Weatherproofing of New York City Public Housing for Energy Savings

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https://youtu.be/BL4UcOQq_dY

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Introduction

- Nearly **70% of greenhouse gas emissions** in New York City come from buildings (City of New York, 2018).
- As the largest landlord in the City, the New York City Housing Authority (**NYCHA**), is the greatest contributor to these emissions.
- NYCHA funding has declined in the past few decades and NYCHA housing is currently in need of **$32 billion in repairs** (NYCHA, 2019a). This means that NYCHA lacks the resources to invest in high-cost clean energy solutions, but would benefit greatly from them.
- Over **30% of** these **repairs** are for building components such as **windows**, floors, **roofs**, and doors, which can be improved to **increase insulation**, reducing heating and cooling demands.
- Increased insulation would improve quality of life of NYCHA's 400,000 residents by reducing drafts.

(Ferré-Sadurní, 2018)

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Objective

- This project proposes a two-pronged approach for NYCHA to **improve insulation** of the most expensive aspects of its buildings that it has not already upgraded: **roofs and windows**.
- Although it is acknowledged that existing regulations should be amended to reduce energy use in subsidized housing (Reina & Kontokosta, 2017), it is important to evaluate the extent to which positive change can be seen within the current legal and economic constraints.
- New York City has the greatest amount of public housing and some of the most progressive energy policies of all U.S. cities, so NYCHA is the ideal setting to evaluate how effective retrofitting can be in easing the transition to more energy efficient public housing, if they are effective at all. This would inform other cities on whether to implement similar policies.

Methods: Cost Benefit Analysis for Windows

Found U-value for combination of each shade type with single pane glass and 1-2” air space (Boschetti, 1984):

$$\text{U-value}\ [\frac{\text{BTU}}{\circ\text{F}\cdot\text{ft}^2\cdot\text{h}}] = \frac{1}{\text{R-value}_1 + \text{R-value}_2 + \text{R-value}_3 + ...[\frac{\circ\text{F}\cdot\text{ft}^2\cdot\text{h}}{\text{BTU}}]} \quad (1)$$

Then, calculated heat loss for each combination of single pane glass and shade type (Boschetti, 1984):

$$\text{H [kWh]} = 24\ [\frac{\text{h}}{\text{d}}]\cdot\text{HDD}\ [\frac{\circ\text{F}}{\text{y}}]\cdot\text{U-val}\ [\frac{\text{BTU}}{\circ\text{F}\cdot\text{ft}^2\cdot\text{h}}]\cdot\frac{\text{A}\ [\text{ft}^2]}{\text{window}}\cdot\#\ \text{windows}\cdot\frac{1\ \text{kWh}}{3412\ \text{BTU}} \quad (2)$$

Calculated payback period for each window combination. 7.52¢/kWh used as the fuel cost, representing average 2018 cost of U.S. No. 2 fuel oil with losses and conversion factors for standard boilers.

$$\text{PB [y]} = \frac{\text{Cost}_{\text{window}}[\$]}{\text{Cost}_{\text{fuel}}[\frac{\$}{\text{kWh}}]\cdot(\text{H}_{\text{original}}[\frac{\text{kWh}}{y}] - \text{H}_{\text{insulated}}[\frac{\text{kWh}}{y}])} \quad (3)$$

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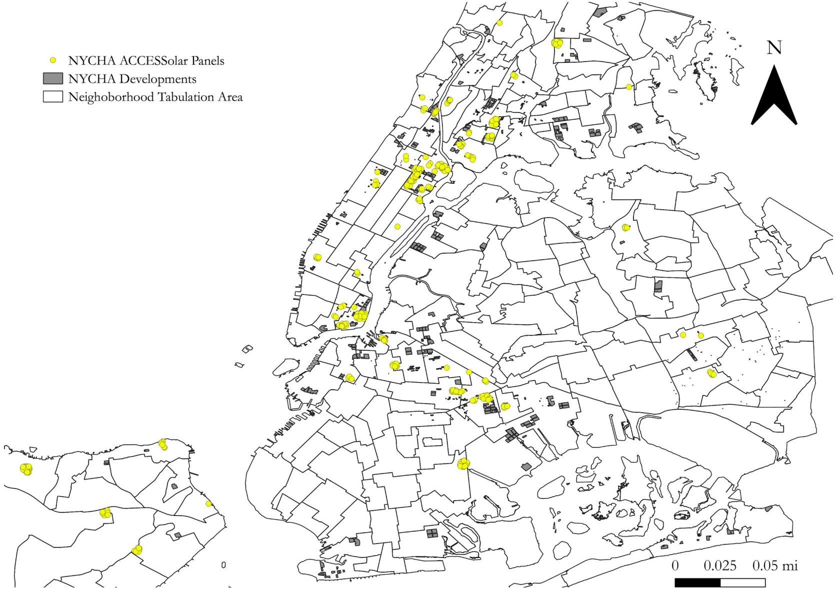
Methods: Cost Benefit Analysis for Roofs

- Three main energy-saving roofing alternatives to standard black asphalt roof: green roofs, white (or cool) roofs, and solar panels. Solar panels removed from analysis due to ACCESSolar program



- Factored in fixed costs such as installation, variable costs such as maintenance, and benefits such as energy cost savings. Additionally, considered current roofing types and ease of implementation.

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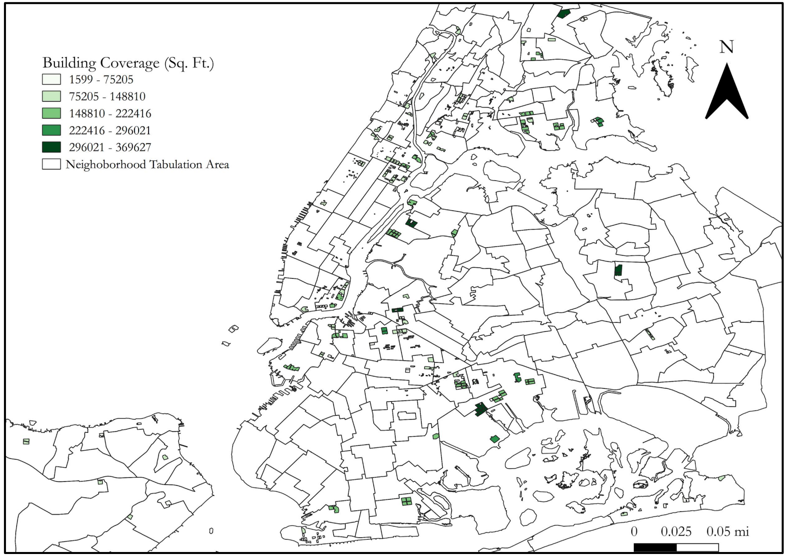
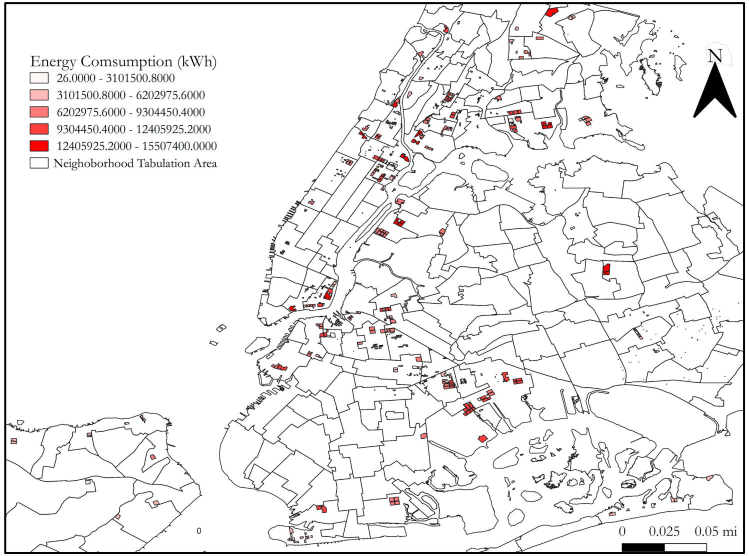
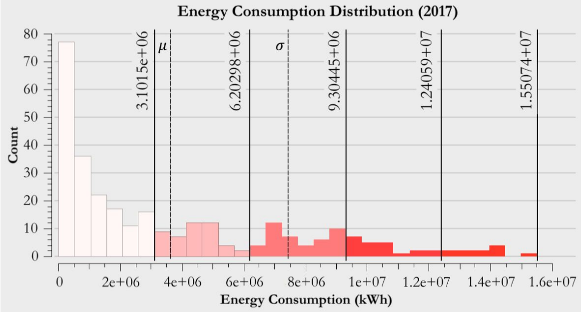
Methods: Selecting Roof Area





- A small number of large buildings consume far more energy per year than the vast majority of others.
- 10,000 ft^2 roof area used for initial analysis as this is average roof size of top 20% of NYCHA developments by 2017 energy consumption.
- Smaller and larger areas tested to confirm trends hold.



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Results: Windows

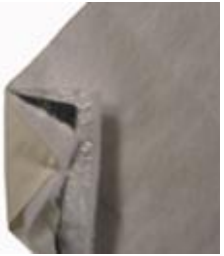
Material		U-value	H (kWh)	Payback (y)
Single pane glass	Single pane glass			
Double pane glass	1/4" air space			
	1/2" air space			
Air space	3/4"-4" deep			
Drapery	Conventional (not insulated or sealed)	0.5	63.24	-0.95418098
	Two-layer system (drapery and lining on separate tracks)	0.2674	33.8182	-14.7690367
	Window Quilt	0.1818	22.9964	28.8738766
	Cornice and drapery	0.3226	40.8	-0.89445562
Roller-shade	Conventional	0.5051	63.8788	-8.02851612
Venetian blinds	Venetian blinds	0.5	63.24	-2.72623137
Interior shutter	3/4" polystyrene core b/w 1/8" plywood panels	0.1493	18.8776	113.94992
Cellular shades	Single cell	0.2941	37.2	-28.7004633
	Premium blackout double	0.1471	18.6	34.6603486
	Premium blackout single	0.1471	18.6	28.9627571
	Premium light filtering double	0.1563	19.7625	28.6498269
	Premium light filtering single-Group B fabrics	0.1626	20.5659	48.1359312
	Deluxe light filtering double	0.1587	20.0762	26.5948728
Insulation board	Clip-on	0.0752	9.50978	0.42792167
Insulated Roman shades	1 layer of fiberfill	0.2326	29.414	-64.7417992
	2 layers of fiberfill	0.1724	21.8069	3.59501357
	3 layers of fiberfill	0.137	17.326	5.34174724
	Prelayered fabric	0.1136	14.3727	3.55821116

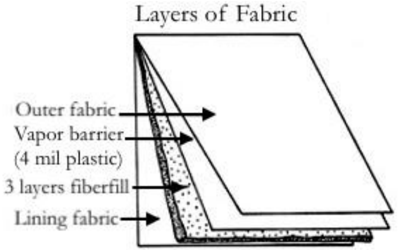
Factor	*Value*	*Source*	Notes
NYC HDD (2017)	3996	https://www	
Fuel cost ($/kWh)	0.19334097	https://www	
Window Area (sq ft)	4.5		Standard 27" window
Number of windows	1		
Original H	29.0904189	https://www	U-value of 0.23
Tax credit ($)	0.1	https://www	10% of cost, up to $200, exclude installation

Legend		
Variable		
U-value	*H*	*Payback*
<Original U-value	>Original H	>5 y
>Original U-value	<Original H	5-10 y
		0-5 y

Single pane glass with prelayered insulated Roman shades was most cost-effective window pairing

- 3.56-year payback period
- Nearly 50% less heat loss than current NYCHA windows.





Results: Roofs

Time (years)	2.2	Area (sq ft)	10000			
	Green Roof	*Source*	*Notes*	CoolRoof	*Source*	*Notes*
Installation Cost relative to conventional, black roof ($/sq ft)	-11	https://www	Range (size)	0	https://www	Free installation for affordable housing
NPV Maintainence Cost rel. conventional, black roof ($/sq ft/y)	-17.5	https://www	Range (size)	-0.7	https://www	Liquid applied coating. Avg roof lifetime 25 y
NPV Stormwater ($/sq ft/y)	13.5	https://www	Range (size)	0		
NPV Energy ($/sq ft/y)	7	https://www	Range (size)	0.032	https://web.	Estimates from ORNL calculator
Tax abatement ($/sq ft)	4.5	https://www	$100,000 cap. One-time	0		
NPV CO2 ($/sq ft/y)	2.1	https://www	All sizes	0.25	http://www.	10 metic tons CO2
NPV Real Estate Effect ($/sq ft/y)	110	https://www	Range (size)			
NPV Community Benefits ($/sq ft/y)	30.4	https://www	All sizes			
TOTAL ($)	**1000**			**88**		

Legend	
Inputs	*Outputs*
Exact	>0
Estimate	0
Ignored	<0
Variable	

Green roofs were the most cost-effective alternative roofing.

- White roofs have a near-zero payback period, while green roofs have a 2.17-year payback period.
- After 2.17 years, green roofs save far more in energy costs than white roofs. For example, after 5 years, green roofs save $85,000 in energy costs, while white roofs save only $200.
- This trend holds for smaller roof areas.
- Green roofs provide supplementary benefits, including for air quality, biodiversity, and mental health.

Conclusions

- Overall, NYCHA's implementation of energy-saving roofing and windows would improve the energy efficiency and climate resiliency of its buildings.
- Green roofs were found to be the most beneficial roofing material, with $85,000 in energy costs for the NYCHA buildings that consume the top 20% most energy.
- Single pane glass with Roman shades with prelayered fabric was the most cost-effective window pairing, decreasing heat loss by nearly 50% relative to current NYCHA windows.
- Combined, these improvements would take under six years to pay off, and would provide long-lasting benefits, ranging from energy and maintenance savings for NYCHA to an increased quality of life for residents of NYCHA buildings.
- Improved insulation would provide NYCHA with the much-needed funds to repair the aging infrastructure on its properties, creating a sustainable solution, both environmentally and economically, that targets the root cause of the problems that affect NYCHA residents.

Future work

- Evaluate effects of increased insulation on indoor air quality and compare to existing NYCHA plans to update ventilation in their apartment buildings, as detailed in its NextGeneration Sustainability Agenda (Ghabaee, 2019).
- Develop maintenance plan for green roofs and shades as NYCHA has struggled with its inability to address major maintenance issues due to a lack of funds and manpower (Santiago, 2019).
- Discuss findings with NYCHA to incorporate into sustainability planning.
- Perform similar analysis with on other public housing systems to determine universality of strategy.

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