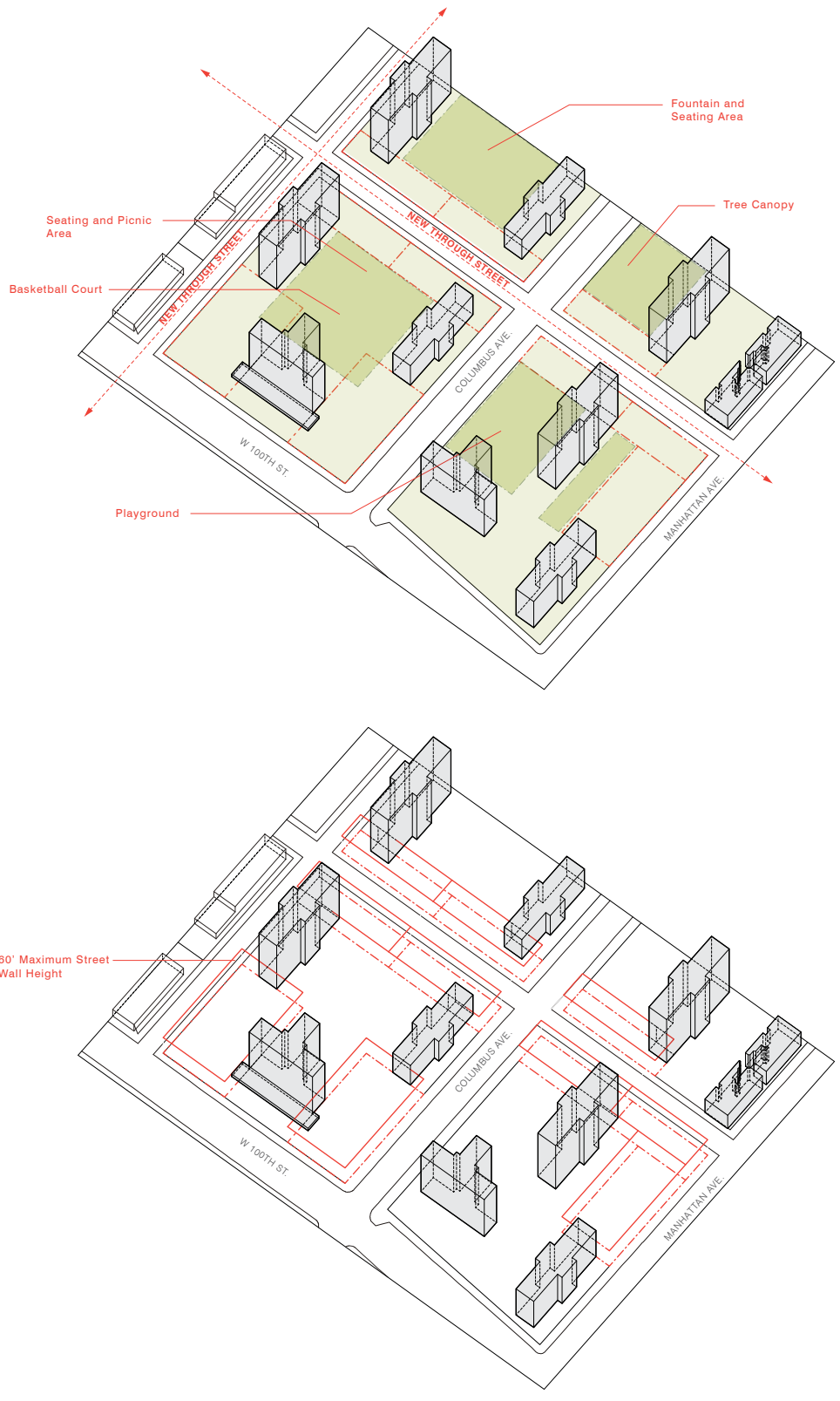


Figure 4-1. New perimeter zones are defined (top) and potential areas for development are raised to a 60' maximum (bottom).

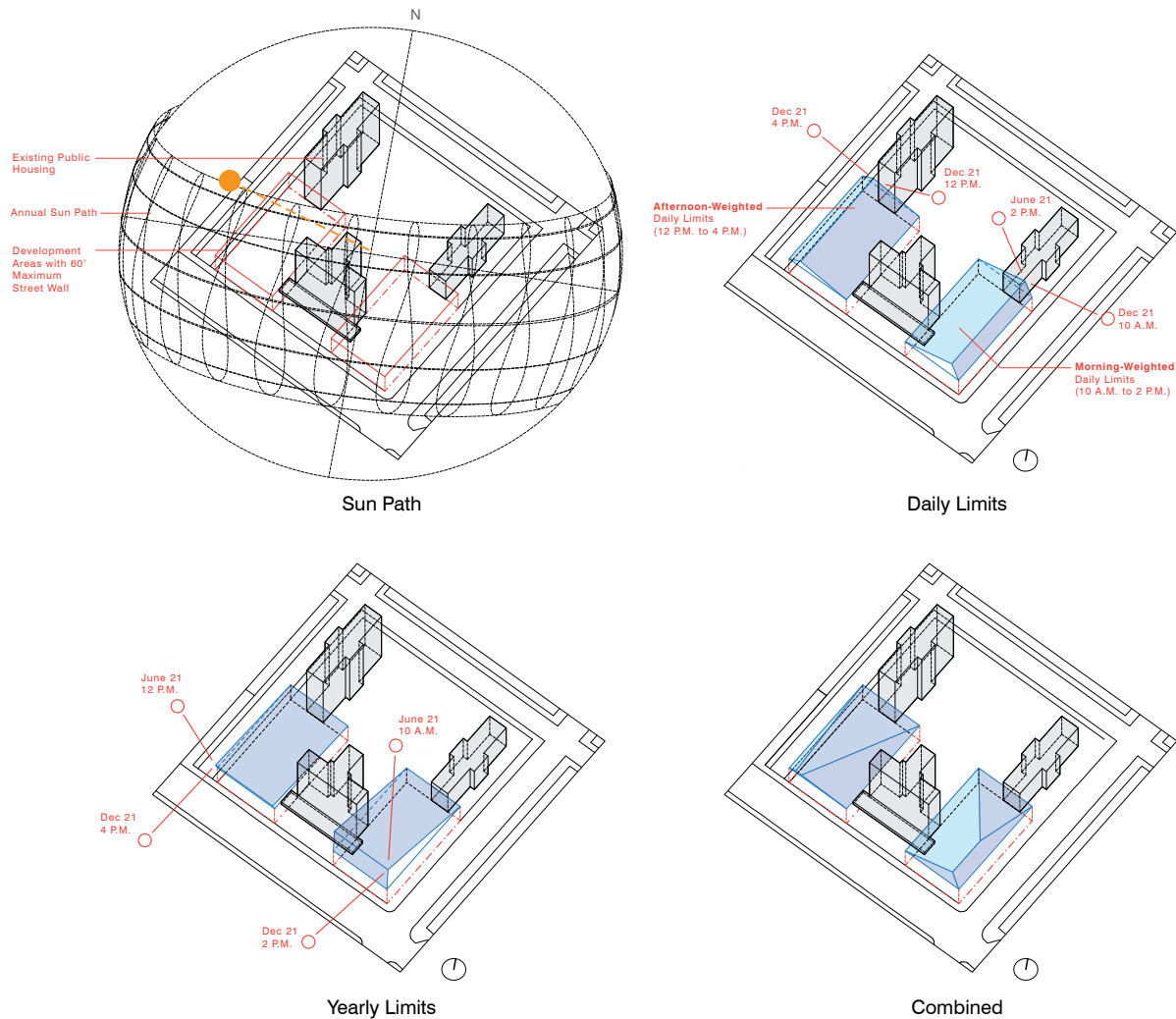


Figure 4-2. Starting at the 60' max. street wall, a hip-roof shape emerges that preserves solar access to its perimeter at given hours of the day.

by Ralph L. Knowles in 1981,²² and incorporated into DIVA-for-Rhino by Jeffrey Niemasz in 2011.²³ Depending on the shape and latitude of a given site, the solar envelope defines a three-dimensional enclosure within which any buildings will not cast shadows at the enclosure's perimeter for a specified duration of time (figure 4-2).

First, I established daily limits that form the east-to-west faces of the envelope. In the indicated portion of the Douglass Houses complex shown (buildings

22. Knowles, *Sun Rhythm Form*, 51-71.

23. Niemasz, Sargent, and Reinhart, "Solar Zoning and Energy," 801-13.

one, two, and three), the development area to the east of building two was shaped to protect solar access in the morning, while the area to the west of building two was shaped to permit afternoon sun rays. The daily limits created a pitched-roof shape for the two areas according to the sun's altitude at defined hourly limits, during the time of the year where the sun is at its lowest point. Next, I defined the yearly sun angles that form the north-to-south faces of the envelope. Using the same hourly limits from the previous step, a pitched roof in the opposite direction emerged according to the sun's altitude at extreme summer and winter sun angles. When these two pitched-roof-like shapes are intersected, the resulting volume preserves solar access to all four sides of its footprint—in this case, the top of the 60' street wall.

I aggregated the solar envelope onto the areas of potential development according to each area's hourly relationship to existing public housing buildings. I then subtracted areas conflicting with streets as well as with corresponding zoning sky exposure planes. I made further removals to preserve access to existing public housing entrances, and I expanded amenity and public areas at the ground level of the existing buildings to further engage the street edge (figure 4-3).

I then analyzed the resulting massing for floor area and solar radiation. Based on the 925 sf unit size assumption used by NYCHA to determine unit counts for the Land Lease massing,²⁴ my proposal provides 616 new units of housing, 59 more units (55,000 sf) than provided by the Manhattan Ave. and West 100th St. sites from the 2013 Land Lease Initiative (figure 4-5). A radiation map analysis for both sites also demonstrated that the new proposed massing restores solar access to the previously overshadowed facades (figure 4-6).

24. NYCHA "Land Lease Program," Presentation to ULI, 2013

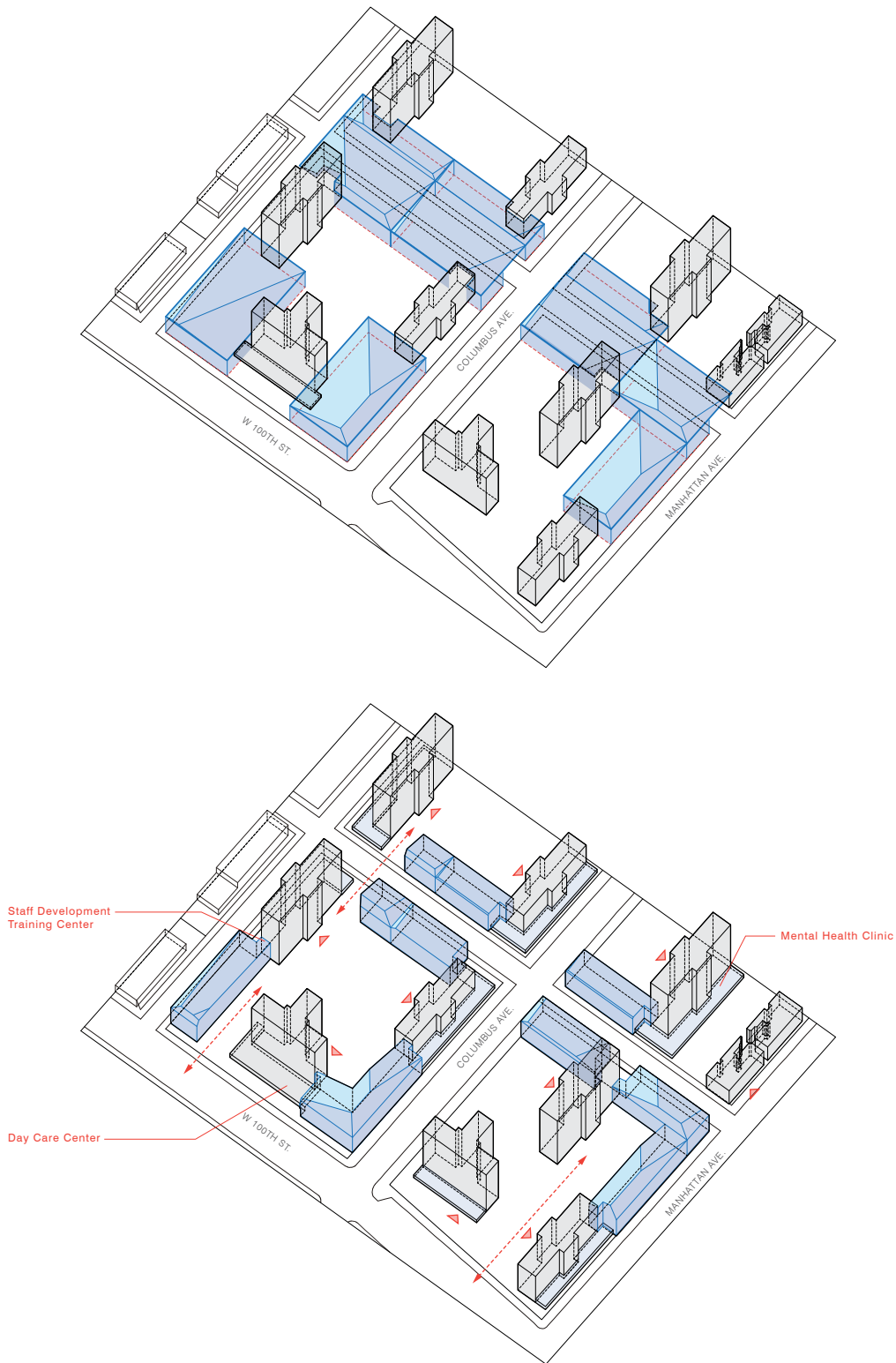


Figure 4-3. (Top) Areas of development are populated according to hourly relationships to existing public housing. (Bottom) Streets and access to existing public housing entrances carve away at the massing.

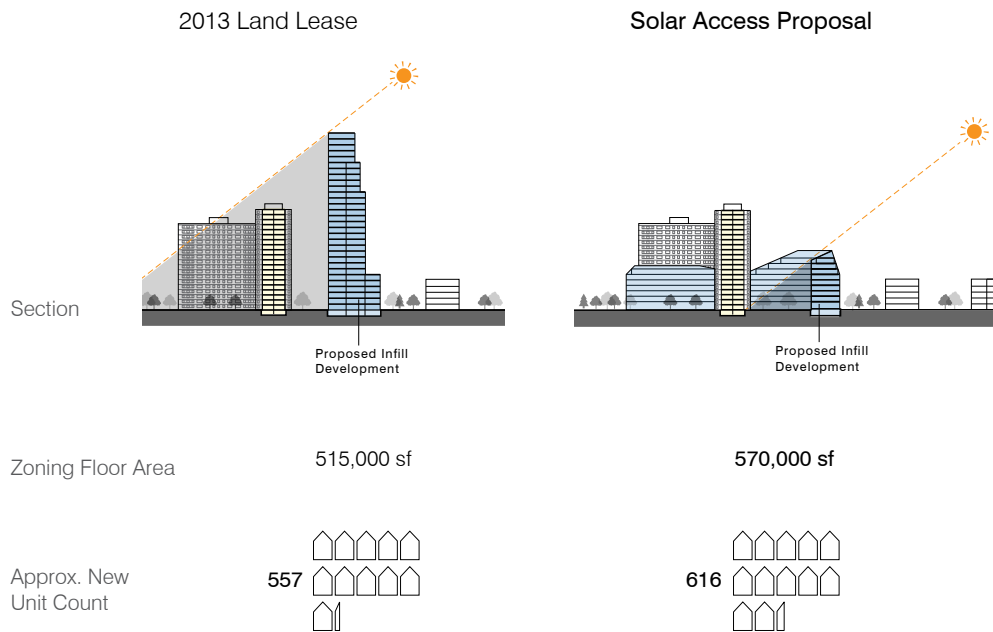


Figure 4-5. The Solar Access Proposal provides more units of housing while preserving sunlight to the existing facades.

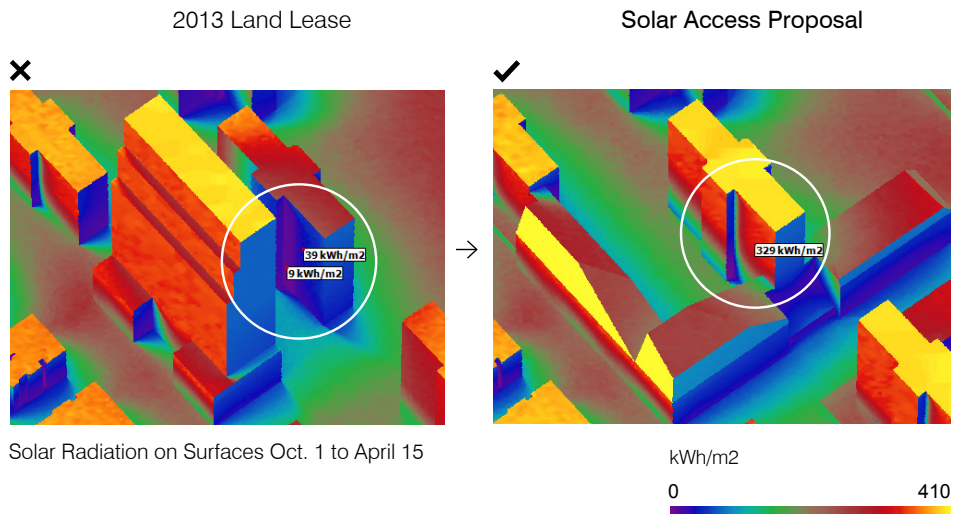


Figure 4-6. The Solar Access Proposal provides more units of housing while preserving sunlight to the existing facades.

05 Solar Expansion

Using the solar access infill development as a departure point, this section explores how to retrofit existing public housing in a way that utilizes the sun for passive solar heating and daylight. The goal of this portion of my study is to utilize and test sunspace extensions, a housing expansion strategy that can simultaneously improve the daylight quality of living space while reducing space-heating demand.

Precedents by Lacaton, Vassal, and Druot

In January 2015, I traveled to France through MIT's Toda Fund to investigate the success of such an approach on the ground. During my two weeks in France, I researched three social housing rehabilitation projects by architects Lacaton, Vassal, and Druot: Tour Bois-le-Prêtre in Paris, Plein Ciel in Saint Nazaire, and Cite du Grand Parc in Bordeaux. The defining component of each project was the addition of unconditioned, independently-structured "winter



Figure 5-1. Winter gardens at Cite du Grand Parc, Bordeaux, by Lacaton, Vassal, and Druot. Photos by author.

gardens,” or what I’ll refer to as sunspaces, to add to and upgrade run-down social housing. I documented the architectural designs and planning decisions for each project, and interviewed residents at each location. As I learned through interviews and through a construction site visit to the rehabilitation of Cite du Grand Parc in Bordeaux, the architects and construction firm successfully collaborated to minimize to the greatest extent possible any disruption to the existing residents; in fact, the team guaranteed the residents the ability to return to their apartments every night during construction.

Sunspaces

Common in lower-density construction in Northern Europe, sunspaces are unheated, fully enclosed spaces adjacent to conditioned rooms (Figure 5-2). They are often fully glazed to permit high levels of sunlight and views. Sunspaces can be beneficial for residential heating energy savings as they act as solar heat collectors and as thermal buffers between an apartment and the outside climate during colder months.²⁵ From a functional standpoint, they can serve as an extension to living spaces when open to the interior, often most viable during the shoulder seasons when solar gains promote an interior environment within comfortable temperature ranges. Additionally, these spaces can provide

25. Yannas, Simos. *Solar Energy and Housing Design*, 105-112.

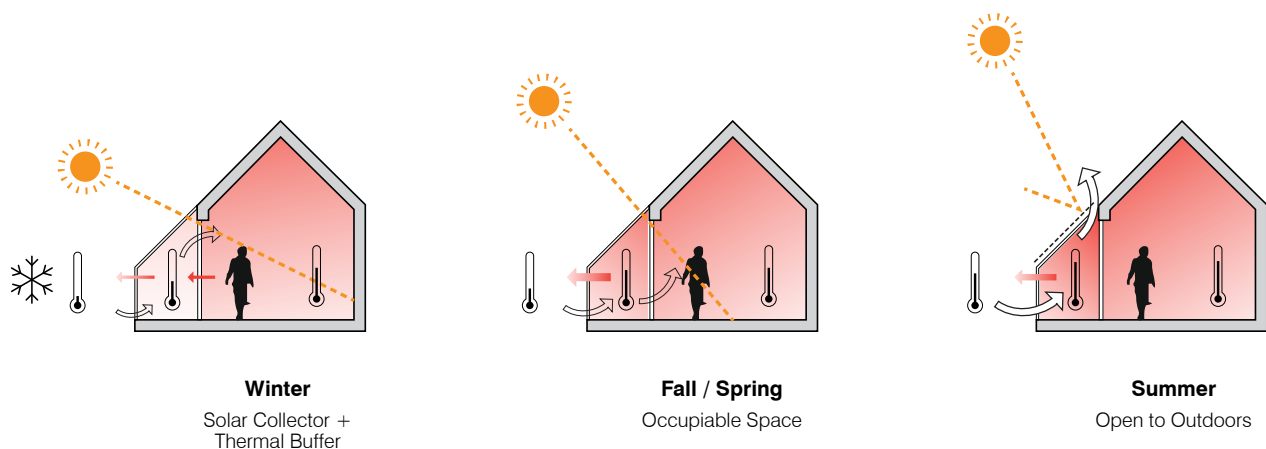


Figure 5-2. Diagram of varying seasonal sunspace performance (redrawn from Simos Yannas, *Solar Energy and Housing Design*)

a greater connection to the outdoors by expanding access to views, light, and air, especially when operable to the exterior. Thermal mass at the floor slab, natural ventilation through operable windows, and shading typically manage overheating during the summer months. As I will discuss later in this section, when sunspaces are used in master-metered multifamily buildings such as public housing (where units are not individually metered for utilities), care needs to be taken by owners and housing authorities to prevent or limit the use of electrical heating, which can adversely affect energy and carbon savings.

Application at Douglass Houses

Inspired by the projects by Lacaton, Vassal, and Druot, I applied the sunspace strategy as the second of my two-part redevelopment process at Douglass Houses. I situated the sunspaces at the fully- and partially- south facing facades of the existing buildings (figure 5-3), and to communicate the existing living spaces with the additions, I explored the benefits of enlarging the openings in the existing non-loadbearing walls (figure 5-4).

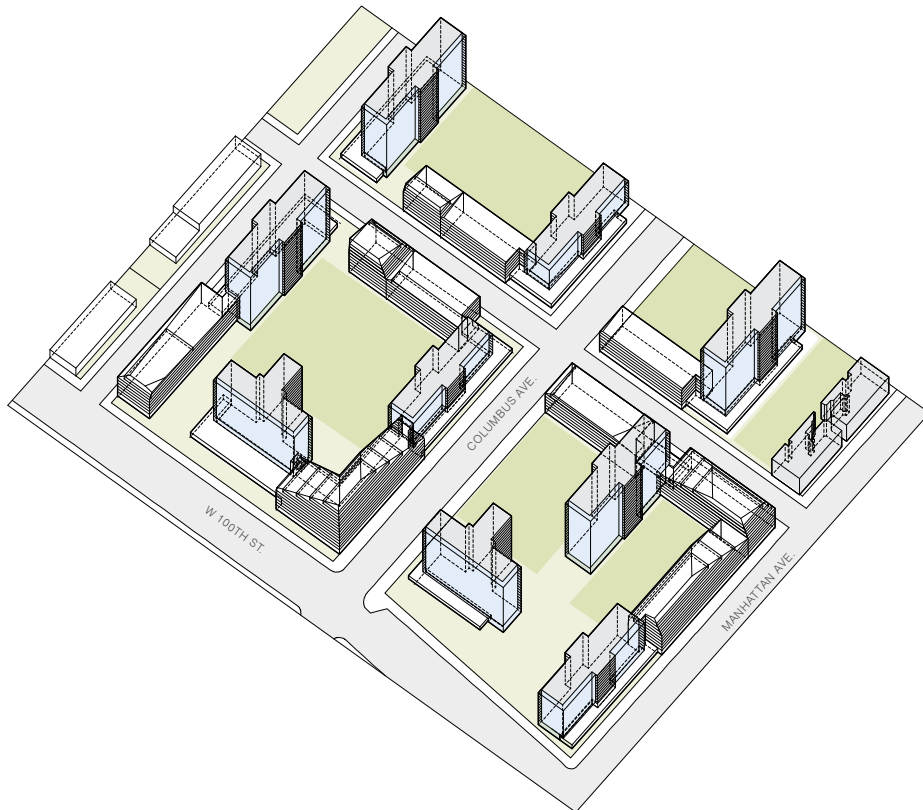


Figure 5-3. Proposed Douglass master plan with solar access zoning and sunspace retrofits.

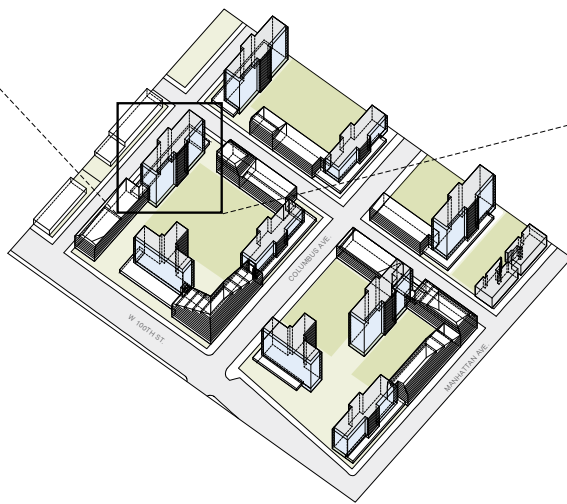
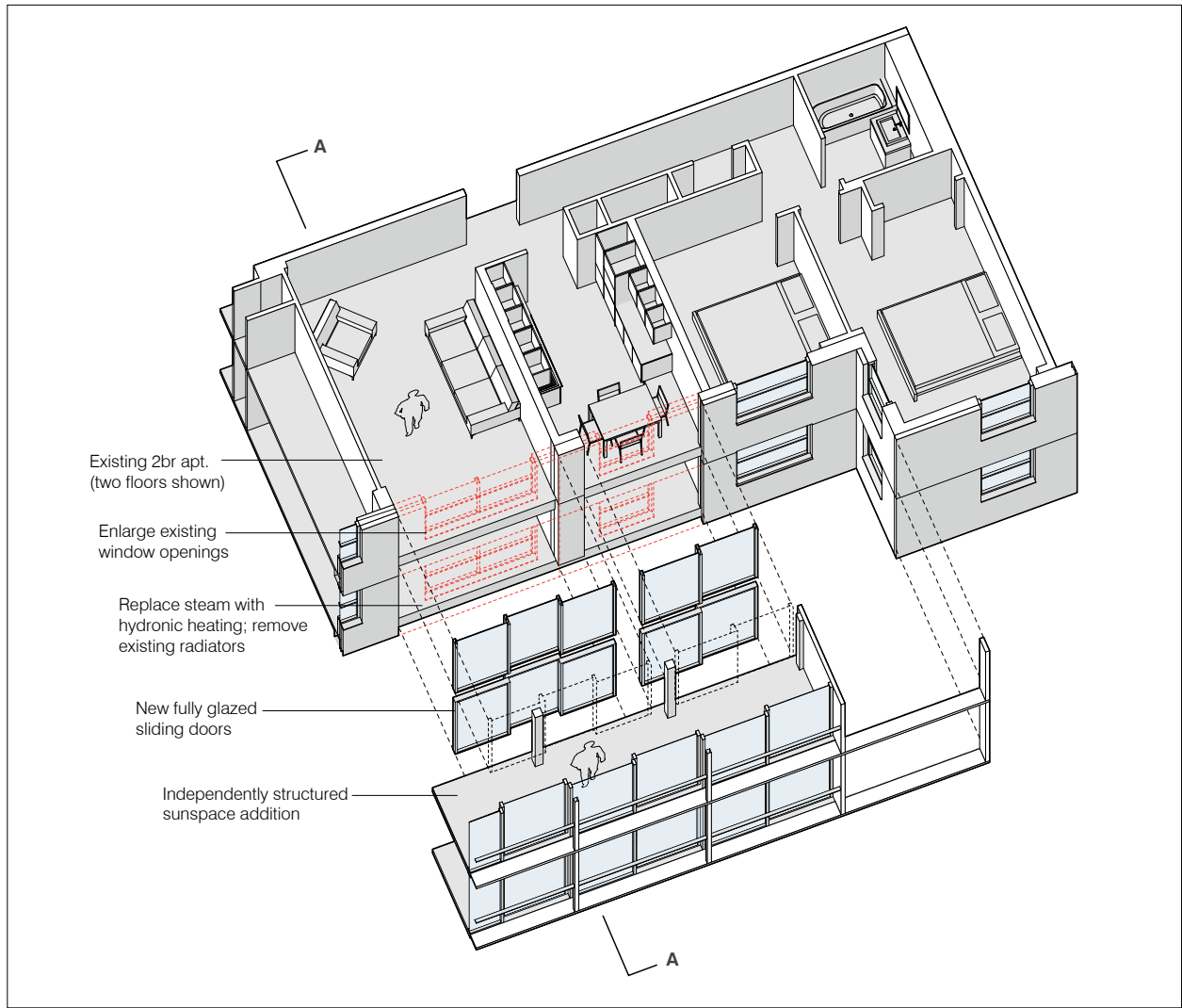


Figure 5-4. An unheated sunspace addition connects to a typical apartment by means of enlarged existing window openings and new glazing materials.

Daylight Analysis

Using the same reference apartment from the overshadowing analysis, I tested depth and materials of the sunspace addition in DIVA to optimize for interior brightness and daylight autonomy (see appendix 02 for inputs). Figure 5-5 shows how a 6'-6" deep addition with fully glazed interior sliding doors provides the existing living room with 68% higher mean luminance levels midday on September 21st than compared with the existing conditions.

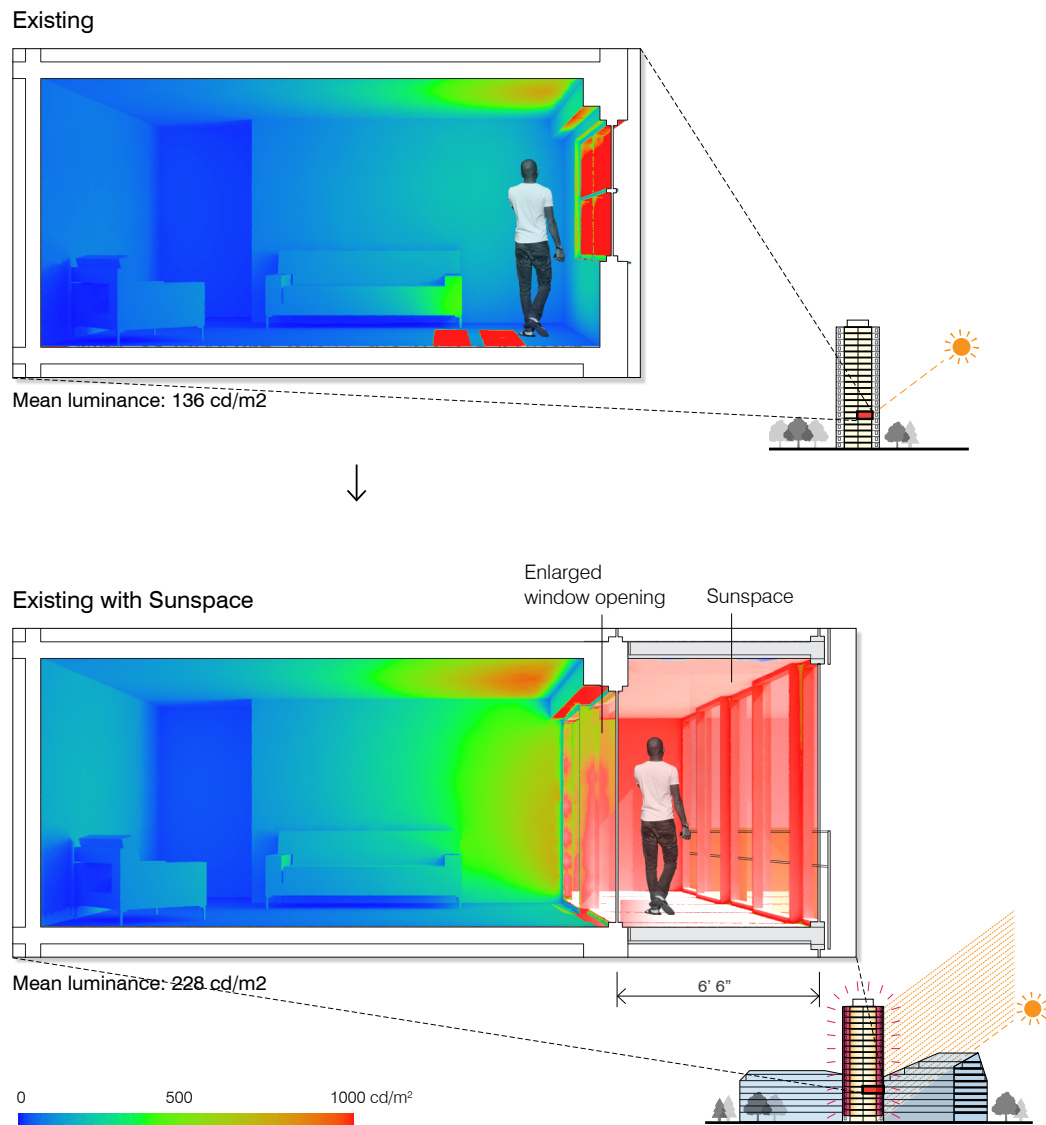


Figure 5-5. Section A-A showing point-in-time luminance values at noon on 9/21 (clear sky)

I then tested the relative annual daylight performance by running a daylight autonomy comparison for the two cases. The results show a noticeable increase in daylight autonomy deeper into the living room as a result of the sunspace and enlarged opening (figure 5-6, bottom). The addition also increases the daylit area (percentage of the room exceeding 50% daylight autonomy) of the living space by 32% when compared to the existing case (figure 5-6, top).

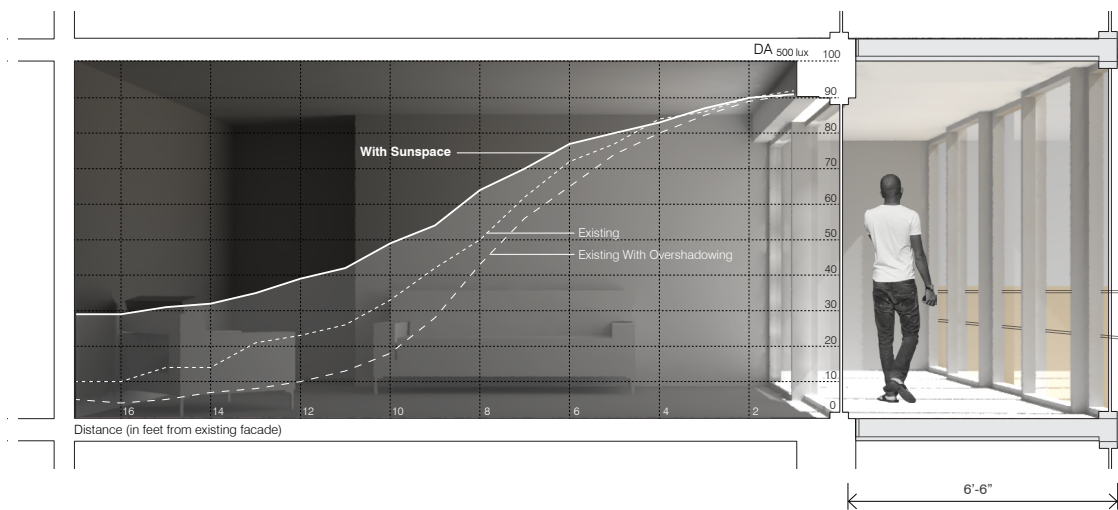
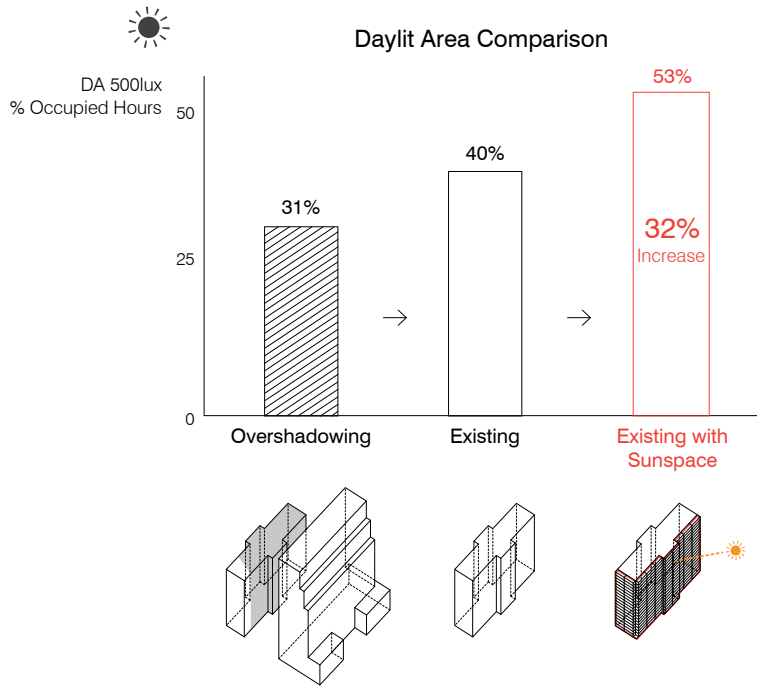


Figure 5-6. (Top) Daylit area comparison, (Bottom) section perspective with comparative overlay of daylight autonomy within the living space.

Energy Analysis

Using Archsim, I performed a whole-building energy model for building six incorporating the sunspace additions on the south-east and south-west facing facades (figure 5-6). Assumptions for the model are listed in appendix 01. The addition of the sunspace resulted in a 33% heating energy intensity reduction in the model, with no change in cooling loads (figure 5-7).

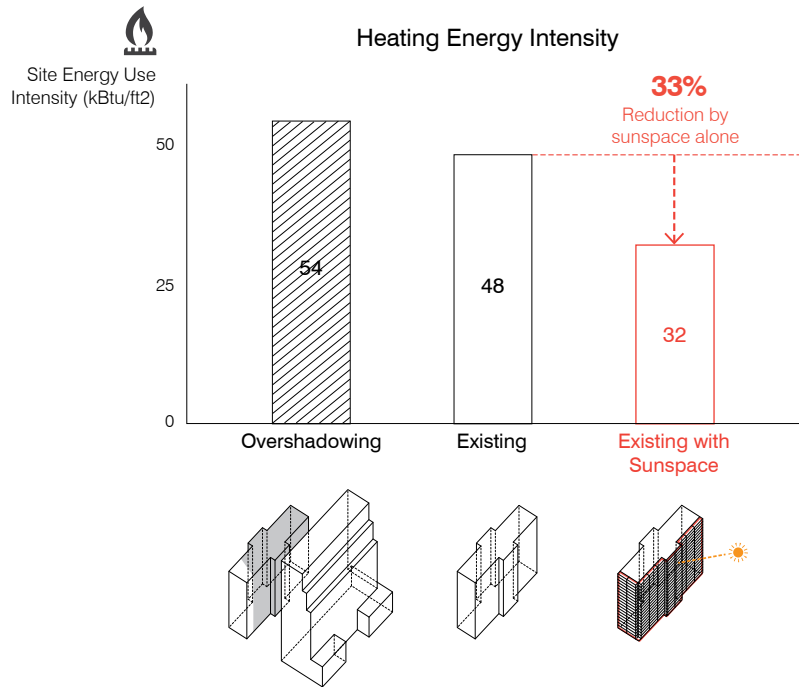


Figure 5-7. Heating Energy Intensity

This heating reduction relies on the sunspace performing as an unconditioned thermal zone, without any additional energy use associated with unpredictable occupant behavior (such as electric resistance heating). A sensitivity analysis points to a risk that, if half of the modeled apartments were to use electric radiators to maintain comfortable temperatures in the sunspaces, the resulting carbon emissions may cancel out the initial savings (see appendix 03). Therefore, regulations that limit the use of electric heating should be considered by the housing authority.

It should also be noted that the passive solar benefits demonstrated by the energy simulation would depend on a responsive heating system that is

capable of turning off when individual apartments receive free solar heat gain. While nearly all of the units in New York’s public housing are master-metered,²⁶ recent installations of wireless energy modules (WEM’s) at NYCHA’s Castle Hill and East 180th St.-Monterey Avenue developments in the Bronx allow central heating systems to respond to individual apartment temperatures.²⁷ Therefore, I investigated the effect of upgrading the boilers and building management systems at the Douglass Houses retrofit, along with additional heating load-reducing measures to ensure the lowest-capacity heating system replacement.

Insulating the non-sunspace facades to R-13 and weather-sealing the perimeter and windows resulted in a further heating energy intensity reduction of 50%. If taken together, these measures lead to a greatly reduced heating demand, necessitating a new boiler and controls with a much lower capacity than if installed without any passive strategies (figure 5-8). The final heating energy savings for Douglass Houses will yield a cost savings of \$450 dollars per unit annually. If this annual unit savings is aggregated across all 2,054 units of the Douglass Houses campus, the proposed measures could save **nearly a million dollars in heating energy cost savings** per year.

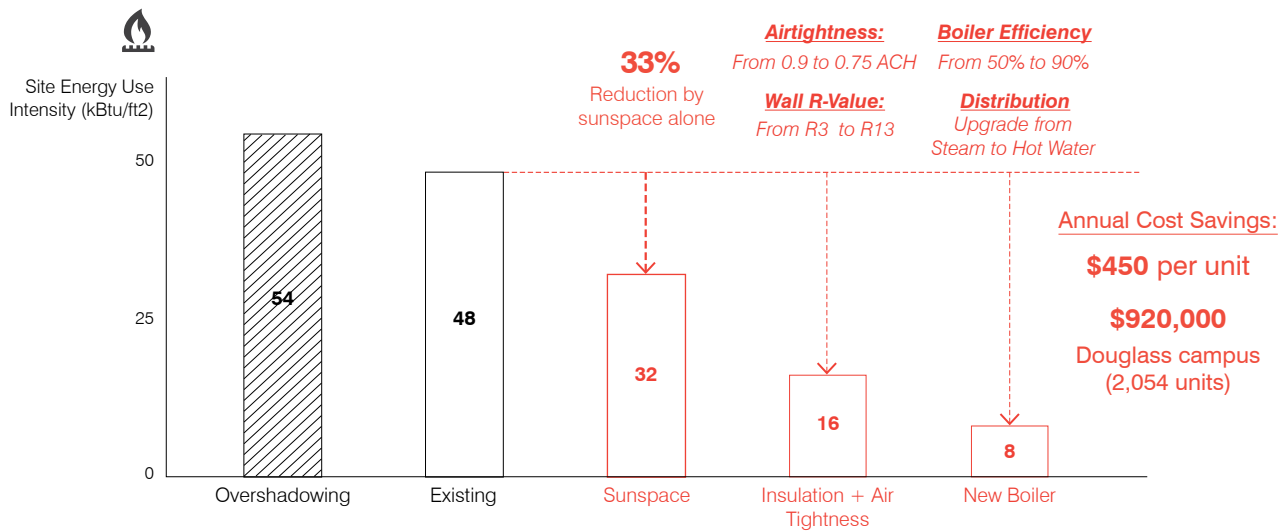


Figure 5-8. Further heating energy reduction measures can add to a significant cost savings for the entire Douglass Houses development

26. HUD. *Affordable Green*, 6.

27. Con Edison. “NYCHA, ConEd Team Up on Energy-Saving System”

06 Projections

Architectural Prototype

Looking more closely at the northwest corner of West 100th St. and Columbus Ave., I developed a design prototype for the intersection of the new infill housing development and retrofitted public housing building based on the previous investigations. The purpose of this prototype is to explore and illustrate the potential for a holistic architectural approach that integrates new construction with existing upgrades.

As the proposed infill development at this location takes on an “L” shape, I divide it into two zones: a double-loaded wing of flats, and a gallery-access bar of duplex apartments (Figure 6-1). The two apartment layout typologies allow for a well-balanced mix of unit types, while the access gallery—which has the same proportions as the sunspace addition—presents an architectural link between the new and existing buildings in the form of a continuous building skin. The axonometric drawing (Figure 6-2) demonstrates how the design creates a consistent street wall frontage at ground level, providing a greater connection of community amenities and retail spaces with the sidewalk on Columbus Ave.

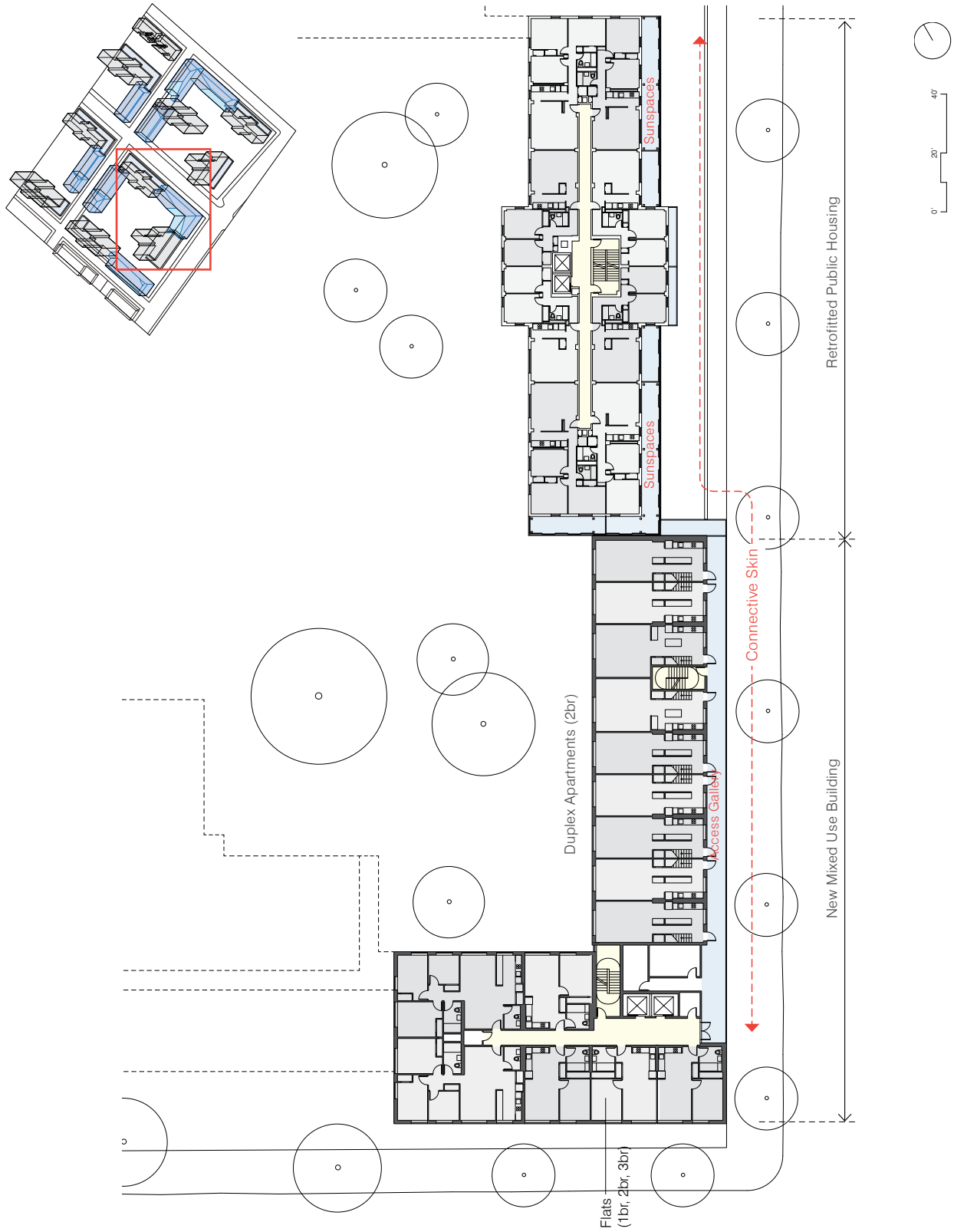


Figure 6-1. Typical floor plan of new infill development with upgraded existing public housing.

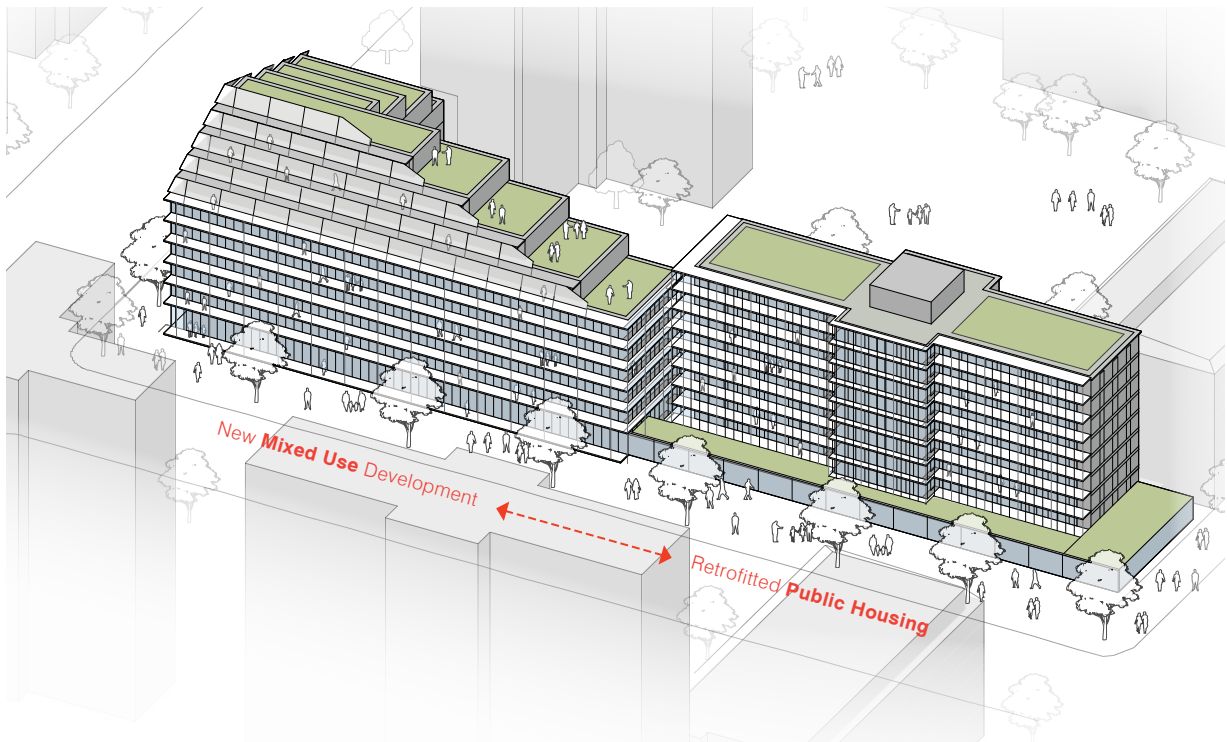
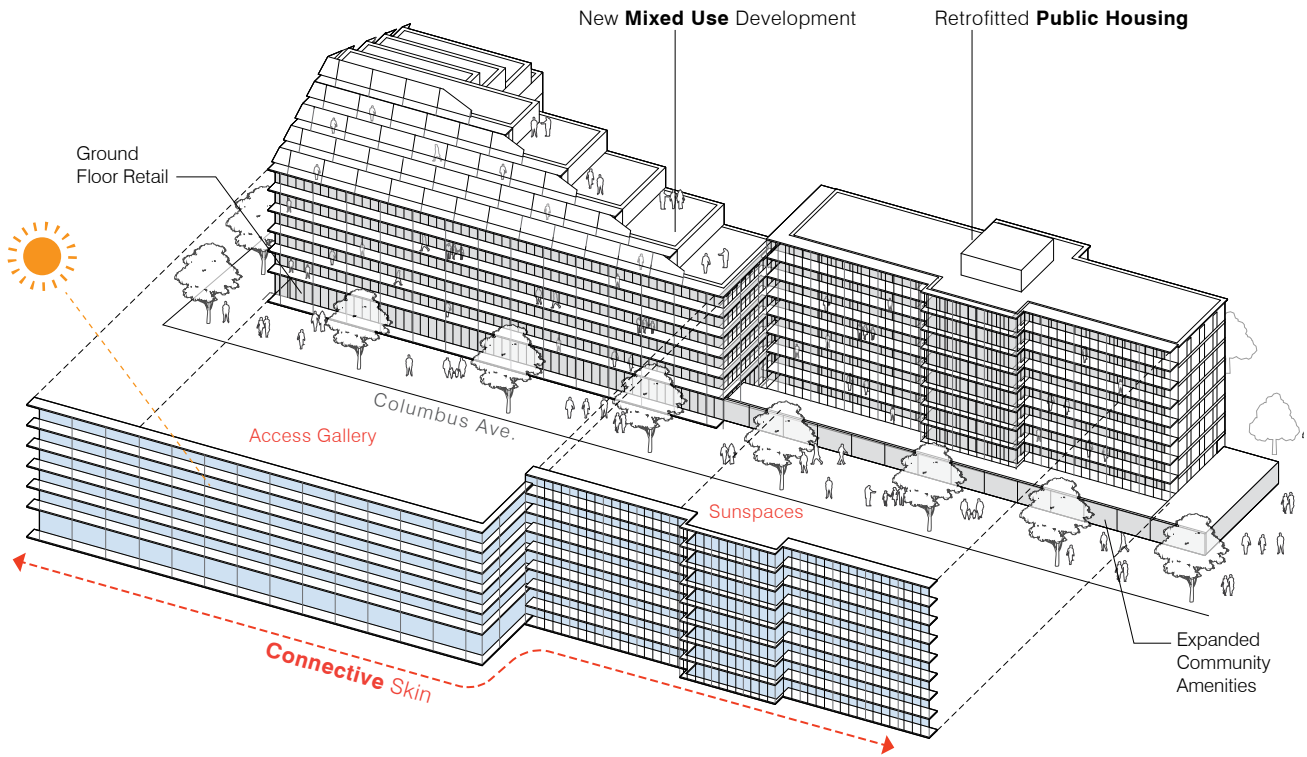


Figure 6-2. Axonometric drawings showing architectural link between new infill development and retrofitted public housing

Finance

The following discussion considers how my proposed passive solar redevelopment strategy has advantages that make it financially viable as a public-private partnership despite potentially higher associated initial costs.

As discussed in earlier sections, the 2013 Land Lease Initiative assumed maximum as-of-right development for its infill proposals, which would lead to denser, taller residential building typologies with inherent efficiencies between construction cost and rentable area. It is reasonable to assume that a lower-density, more distributed development, such as the solar access infill proposal, would result in higher construction costs to achieve the same number of units, owing to greater quantities of building envelope, elevator cores, structure, and foundations. To estimate this difference, I compared the per-dwelling-unit project costs of two recent housing developments: the Elliott-Chelsea Tower in Manhattan and Via Verde in the Bronx.

The Elliott-Chelsea Tower predates the Land Lease Initiative, but its size and construction on a purchased NYCHA parking lot bears many similarities to the proposed Land Lease schemes. According to a recent report by HR&A Advisors, the total project cost per dwelling unit for Elliott-Chelsea was \$386,000.²⁸ Via Verde is an example of a lower-rise development with multiple sustainable design features (such as cross-ventilated apartments and green roofs contributing to LEED Gold Certification) resembling my proposal's massing and construction typology. The HR&A report indicates its total project cost per dwelling units as \$441,000.²⁹ Adding to this project cost discrepancy, my proposal argues for the inclusion of significant existing building upgrades. How might these greater initial costs be supported?

First, the increased sidewalk frontage along existing and new streets offered by my proposal presents a greater opportunity for ground floor retail in a neighborhood with high commercial demand. The Douglass Houses superblock, despite its proximity to major mixed-use thoroughfares, is devoid of any retail activity owing to its residential zoning district. This is particularly evident along

28. HR&A Advisors, "Cost of Rehabilitation versus the Cost of Replacement," 20.

29. *ibid*, 20 (12% of the project cost of Via Verde included brownfield remediation.)

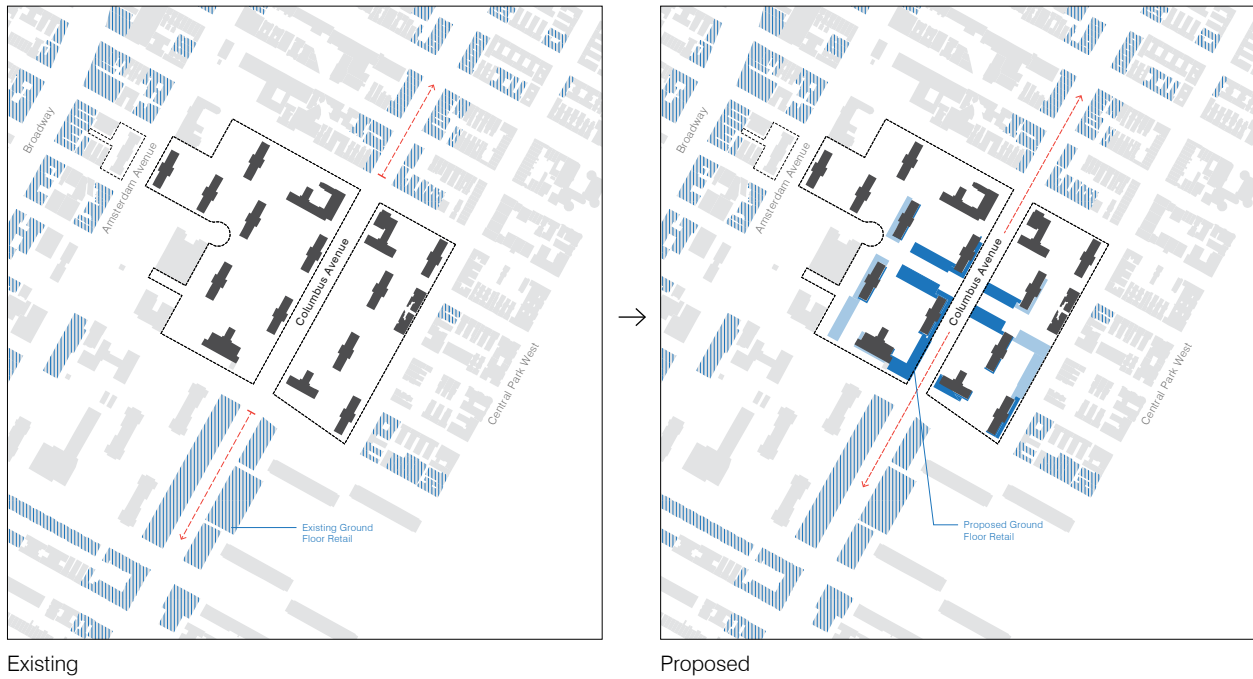


Figure 6-5. Providing continuity along the Columbus Ave. Retail Corridor.

Columbus Avenue, one of the Upper West Side’s busiest retail corridors, which is interrupted by the thousand-foot stretch at Douglass Houses. Providing a continuity of retail spaces along Columbus Avenue could bring in added value for enhanced ground lease revenue to benefit both NYCHA and potential development partners (Figure 6-5).

Second, operational cost savings from ambitious energy-efficiency approaches for both the existing and new buildings can have feasible payback potential for the initial higher costs of construction. This is a particularly interesting direction if both the public housing upgrades and new infill development are carried out through a public-private partnership. Programs such as the Rental Assistance Demonstration (RAD) and Energy Performance Contracting give the housing authority the ability to leverage additional private capital to finance existing building upgrades.³⁰

30. NYCHA. *Annual Agency Plan for Fiscal Year 2015*, 16, 111.

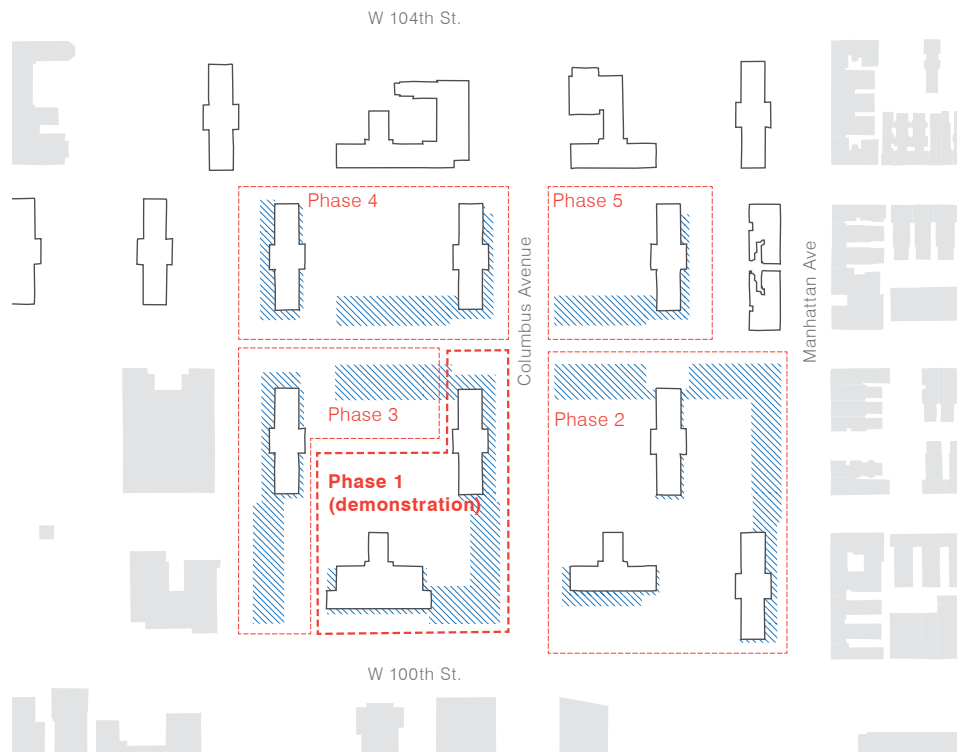


Figure 6-6. Phasing of development to allow for initial “demonstration” pilot area.

Lastly, as a larger master plan that can be subdivided into multiple project areas, my study presents the opportunity for reduced investment risk through phasing.³¹ For example, in the Douglass Houses master plan, should one real estate developer undertake the infill and rehabilitation of a smaller initial portion of the site without committing to the entire development, this first phase may serve as a demonstration pilot project (Figure 6-6). The demonstrated success of a smaller pilot project can promote future investment and has the potential to present less risk for the retrofitting and development of subsequent phases.

31. Geltner and Miller. *Commercial Real Estate*, 780.

Reproducibility

I studied the potential scalability of my integrated retrofitting and development proposal. Starting with a map of NYCHA's 334 developments, I spatially related public housing sites with zones of potential future urban development. To approximate future development, I overlaid the map with a spatial visualization of median property value per lot area (property value intensity) by neighborhood in New York,³² indicating the proximity of local housing authority projects to higher-value areas where there may be more market demand for increased housing supply (figure 6-7). I found that approximately 36% of NYCHA's de-

32. NYC's MapPluto, <http://www.nyc.gov/html/dcp/html/bytes/applbyte.shtml>

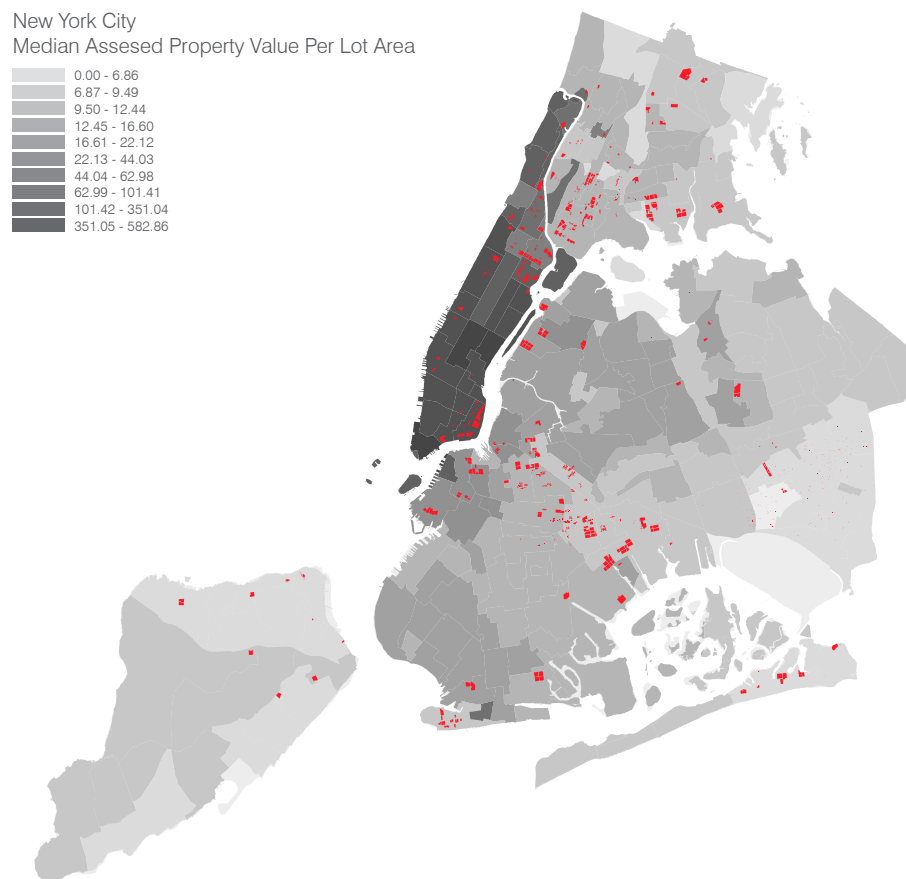


Figure 6-7. Map of median assessed property value per lot area with grayscale gradient by neighborhood, and an overlay of NYCHA public housing developments in red.

velopments lie within a half mile of neighborhoods having at least the median property value intensity (figure 6-9, middle).

Within these developments, I identified those public housing sites that have sufficient open space to support increased residential and commercial density. I used lot coverage as criteria for determining which developments are suitable for infill development. For example, the existing buildings within the Douglass Houses campus are oriented parallel to the surrounding street grid with a low (16%) lot coverage, leaving a network of relatively large interstitial spaces with a high potential for infill development (Figure 6-8). By contrast, older developments such as the Williamsburg Houses in Brooklyn have higher coverages with smaller and more oddly shaped patches of open space that would be less conducive to new infill. Only including those sites with less than 20% lot coverage leaves 11% of NYCHA developments, or 19,600 dwelling units.

Based on the heating energy cost savings calculation from the previous section, this mapping study suggests that, if applied toward these applicable NYCHA developments, my proposed model for public housing redevelopment has the potential to yield an **annual utility savings of \$8,770,000**.

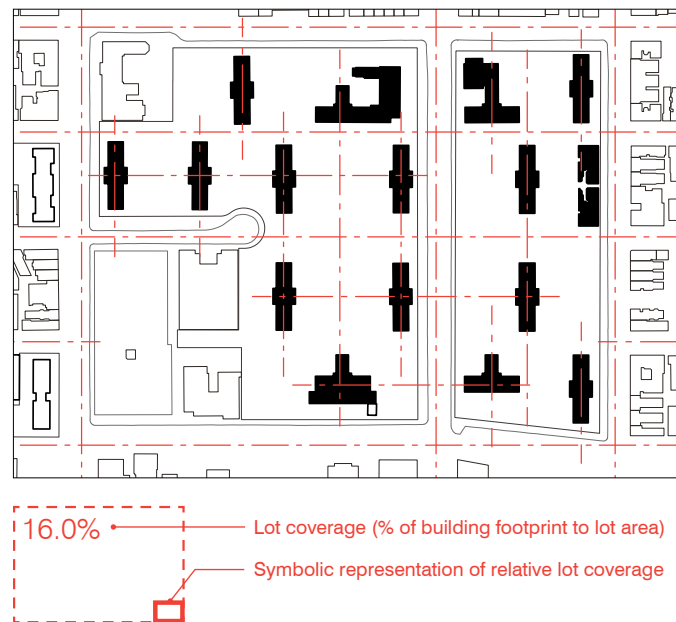


Figure 6-8. Plan of Douglass Houses showing lot coverage and relationship to surrounding urban grain.

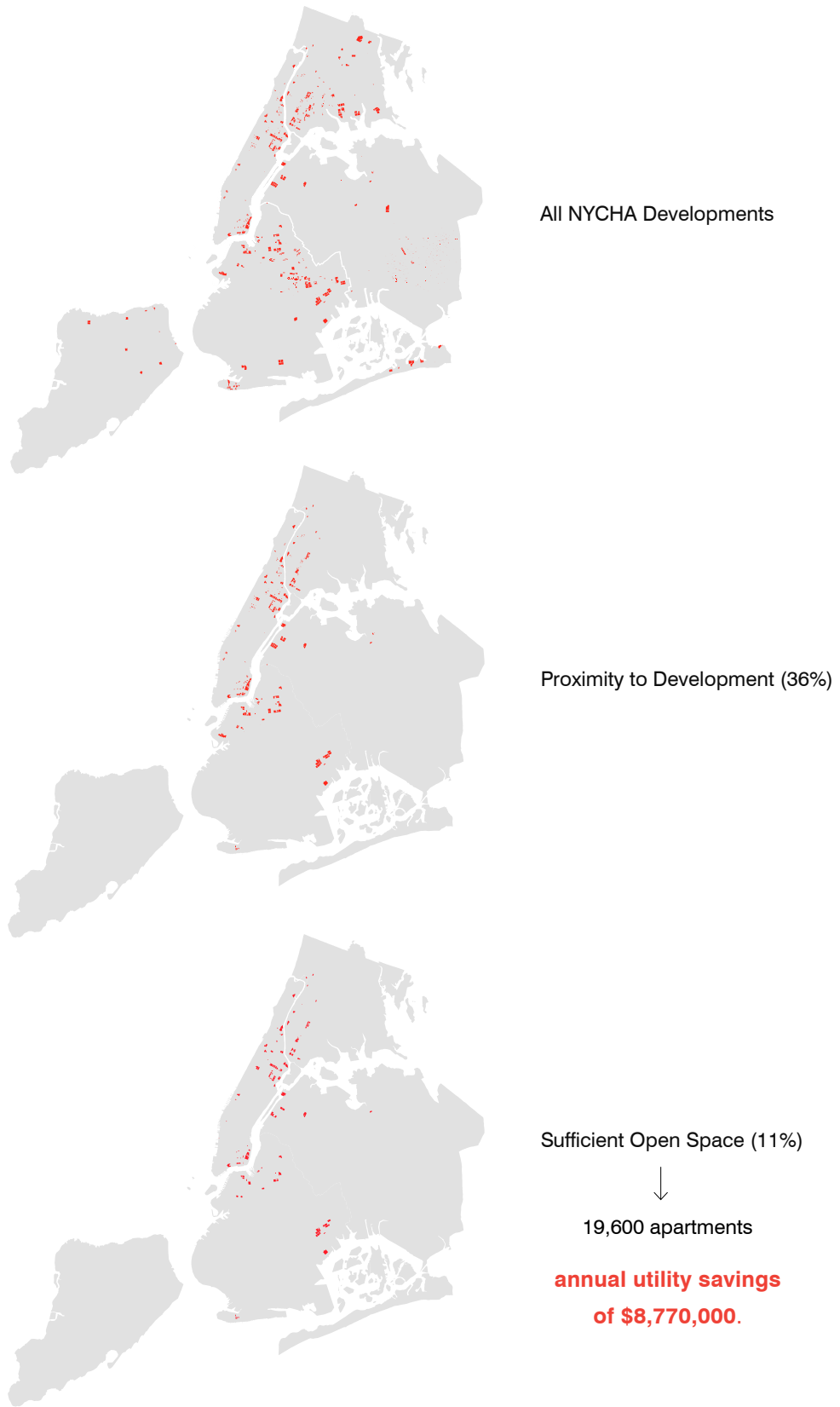


Figure 6-8. Filtering of sites for potential redevelopment uptake.

07 Conclusion

This thesis explored how an environmentally-responsive public housing redevelopment approach creates a strong link between existing building upgrades with new infill development. Typically viewed as separate, exclusive processes, energy retrofits and land asset management can have a mutually beneficial relationship as part of a collective redevelopment strategy.

With the Douglass Houses in Manhattan as a case study, I used solar radiation and daylighting analysis to demonstrate overshadowing problems associated with the 2013 Land Lease approach. In response, I employed a data-driven solar zoning technique to inform a more distributed, lower-rise pattern of infill development that preserved solar access to the existing buildings. I then explored the passive solar and daylighting benefits of unconditioned sunspace expansions to the existing building facades. Combining these methods across precinct, building, and living unit scales, I designed an integrated, energy-efficient master plan for Douglass Houses that, if replicated as a model on other eligible NYCHA sites, could significantly advance the city's housing and energy-efficiency goals.

Building on my study, further research might include site-responsive infill development and retrofitting in relation to resilience and climate change—issues that are central to bigger-picture sustainability planning in cities like New York. While my investigation focused on heating energy reduction strategies, managing overheating through passive means such as natural ventilation and shading is critical in sustaining public housing for future generations, especially within the context of global warming and increased storm events. The sunspace retrofit model presented is well situated for this type of study, as the

enlarged operable window areas, added fixed shading depth, and increased thermal mass that the sunspace affords over the existing public housing has the potential to yield improved natural ventilation performance. Further study into net-zero or energy-positive planning solutions, such as micro-grid or energy generation strategies, would also strengthen neighborhood scale public housing redevelopment within the context of environmental performance and resiliency.

My research into New York's public housing redevelopment contributes to ongoing reforms to NYCHA land asset management and energy efficiency planning. Mayor Bill de Blasio's recent declaration of "a total reset" to the approach to public housing includes calls for new ideas about the use of underutilized open space, existing building upgrades, and closing NYCHA's funding gap.³³ The De Blasio administration's release of the *One City: Built to Last* platform demonstrates a commitment to sustaining an energy-efficient future for public buildings in New York, including retrofits to public housing.³⁴ In April of 2015, NYCHA officials announced a series of new Energy Performance Contracts with the Department of Housing and Urban Development (HUD) to retrofit nearly 300 public housing developments.³⁵ As details and requests for proposals emerge in the coming years, my public housing revitalization proposal offers a pathway to not only finance and achieve important quantitative energy savings, but also to improve the quality of neglected urban spaces in the process.

My study also fits strongly with changing priorities at the national level with regard to public housing upkeep and redevelopment. With the Choice Neighborhoods Initiative, HUD is shifting its public housing redevelopment approach from physical improvements to incorporate enhancing social support systems (addressing larger deficiencies in education and safety) at the community scale. Moreover, as HUD expands its focus on the Rental Assistance Demonstration Program (RAD), more housing authorities are converting conventionally funded public housing to privately-funded, HUD-subsidized property for

33. Navarro, Mireya. "Public Housing in New York Reaches a Fiscal Crisis."

34. City of New York. *One City Built to Last*.

35. Office of the Mayor of New York City. "Nation's Largest Energy Savings Program for a Public Housing Authority."

more flexible financing.³⁶ With the rise of neighborhood-scale redevelopment and public-private partnerships at the national level, there are greater opportunities for city officials, developers, and housing advocates to collaborate in promoting strong links between the fields of urban design, socially responsible planning, and energy-efficiency.

As cities like New York tackle present and future affordable housing needs, the preservation of existing buildings and construction of new ones should not be treated as mutually exclusive strategies. A passive solar design approach to public housing that connects new, site-sensitive development with existing building upgrades can avoid adverse environmental consequences and contribute to long-term energy reduction goals.

36. HUD. "Rental Assistance Demonstration," portal.hud.gov/.

Appendix 01 - Energy Model Inputs

Constant Parameters

Analysis tool	Archsim (running on Energy Plus v8.1)
Weather file	New York-LaGuardia AP 725030 (TMY3)
Area per floor	7,300 ft ²
Floors in model	four (Roof modeled as partially adiabatic to simulate high rise)
Natural Gas Rate	\$1.22/therm (NY State residential average) http://www.eia.gov/naturalgas/data.cfm

	Baseline	Sunspace
Constructions		
Roof	R-13 built-up, 2" polyiso, 6" concrete	R-25 4" polyiso + 4" concrete
Exterior Walls	R-3 brick on CMU, no insulation	R-19.5 3" insulated metal panel
Slab	6" concrete	4" concrete
Window-To-Wall Ratio	0.25	0.8 Existing opening enlarged to 40%
Fenestration		
Description	Double IGU uncoated; Air	<i>[Inner]</i> Double IGU; Low-e (#2, #4); Argon <i>[Outer]</i> Single uncoated
U-Value Ctr. (Btu/hr-ft ² -F)	0.482	0.275
SHGC	0.763	0.783
Infiltration (ACH)	0.9	0.4
Internal Gains		
Occupancy (ft ² /person)	270	n/a
Lighting (W/ft ²)	1.0 Corridors: 0.6	n/a
Equipment (W/ft ²)	1.0 Corridors: 0.0	n/a
HVAC		
Heating Setpoint	72 Steam radiators (50% efficiency)	n/a
Cooling Setpoint	75 Window A/C (3.1 COP)	n/a
Zone Mixing		
	n/a	Scheduled (50% of occupied hours between apartment and sunspace zones during heating season)
Design flow rate (cfm)		20
Operable Area		0.4

Schedules
Apartment Thermal Zones

Hour	Occupancy		Lighting		Equipment	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	1	1	0	0	0.3	0.3
2	1	1	0	0	0.3	0.3
3	1	1	0	0	0.3	0.3
4	1	1	0	0	0.3	0.3
5	1	1	0	0	0.3	0.3
6	1	1	0.3	0.2	0.5	0.3
7	1	1	0.4	0.3	0.6	0.4
8	0.5	1	0.5	0.4	0.6	0.5
9	0.25	1	0.4	0.5	0.5	0.5
10	0	0.5	0.3	0.4	0.4	0.5
11	0	0.5	0.1	0.3	0.3	0.5
12	0	0.5	0.1	0.2	0.3	0.5
13	0	0.5	0.1	0.2	0.3	0.5
14	0	0.5	0.1	0.2	0.3	0.5
15	0	0.5	0.1	0.2	0.3	0.5
16	0	0.5	0.3	0.3	0.3	0.5
17	0	0.5	0.4	0.4	0.3	0.5
18	0.25	0.5	0.5	0.5	0.4	0.5
19	0.5	1	0.6	0.6	0.5	0.6
20	1	1	0.6	0.6	0.6	0.6
21	1	1	0.6	0.7	0.6	0.6
22	1	1	0.6	0.7	0.5	0.6
23	1	1	0.5	0.6	0.4	0.6
24	1	1	0.3	0.5	0.3	0.4

Appendix 02 - Daylight Analysis Inputs

Constant Parameters

Analysis tool	DIVA 3.0 (running Radiance and Daysim)
Weather file	New York-LaGuardia AP 725030 (TMY3)
Approx. height of task plane from ground	40'
Ground reflectance	0.2
Outside facade reflectance	0.35
Ambient bounces	3
Ambient divisions	2048
Ambient super-samples	1024
Ambient resolution	256
Ambient accuracy	0.2
Daylight Autonomy Target Illuminance	500 lux
Daylight Autonomy Schedule	8am to 5pm

Radiance Material Assignments

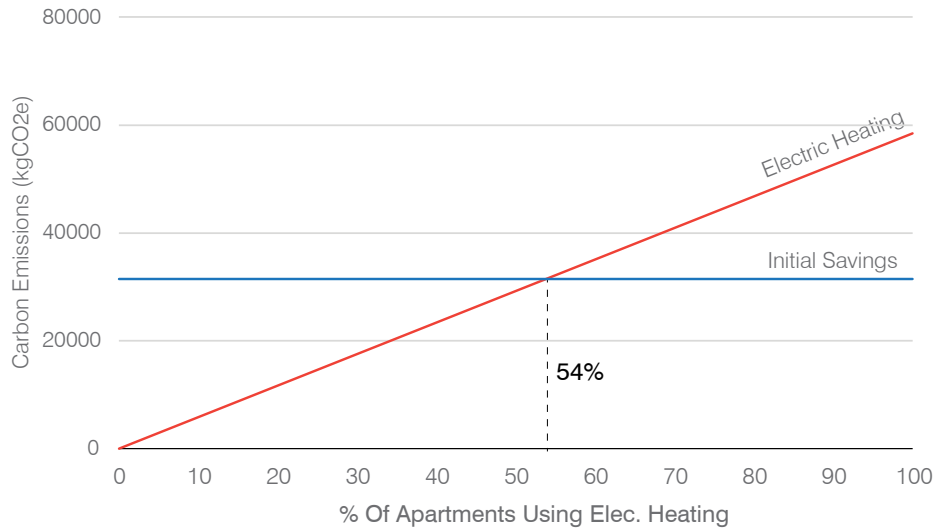
(Reflectance values unless otherwise noted)

	Baseline	Sunspace
Floor	0.2	0.5
Walls	0.5	0.7
Ceiling	0.7	0.9
Glass	0.8 (transmittance)	0.9 (transmittance)
Window Frame	0.3	0.5

Appendix 03 - Sunspace Sensitivity Analysis

The energy benefits of the sunspace addition depends on its thermal performance as a passive, unconditioned space. Unpredictable occupant behavior, such as the use of electric resistance heating in these spaces, can lead to unwanted energy consumption as a result. The graph on the following page shows that the carbon emissions from the daily use of electric heating in the sunrooms would exceed the initial passive solar savings if about half of the apartments used such appliances. Therefore, if sunspaces were considered as an energy savings measure, housing authorities and property managers should work with residents to raise awareness of the passive benefits of an unconditioned sunroom and to limit excessive energy consumption through electrical equipment.

Electric Heating Sensitivity Analysis Carbon Emissions



Schedule Simulated Electric Heating Use

Hour	Weekday	Weekend	Hour	Weekday	Weekend
1	0	0	13	0.1	0.2
2	0	0	14	0.1	0.2
3	0	0	15	0.1	0.2
4	0	0	16	0.3	0.3
5	0	0	17	0.4	0.4
6	0.3	0.2	18	0.5	0.5
7	0.4	0.3	19	0.6	0.6
8	0.5	0.4	20	0.6	0.6
9	0.4	0.5	21	0.6	0.7
10	0.3	0.4	22	0.6	0.7
11	0.1	0.3	23	0.5	0.6
12	0.1	0.2	24	0.3	0.5

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