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Carbon Trading for New York City's Building Sector:

Report of the Local Law 97 Carbon Trading Study Group to the New York City Mayor's Office of Climate & Sustainability

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Abbreviations

ARP	Acid Rain Program
BAU	Business as usual
CLCPA	Climate Leadership and Community Protection Act
DEEP	Decarbonized Energy Economy Planning
DOB	Department of Buildings
DOHMH	Department of Health and Mental Hygiene
EJ	Environmental justice
EJC	Environmental justice community
EPA	Environmental Protection Agency
ETS	Emission trading system
EU	European Union
GHG	Greenhouse gas
HCR	Homes and Community Renewal
HDFC	Housing Development Fund Corporation
IWG	Interagency Working Group
LL84	Local Law 84 of 2009
LL97	Local Law 97 of 2019
MOC&S	Mayor's Office of Climate & Sustainability
NPV	Net present value
NYC	New York City
NYCHA	New York City Housing Authority
NYU	New York University
REC	Renewable energy credit
RECLAIM	Regional Clean Air Incentives Market
RGGI	Regional Greenhouse Gas Initiative
RPIE	Real Property Income and Expense
SCAQMD	South Coast Air Quality Management District
UGC	Urban Green Council

Executive Summary

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New York City's Local Law 97 (LL97) of 2019 caps the volume of greenhouse gas emissions that large buildings can release each year without paying a penalty. The law takes effect in 2024, and the caps become progressively more restrictive until 2050. With some exceptions, commercial, residential, institutional, and industrial buildings with more than 25,000 square feet are all subject to the caps.

As it is currently written, LL97 outlines several compliance pathways for building owners whose properties emit more than the caps allow. They can avoid exceeding the emissions caps in the first place by investing in energy efficiency improvements or using clean distributed generation for a portion of their energy needs. They can also purchase renewable energy credits or greenhouse gas offsets, or pay a penalty to cover their excess emissions. The law does not, however, permit owners to buy emissions credits from other owners who emit less than they are legally obligated to do. In other words, the law does not provide for emissions trading. Instead, it calls for the Mayor's Office of Climate & Sustainability (MOC&S) to conduct a study into whether it would be feasible for the City to develop an emissions trading program as an alternative compliance pathway and to report its findings to the Mayor and City Council.

This report details the results of that study. The Study was conducted by an interdisciplinary team of researchers at New York University, The Brattle Group, HR&A Advisors, Steven Winter Associates, and Sustainable Energy Partnerships, who worked in collaboration with MOC&S. Working over more than a year, the Study conducted an extensive review of the literature regarding emissions trading programs, expert interviews, and legal analysis of the potential for New York City to adopt a trading program. The Study also built a detailed economic optimization model to predict the impacts of different trading market designs.

In considering the potential impacts of a trading program, the Study specifically focused on whether it would be feasible to design a trading program for buildings' GHG emissions that would promote environmental justice. Thus, the Study aimed to design a program that would advance a suite of goals including accelerating GHG reductions from buildings, reducing the costs of GHG emissions reductions, and stimulating more investment in environmental justice communities (EJCs) compared with LL97 as is. In addition, the Study sought to ensure that EJCs would experience at least the same improvements in air quality under a trading program as they are expected to experience under LL97, and more if possible.

The idea of developing a carbon trading program for buildings is quite novel and therefore warranted bespoke analysis. Most trading programs have regulated the electricity and industrial sectors, and no other jurisdiction in the world has developed an emissions trading program for buildings that regulates nearly as large or diverse a group of properties as LL97 regulates. In addition, New York would be the first city to design a trading program that actively seeks to further environmental justice alongside other long-standing goals for trading programs, such as reducing the costs of lowering pollution levels.

The Study's findings indicate that a carefully designed trading program could further the City's diverse goals. Below, we describe some of the key choices the City would have to make in designing a trading program, if it chooses to do so, and how these choices would shape outcomes. But first, it is necessary to provide some background information on the predicted impacts of LL97 without trading, because some of these underlying dynamics shape the outcomes that would occur if trading were adopted.

Background on the Impacts of LL97 without Trading

There are some important underlying features of LL97 that drive several of the outcomes that we observe under a simulated trading program. These are:

1.

Most buildings will not have to take any action to meet their emissions caps in the first compliance period, which runs between 2024 and 2029. The reason this matters when thinking about a trading program is because it suggests that emissions credit prices would be quite low in the initial compliance period unless measures are implemented to stimulate demand or restrict the supply of credits.[1] There are several tools that policymakers could adopt to achieve these ends, including setting a minimum price for credits, restricting the use of offsets, strictly defining the baseline below which emissions must drop to generate credits, and/or enabling credit banking. We discuss each of these options further below.

2.

Grid decarbonization will substantially lower buildings' emissions and therefore lower the cost of complying with LL97. If the electricity grid is decarbonized by 2040, as outlined in the Climate Leadership and Community Protection Act (CLCPA), grid decarbonization will drive most of all citywide emissions reductions necessary to comply with LL97 at a city level.[2] This greatly reduces the cost of complying with LL97. In fact, we estimate that if the grid is decarbonized on pace with the CLCPA, LL97 will only require owners to spend $1.2 billion (2020$, 2020 NPV) to bring their properties into compliance with the law over the 26 years that it is supposed to be in effect.

3.

The anticipated low cost of complying with LL97 limits the potential for trading to reduce compliance costs. If LL97 itself is not predicted to impose very substantial compliance costs on property owners, adding the option of trading can only produce modest cost savings. Of course, this does not mean that trading cannot provide other significant benefits such as earlier GHG reductions, or that it will not provide significant cost savings to individual property owners who have higher-than-average costs.[3] Still, our prediction that LL97 will not impose very substantial costs on most building owners necessarily limits the amount of money that trading can save the average building owner.

Some stakeholders are skeptical that the State will decarbonize the grid at the pace the CLCPA mandates, and a prior estimate of the costs that LL97 would impose on building owners did not factor in grid decarbonization.[4] If the costs of LL97 are higher than our model describes, the cost savings that trading provides will likely be higher too, because more action will need to be taken by more owners. But because the State has legally mandated that the grid be decarbonized by 2040, the Study included it as the base case assumption for modeling.[5] If the grid is not decarbonized at this pace, the cost of LL97 will be higher, and the potential for trading to lower costs would be larger too.

If the electricity grid is decarbonized by 2040, as outlined in the Climate Leadership and Community Protection Act (CLCPA), grid decarbonization will drive most of all citywide emissions reductions necessary to comply with LL97 at a city level.

1. Low credit prices can be considered problematic because they do not provide robust incentives to invest in retrofits.

2. For more details on how grid decarbonization drives emissions reductions from buildings with LL97 caps, see Part 6.

3. The Study's modeling methodology considers the average costs of compliance for different types of buildings, and both costs and cost savings could be significant for some buildings.

4. See Part 6 for more discussion of this point.

5. We included a robustness check that assumed a ten-year delay on CLCPA implementation as well. See Part 8.B.

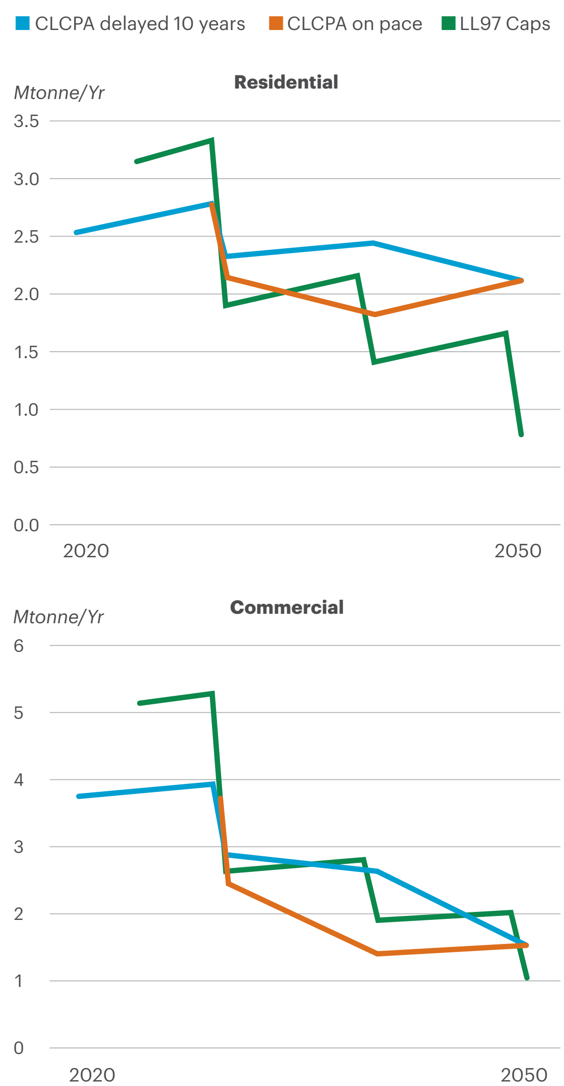
4.

At the anticipated pace of electricity grid decarbonization, LL97 will require residential building owners to take more action than commercial building owners. The reason for this is that commercial buildings are far more electrified than residential buildings. While roughly 74% of the residential buildings subject to the LL97 emissions caps are attributable to onsite combustion of fossil fuels for heating and hot water, only 42% of covered commercial buildings' emissions are attributable to onsite combustion.[6] (As used in this report, "commercial buildings" include office, retail, and hospitality sectors.) Most of the rest of commercial buildings' energy comes from electricity. As a result, if the grid decarbonizes at pace with CLCPA, commercial buildings in general will see their emissions rapidly decline over the next two decades even if they do not invest in energy efficiency improvements or other carbon abatement measures.[7] Residential buildings' emissions will decline as well, but not as significantly. Figure 1 describes the impact of grid decarbonization on commercial and residential buildings emissions.

5.

On average, building owners in environmental justice communities will need to spend more money to bring their buildings into compliance than building owners outside of those neighborhoods. The different impacts that LL97 emissions caps have on commercial and residential properties leads to another dynamic that is important to understand: because commercial buildings are concentrated in midtown and lower Manhattan, which are not EJCs, a higher share of covered buildings in EJCs than non-EJCs will be over their LL97 caps if they continue business as usual. This leads to two effects when trading is introduced: first, introducing trading provides greater cost savings for building owners in EJCs than non-EJCs; second, without targeted subsidies or restrictions, building owners in EJCs will be net purchasers of emissions credits and non-EJC building owners will be net sellers. Figure 5 provides a map of the areas of the City that we have defined as EJCs for the purpose of this study.

Figure 1. Impact of CLCPA grid decarbonization on residential and commercial building emissions.



6. These percentages differ slightly from those in the TWG One City Built to Last report, which finds that fossil fuels account for 73% of residential buildings' energy use and 45% of commercial energy use. The slight discrepancies may be due to the fact that the figures in this study summarize only properties covered under LL97. Because residential buildings derive more of their energy use from onsite combustion of fossil fuels than electricity, the average covered residential building needs to reduce energy consumption to meet their LL97 limits even after the grid is decarbonized. By contrast, up until 2050, the average commercial building will see its emissions fall below the LL97 cap if the grid decarbonizes at pace with CLCPA without having to take further action. In aggregate, at a city-wide level, this results in electricity decarbonization doing most of the work for the City to comply with the aggregate city limit. But that does not mean all buildings will be below their caps if electricity decarbonizes.

7. Note that energy usage across individual commercial buildings may vary greatly depending on their uses and so the impact of decarbonizing the grid will vary as well.

Designing a Tailored Trading Program for LL97

Emissions trading programs can take many different forms, and so the City has a number of choices to make in designing an emissions trading program that furthers its specific goals, including its environmental justice priorities.[8] Consistent with the City's direction, in developing a potential trading program design that could be adopted pursuant to LL97, the Study homed in on structures that prioritize emissions reductions and investment in EJCs. The Study generated two illustrative trading design proposals, the elements of which are summarized in Table 1.

Credit Allocation Method

The highest impact decision the City faces in designing a trading program is whether to allow buildings to freely emit up to the buildings' LL97 emissions caps or to make buildings purchase credits equal to some percentage of such emissions at auction. Auctions provide a convenient means of implementing a price floor,[9] which is important in reducing investor and decision-making uncertainty, driving early action, and achieving greater overall GHG reductions. The sale of emissions credits at auction also generates a source of funding that can be used to directly invest in retrofitting buildings in EJCs. And if only a portion of the credits are auctioned, with the remainder given out for free, the City can give a larger portion of free credits to buildings in EJCs than non-EJCs. A trading program that combines these measures (price floor, more free allocation to EJCs than non-EJC buildings, and targeted investment of auction proceeds) could meaningfully increase investment in EJCs compared to LL97 without trading and substantially reduce air pollution in EJCs. It could also increase the total economic benefits of LL97 to the City as a whole.[10]

However, there are some drawbacks to auctioning off a portion of credits as well. To begin with, requiring non-EJC building owners to purchase credits to cover some of the emissions that LL97 currently allows them to emit for free effectively tightens the caps for these buildings. This could increase costs for building owners in non-EJCs who would have to pay for a higher percentage of their total GHG emissions than they would under LL97 without trading.[11] The Study also assumed that the City would seek and obtain State legislative authorization before implementing an auction. Additionally, the City has traditionally shied away from earmarking revenue to spend on specific purposes.[12] Developing and running an auction program would impose additional administrative costs on the City as well.

8. See Part 7 for a discussion of the variable elements of emissions trading programs.

9. It may also be possible to implement a price floor without auctions by requiring a fee equal to the price floor to be paid upon surrender, but this has not been a common approach in precedent trading markets.

10. We define economic benefits broadly to include the monetized benefits of things such as lower energy bills from energy efficiency savings and air quality improvements from reduced pollutant emissions. While not calculated here, retrofits may also increase tenant living conditions and environments.

11. See Appendix D for detailed cost impacts.

12. Importantly, the Study did not discover any concrete legal obstacles to earmarking.

Table 1. Summary of illustrative trading program designs proposals.

Design Element	Proposal #1	Proposal #2
Credit Allocation Method	This proposal uses a combination of free allocation and auctions. Buildings in EJCs are freely given credits equal to 100% of their LL97 cap or 2018 emissions, whichever is less. Buildings in non-EJCs are freely given credits equal to the 70% of their LL97 cap or their 2018 emissions, whichever is less. The City auctions off credits equal to 30% of the non-EJC buildings' caps. 2018 emissions are adjusted for grid decarbonization after 2029.	This proposal does not include an auction. All buildings can emit up to their LL97 caps without having to purchase any credits; buildings can generate credits if they emit less than both their LL97 cap and 2018 emissions. 2018 emissions are adjusted for grid decarbonization after 2029.
EJ Policies	All Section 321 and NYCHA buildings are eligible for opt-in. Section 321 buildings are freely given credits equal to their 2018 emissions minus projected emissions savings provided by the prescriptive measures listed in Section 321. NYCHA buildings are freely given credits equal to their 2018 emissions. Buildings that opt in can sell excess credits. 2018 emissions are adjusted for grid decarbonization after 2029. Auction proceeds fund 20% of cost of retrofits in EJCs. EJC buildings get 100% free allocation up to lesser of 2018 emissions or LL97 cap.	All Section 321 and NYCHA buildings are eligible for opt-in. Section 321 buildings generate credits that they can sell if they emit less than their 2018 emissions minus projected emissions savings provided by the prescriptive measures listed in Section 321. NYCHA buildings generate credits that they can sell if they emit less than their 2018 emissions. 2018 emissions are adjusted for grid decarbonization after 2029. Assume accelerated phase-out of fuel oil #4 by 2025 instead of 2030.
Price Floor	$50 price floor	None
Banking	Banking is allowed but credits decrease in value by 20% each year.	Banking is allowed but credits decrease in value by 20% each year.
Offset Eligibility	Offsets are not allowed in any compliance period.	Offsets are not allowed in any compliance period.

Given the pros and cons of auctions, the Study developed two illustrative trading program design proposals for the City to consider, one of which incorporates an auction (Proposal #1) and one of which does not (Proposal #2). Under Proposal #1, the City would create and allocate credits to buildings with LL97 emissions caps through a combination of free allocation and auctions. EJC buildings would be freely given credits equaling the lesser of their LL97 building caps or their 2018 emissions. Non-EJC buildings would receive free credits equivalent to 70% of the lesser of their LL97 building caps or 2018 emissions; these buildings would need to buy additional credits they require to comply with LL97 at auction or on the secondary market. Under Proposal #2, credits would be generated by buildings that reduce their GHG emissions below their LL97 buildings caps and 2018 emissions. [13]

Environmental Justice Policies

To promote investment in EJCs, both proposals permit NYCHA properties and properties subject to prescriptive measures under Section 321 of LL97, which includes a large number of affordable housing buildings, to opt into a trading program.[14]

Proposal #1 allocates auction proceeds to fund 20% of the cost of retrofitting buildings in EJCs. This use of auction proceeds will promote investment in EJCs.

Allocating auction proceeds to fund retrofits in EJCs also helps to ensure that Proposal #1 meets MOC&S' goal that trading not increase any local air pollutant in EJCs in any given year between 2024 and 2050 compared to LL97 without trading. As described further in Part 4 , LL97 calls for a trading study to examine methods to ensure that trading does not produce "any localized increases in pollution"[15] but does not specify a geographic or temporal scale that should be used to measure such increases. MOC&S interpreted this provision as requiring that a trading program could not increase any local air pollutant ($PM_{2.5}$, SO_x, or NO_x) in EJCs in any given year compared to LL97 without trading.

The Study's modeling found that a simple trading program that did not invest any auction proceeds to retrofit buildings in EJCs would result in less total GHG, SO_x, and $PM_{2.5}$ emissions over the course of the study period than under LL97 without trading, thus reducing aggregate levels of pollution by more than LL97 as is. However, modeling also indicated that such a program would lead to a small increase in NO_x emissions in EJCs in the first compliance period (2024–2029) compared to LL97 without trading,

13. After 2029, buildings' 2018 emissions will be adjusted downward to reflect the effects of electricity grid decarbonization. Failure to adjust 2018 emissions in this manner for the purpose of allocating credits would create a windfall allocation for building owners who could see their emissions fall as the grid decarbonizes.

14. See Part 2 for more details on the properties covered by Section 321.

15. N.Y.C. Admin. Code § 28-320.11.

which violated MOC&S' criteria.[16] Investing a portion of auction proceeds to retrofit buildings in EJCs is one way, among others, to correct this problem. Allocating auction proceeds to fund retrofits in EJCs enables Proposal #1 to avoid a small increase in NO_x emissions in EJCs in the first compliance period compared to LL97 as is, and also generates additional investment in EJCs, which is another of MOC&S' goals.

Proposal #2, which lacks an auction to fund investments in EJCs, relies on a different mechanism to ensure that there is no increase in NO_x emissions in any year in EJCs compared to LL97 without trading. Specifically, under Proposal #2, the City would accelerate the phase out of fuel oil #4, prohibiting its use in 2025 rather than 2030. Legislation to accelerate the phase out of fuel oil #4 has already been introduced to improve air quality; such a phase out would address the mismatch in the timing between the Clean Heat Law (which phases out fuel oil #4 in 2030) and LL97's first compliance period (which runs until 2029). Another option for avoiding a small increase in NO_x emissions in EJCs in the first compliance period compared to LL97 without trading is to fund the conversion to fuel oil #2 or natural gas of some of the properties in EJCs still using fuel oil #4.[17]

16. The increase in NO_x emissions in EJCs in the first compliance period is due to the behavior of approximately 60 properties in EJCs that continue to burn fuel oil #4. The choices these buildings make are complex, and reflect the interaction between LL97 and the City's Clean Heat Law, which prohibits fuel oil #4 in 2030. Under a trading program without a complementary policy, in the first compliance period, these buildings would mostly continue to burn fuel oil #4 and buy credits to comply with their LL97 caps. Just before LL97's second compliance period, which starts in 2030, when fuel oil #4 is also prohibited under the Clean Heat Law, these buildings would make a significant investment to electrify to comply with the ban on fuel oil #4 and to sell credits in the trading program. By contrast, under LL97 without trading, these approximately 60 properties switch to fuel oil #2 or natural gas before 2030 to comply with LL97 and the ban on fuel oil #4 and then make relatively minor further changes to meet the tightening LL97 caps in the second compliance period; they do not electrify because, in the absence of a trading program, there is no opportunity to sell surplus credits based on further reducing GHG emissions through electrification. As a result, trading produces more investment in these approximately 60 properties over the course of the 26-year study period but less investment in the 2024–2029 period. See Part 7.D for further discussion.

17. The building segments causing most of the decrease in NO_x emission reductions compared to LL97 without trading are listed in Part 7.D.

Banking and Offsets

Although Proposals #1 and #2 initially allocate credits differently, many of the other elements of the two proposed designs are the same. Both proposals include a limited form of banking,[18] and neither permits owners to meet their obligations with GHG offsets, which LL97 currently allows. The reason these proposals include a limited form of banking is that banking provides flexibility and incentivizes early action, but it needs to be restricted to avoid allowing owners to build up a large bank in the early years that limits action in later years. Otherwise, banking could lead to a relative increase in air pollution in the later years.

As for offsets, LL97 in its current form provides building owners with the flexibility to use offsets to comply. However, offsets could channel investment and the associated air quality improvements outside of New York City. Given that trading provides owners with more flexibility and is itself a form of NYC-specific offset, there is little need to provide access to offsets from outside the City if a trading program is introduced. Removing offsets has little impact on trading's ability to reduce costs and provides the significant benefit of focusing action on local investments that also improve air quality and living conditions (though the latter were not quantified here). In essence, trading provides the flexibility of offsets while also keeping air pollution benefits and investment local.[19]

18. See Part 7.E for more details on the impacts of banking. As will be described, the undesired impacts result from interactions of some particular features of LL97.

19. Removing offsets as a compliance mechanism would require a legislative amendment to LL97. However, implementing any form of trading program would require new legislation, and thus offsets could be removed in conjunction with the legislation establishing a new trading program.

Evaluating the Illustrative Trading Proposals

Both of the illustrative proposals would accelerate local GHG reductions, avoid more premature deaths due to air pollution, lower the cost of pollution abatement, and generate more investment in the local economy than would occur if LL97 proceeds as is without trading.

Table 2. Summarized performance of illustrative trading proposals relative to base-case LL97 without trading between 2024 and 2050.

Evaluation Metric	**LL97 Without Trading**	**Proposal #1** (absolute and percentage change from base case LL97 without trading)	**Proposal #2** (absolute and percentage change from base case LL97 without trading)
GHG Emissions Reductions (metric tons CO_2e)	14 million	+ 2.7 million metric tons CO_2e **+ 19% CO_2e reductions**	+ 0.8 million metric tons CO_2e **+ 6% CO_2e reductions**
Pollutant Reductions (metric tons)	$PM_{2.5}$: 22,678 NO_x: 27,002 SO_x: 2,760	+ 3427 primary $PM_{2.5}$ reductions **+ 15% primary $PM_{2.5}$ reductions** + 380 NO_x reductions **+ 1% NO_x reductions** + 257 SO_x reductions **+ 9% SO_x reductions**	+ 2403 primary $PM_{2.5}$ reductions **+ 11% primary $PM_{2.5}$ reductions** + 702 NO_x reductions **+ 3% NO_x reductions** + 223 SO_x reductions **+ 8% SO_x reductions**
Owner Net Savings (2020$, 2020 NPV)	$2.0 billion	+ $305 million **+ 15% owner net savings**	+ $853 million **+ 42% owner net savings**
Tenant Bill Savings (2020$, 2020 NPV)	– $6 million	+ $98 million	+ $107 million
City Penalties and Auction Revenue (2020$, 2020 NPV)	$224 million	+ $450 million **+ 201% additional penalty and auction revenue**	– $185 million* **– 83% lower penalty revenues**

*For energy efficiency measures, common area savings are assumed to accrue to the owner, and tenant space savings are assumed to accrue to the tenant. For renter-occupied commercial and residential properties, we assume that 85% of gross building space is occupied by tenants, and whole-building energy savings that go to tenants are scaled accordingly. For electrification measures, we assume that owners benefit from reduced fuel costs because non-electric heating is typically centrally located, and that increases in electricity costs are fully passed through to tenants. Thus, we did not consider any particular legal protections that may be in place to protect affordable housing tenants from utility bill increases. For more information on tenant bill savings, see Appendix B.

**Under Proposal #2, a combination of trading and early actions with banking results in significant reductions in penalties.

Table 3. Monetized net benefits of the illustrative proposals by EJ status. Units are NPV of millions of 2020 dollars.

	EJCs		Non-EJCs	
	Proposal 1	**Proposal 2**	**Proposal 1**	**Proposal 2**
Total	**$3,323**	**$1,790**	**$773**	**$1,476**
Property Owners	$427	$208	– $123	$646
Tenants	$3	$3	$95	$104
Society: GHG Emissions	$115	– $5	– $16	$25
Society: Avoided Deaths	$2,778	$1,584	$817	$701

Both cost savings and pollutant reductions accrue to both EJCs and non-EJCs, but the size and distribution of benefits varies between the programs. The tables above summarize the results of our benefit-cost analysis[20] and how benefits and costs are distributed between different stakeholder groups under each proposal. The two left-most columns in the table above describe the net benefits of each proposal for stakeholder groups in EJCs, while the two right-most columns present net benefits for stakeholders in non-EJCs.

The Study evaluated the two proposals under many other metrics as well, including their ability to drive investment towards EJCs. A full accounting of these metrics is presented in Part 8 and Appendix B. To summarize, the modeled trading proposals result in greater uptake of energy efficiency and electrification measures and less use of offsets and RECs in both EJCs and non-EJCs than occurs under LL97 without trading (see Figure 2).

With regard to credit sales and purchases, a notable difference between the two proposals is that Proposal #1 leads residential condos and office buildings to purchase more credits (and sell fewer) than they would under Proposal #2 (see Figure 3). Under Proposal #2, office building credit sales increase in amount and proportion of total sales, while opt-in by Section 321 and NYCHA buildings also increases due to higher trading prices. Under both proposals, opt-in buildings sell a significant proportion of total credits sold.

20. To compute net benefits of each proposal by EJC status, we calculated the incremental costs and benefits that would accrue to property owners, tenants, and society overall compared to a scenario in which LL97 is implemented without trading. The costs and benefits we included for each group are as follows. Property owners: Costs to property owners include investment in abatement measures and costs related to penalties and trade, auction, offsets, and renewable energy credits. Benefits to property owners include trade revenue and energy savings, taking into account any benefits passed on to tenants. This category also reflects subsidies, if any, as lowering abatement costs. Not included in the analysis are the lost benefits to owners from replacing building systems in advance of the end of their useful life. Tenants: Costs and savings passed-through from owners to tenants, specifically impacts to tenant-paid utilities. Society—Greenhouse gas emissions: Benefits that result from net reductions in greenhouse gases, monetized by the Interagency Working Group's Social Cost of Carbon. Society—Avoided Deaths: Benefits related to avoided $PM_{2.5}$-related premature deaths due to net reductions in air pollutants, calculated by using the tool InMAP and monetized by the Value of Statistical Life determined by the U.S. Environmental Protection Agency.

Figure 2. Change in GHG reductions by compliance pathway relative to LL97 without trading, 2024–2050 (thousand metric tons CO_2eq).

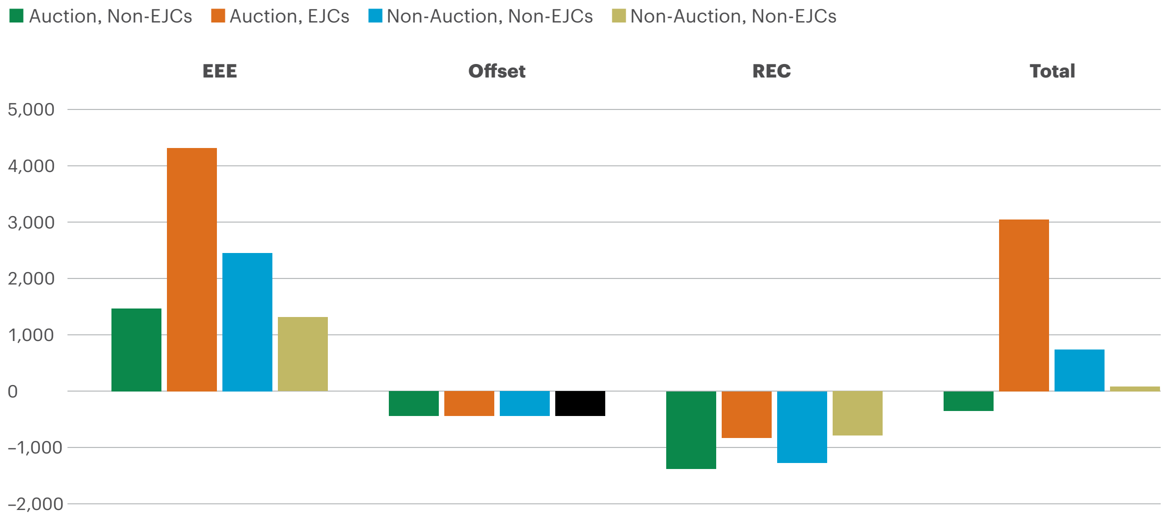
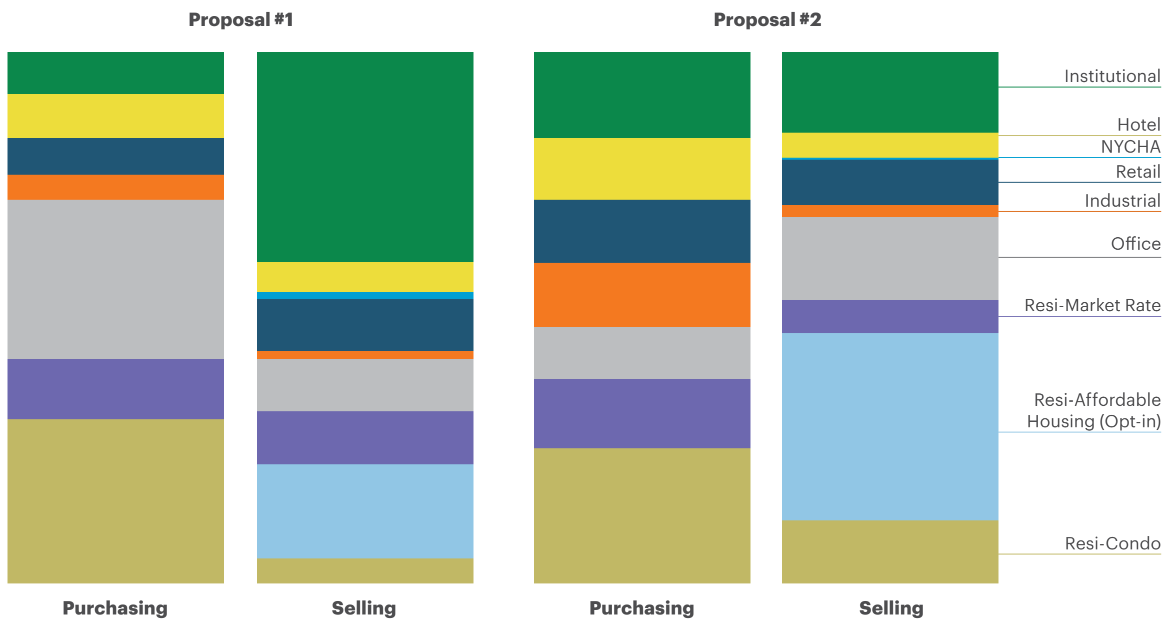


Figure 3. Proportion of credit purchases and sales by building type.



The two proposals impose different amounts of administrative costs and complexity as well. While Proposal #1 generally performs better on quantitative metrics, such as monetized net benefits, Proposal #2 generally performs better on qualitative metrics, such as implementation complexity. Proposal #1 is expected to impose more substantial administrative costs on both the City and regulated entities. A key reason that Proposal #2 is predicted to be so much less complicated for the City to implement is that it would not require the City to develop or run an auction. This would remove some of the administrative complexity of developing the program, including removing the potential need to seek State authorization. Proposal #2 also relieves the City of the need to establish baseline emissions for all covered buildings because it would not be centrally creating and then allocating credits. As for the regulated entities, under Proposal #2, any regulated entity that felt that participating in a carbon market was overly complicated could opt not to participate in the program because it would be allowed to emit up to its LL97 limits without purchasing credits at auction, and then could use the existing compliance pathways (RECs, distributed generation or penalty) to offset any surplus emissions. For all these reasons, which are reviewed in more depth in a separate Implementation Plan, Proposal #2 is likely less administratively complicated. Still, Proposal #2 entails some administrative complexity of its own because it assumes the City Council takes separate action to phase out fuel oil #4. Alternatively, the City could use another source of funding to pay to convert a small number of buildings in EJCs using fuel oil #4 to fuel oil #2.[21]

Conclusion

In sum, this study indicates that adding a carbon trading program to LL97 could produce a variety of additional benefits for New York City above and beyond those that LL97 is already predicted to produce. However, there are many different ways that a trading program could be structured, and these design decisions impact the precise costs and benefits that trading would have. This study developed two illustrative proposals that we hope will help officials in New York City and beyond assess the opportunities for implementing emissions trading in the building sector.

21. Note that the Study did not model Proposal #2 with a targeted subsidy instead of an accelerated phase out of fuel oil #4. However, preliminary analysis suggested that a limited targeted subsidy to convert some buildings in EJCs from fuel oil #4 to fuel oil #2 could negate the small increase in NO_x relative to LL97 without trading that might otherwise occur in EJCs during the first compliance period.

1

Introduction

Introduction

In 2019, New York City passed a groundbreaking law that caps the greenhouse gas (GHG) emissions that buildings can release for free. The law, known as Local Law 97 of 2019 ("LL97"), sets individual emissions caps for covered properties based on their square footage and occupancy type. LL97 calls for the Mayor's Office of Climate & Sustainability (MOC&S) to conduct a study into the feasibility of adopting a trading program for building emissions. This report synthesizes the results of that study.

The Study was conducted by MOC&S in collaboration with researchers at New York University (NYU). MOC&S provided direction throughout the Study on key points, including the goals of the Study, and reviewed the research throughout. NYU assembled a large, multidisciplinary team of researchers that included technical experts from across the university as well as private consulting firms, including The Brattle Group, HR&A Advisors, Steven Winter Associates, and Sustainable Energy Partnerships. Two committees of external stakeholders provided comments as the Study progressed via eight formal group meetings and further individual engagements.[22]

The Study examined the feasibility of designing a trading program for building emissions that would accelerate GHG reductions from buildings, reduce the costs of emissions reductions, and stimulate more investment in environmental justice communities (EJCs) compared with implementing LL97 as is.[23] In addition, the Study aimed to guarantee that EJCs would experience at least the same improvements in air quality under a trading program as they are expected to experience under LL97, and more if possible. With respect to this last criterion, LL97 instructs the Study to examine methods of ensuring that trading does not produce "any localized increases in pollution"[24] but does not specify a geographic or temporal scale that should be used to measure such increases. MOC&S interpreted the provision as requiring that a trading program not increase any local air pollutant ($PM_{2.5}$, SO_x, or NO_x) in EJCs in any given year compared to LL97 without trading.

The idea of developing a trading program for New York City's buildings is innovative in at least two respects. First, while emissions trading programs for industrial pollutants have become commonplace around the globe, at the time of this writing, only one major city (Tokyo) had developed a trading program for building emissions, and that program covers a much narrower group of properties than LL97.[25] New York would be the first city in the world to introduce a trading program covering residential buildings alongside industrial and commercial buildings. Implementing such a program entails substantial administrative complexity. Second, New York would be the first city to design a trading program that centers environmental justice in addition to longstanding goals for trading programs, such as reducing the costs of cutting pollution. Recognizing the pioneering

22. The members of the stakeholder groups are listed in Appendix F.

23. For the purposes of this Study, environmental justice communities were defined based on two environmental and social indicators. The environmental indicator was $PM_{2.5}$-attributable mortalities; the social indicator was high school graduation rate. We provide more information on why these indicators were selected and which communities met the criteria for "environmental justice communities" in Part 2.E.

24. N.Y.C. Admin. Code § 28-320.11.

25. Of particular importance, the Tokyo program does not cover residential properties. Tokyo Metropolitan Government, 2015.

nature of the potential program, the Study spent over a year examining how a trading program could be structured to meet the unique context of the New York City real estate sector and what the impacts of adding such a program would be.

The Study's modeling found that a carefully designed trading program could effectively further the City's goals and amplify the total benefits that LL97 is anticipated to provide. More specifically, our modeling indicated that, if implemented according to the parameters we assumed, allowing trading could lead to fewer total GHG emissions, fewer premature deaths from air pollution, more total investment in the local building stock, and lower costs for building owners over the 26-year lifetime of LL97 than would occur if LL97 proceeds without trading. We also found that trading programs could be structured to generate more investment in properties in environmental justice communities than would occur without trading, leading to less local air pollution and more lives saved in EJCs.

Importantly, there are many different ways that trading programs can be structured, and both the magnitude of benefits to the city as a whole and the distribution of these benefits between stakeholders can vary considerably based on the precise structure adopted. Trading programs can be designed to maximize benefits for the city as a whole, or to target benefits toward specific communities within the city, or to accomplish a combination of both types of goals. Some program designs might do more to lower compliance costs; others might be more effective at reducing localized emissions. The implementation complexity varies depending on the program design as well. In accordance with the City's goals, we focused on developing program designs that would increase benefits for the city as a whole, drive investment in environmental justice communities, and include guardrails to protect against the possibility that EJCs could experience any increase in local air pollution in any year.

After modeling a range of different program designs, we identified two illustrative designs that we believe could effectively advance the City's priorities. This report describes how these programs would function and the relative merits of each. Between these program designs, neither outperforms the other across all dimensions. Both proposals yield benefits for the City as a whole and for EJCs, relative to LL97 without trading. The two proposals impose different costs and benefits upon different groups and incorporate different types of uncertainty. Both proposals would require City legislation to implement because LL97 does not authorize the creation of a trading program.[26]

The first proposal would generate larger benefits for EJCs such as more building investment and more reduction in local air pollution than the second proposal (or LL97 without trading). However, it raises the relative costs of compliance for property owners in non-EJCs compared to LL97 without trading and slightly increases local air pollution in non-EJCs after 2029 compared to LL97 in its current form.[27] This proposal also introduces some distinct administrative complexities, given the need to develop and administer an auction for credits. This option further assumes that the City would obtain State authorization for the auction.

26. See *supra* note 19.

27. LL97 will reduce air pollution throughout the City. Under the first proposal, non-EJCs would experience slightly lower reductions in local air pollution after 2029 than under LL97 without trading, although local air pollution would still improve in non-EJCs over the 26-year study period. See Appendix D (Metric 4.7) and Appendix E.

The second proposal, which is within the City's authority to implement without State legislation, generates cost savings for all property owners, not just those in EJCs, and would be simpler to administer. It also generates benefits for EJCs compared to LL97 without trading, including more investment in EJC buildings and more improvement in local air quality, although they are more modest than under the first proposal.[28] While neither proposal will be simple to implement, the second proposal will likely be less complicated for the City to develop and administer than the first proposal, largely because the second proposal does not include an auction or require that the City allocate credits to all covered buildings.

The remainder of this report proceeds as follows.

In Part 2, we provide background information on LL97 and how the Study defined environmental justice communities. Part 3 describes the theory behind emissions trading and presents the arguments for why it might be beneficial to adopt a trading program to implement LL97. We also discuss the concerns that have been raised about emissions trading and pay particular attention to describing the state of knowledge regarding the impacts of emissions trading programs on environmental justice communities. Part 4 outlines the City's goals for a trading program. Part 5 provides a high-level overview of the methodology this study used to examine the feasibility of developing a trading program to implement the City's goals. Appendix B provides more details. Part 6 describes the predicted impacts of LL97 without trading on GHG emissions and local air pollutants, as well as cost impacts on different stakeholders. LL97 without trading provides the base case for this study, which focuses on designing a trading program to amplify the benefits and reduce the costs of LL97. Part 7 describes the elements of a trading program and the process that we used to identify program designs that would effectively advance the City's goals. It also outlines the findings of the economic modeling of the implications of different trading designs. The two illustrative trading market design proposals are outlined in Part 8. This part also analyzes these design proposals using the eight categories of metrics that the Study developed to ensure that it advanced the City's goals. The body of the report provides only a high-level description of the findings of the economic modeling in narrative form. Appendices D and E offer more detailed results. Finally, Part 9 reprises the key findings of the Study, as well as its limitations, and makes some concluding reflections.

Importantly, the Study also developed a detailed implementation plan for a trading program that the City could refer to if it chooses to adopt such a program.

Before continuing further, it is important to acknowledge the uncertainty inherent in the Study's findings. In order to assess the predicted impact of LL97 with and without trading, the team had to make numerous assumptions about the state of the world both today and in the future, including the future costs of electricity, the rate at which the grid is decarbonized, the costs of retrofitting properties, the availability of renewable energy credits, the rate at which the City's building stock will grow, and more. We also had to predict how the owners of a wide variety of asset classes—from small residential coops to hospitals to large office buildings and more—would react when faced with different investment opportunities and costs. We believe that the forecasts we arrived at on these matters are reasonable, and

28. Note, however, that the second proposal also assumes that the City accelerates the phase out of fuel oil #4, which at the time of this writing was under debate at the City Council. The pollution problem that the accelerated phase-out is intended to address could also be addressed by alternative means, such as a targeted program subsidizing the conversion before 2030 of buildings in EJCs using fuel oil #4 to fuel oil #2. See Part 8.A for additional discussion.

they were discussed extensively with external stakeholders. But, of course, substantial uncertainty remains. Our model also assumes that owners will always behave in an economically optimal manner, which is almost certainly not the case. As such, our results should be interpreted as providing insight into the direction of impacts that trading could have, rather than as providing precise dollar estimates of the benefits and costs of trading.

Setting aside the uncertainty regarding our technical assumptions, there is also political uncertainty as to whether the full suite of policies that we included in the illustrative program proposals would be adopted as described. In particular, Proposal #1 assumes that the State would authorize use of an auction. Proposal #2 assumes that the City would be able to motivate the Council to pass contemplated legislation accelerating the phase out of fuel oil #4, or that the City would adopt a policy to subsidize fuel switching by buildings in EJCs still using fuel oil #4.

2

Background on LL97 and the Study's Definition of EJCs

Background on LL97 and the Study's Definition of EJCs

LL97 was passed in 2019 as part of New York City's "Climate Mobilization Act." The law's overarching aim is to reduce carbon emissions associated with energy use in large buildings.[29] To that end, Section 320 of LL97 caps the amount of carbon-based energy that buildings with more than 25,000 square feet[30] can utilize. Apart from certain specified exceptions, which are listed in Part 2. A below, Section 320 covers all types of properties that exceed the size threshold including commercial buildings (i.e., office buildings), residential buildings, hotels, hospitals, industrial buildings such as factories, and institutional buildings such as schools. Buildings can exceed their caps only if they take some compensatory actions, such as paying a fine or purchasing greenhouse gas offsets.

To calculate a building's annual cap, one multiplies the total square footage by the assigned carbon intensity limit for the relevant occupancy type. The stringency of the carbon intensity limits varies according to the type of occupancy. For example, hotels are permitted to use more carbon-based energy per square foot than office buildings, and office buildings are permitted to use more carbon-based energy per square foot than apartment buildings. For all buildings, the carbon intensity limit (i.e., the amount of carbon-based energy that can be used per square foot) becomes progressively stricter over time; there are three compliance periods—2024 to 2029; 2030 to 2034; 2035 to 2050—and the limits ratchet down in each period.

This part provides background on the types of buildings whose GHG emissions are capped under LL97, these buildings' compliance options under the law as is, the stringency of the caps under the law, and the law's requirement for a study of emissions trading. This part also explains how environmental justice communities were defined for the purpose of this study.

29. Buildings comprise around two thirds of emissions in New York City. MacWhinney & Klagsbald, 2017. Large buildings—those with more than 25,000 square feet—account for over half of all building emissions. Urban Green Council, 2018.

30. Or properties with two or more buildings on the same lot that together exceed 50,000 square feet. N.Y.C. Admin. Code § 28-320.1.

A.

Which Types of Buildings are Subject to the Caps?

Not all properties with more than 25,000 square feet are subject to the emissions caps that Section 320 sets forth. There are eight categories of buildings that are excluded from coverage under Section 320, even though they meet the requisite size threshold:

1.
Power plants and steam plants;

2.
"Garden apartments" (i.e., low-rise attached buildings that have multiple HVAC units under separate control);

3.
City-owned-or-leased properties;[31]

4.
A housing development or building on land owned by the New York City Housing Authority (NYCHA);

5.
Properties in which more than 35% of the units are rent regulated;[32]

6.
Houses of worship;

7.
Properties owned by a Housing Development Fund Corporation (i.e., low and moderate income cooperatives); and

8.
Properties that participate in a project-based federal housing program.

31. These properties are treated under a separate provision of the law. See N.Y.C. Admin. Code § 24-803.

32. These properties are treated under a separate provision of the law, Section 321. As the law was initially passed, all buildings with one or more rent regulated units were excluded. This was amended by Intro 1947 of 2020 to exclude only buildings in which more than 35% of units were rent regulated.

LL97 establishes different requirements for some of these categories of properties. Looking first at publicly owned or occupied buildings, the law instructs NYCHA to make "efforts to reduce greenhouse gas emissions by 40 percent by the year 2030 and 80 percent by the year 2050"[33] across its portfolio of properties and tasks the City with reducing energy usage across its portfolio of owned or leased buildings by an average of 50% by 2030.[34] The law does not contemplate imposing penalties on either NYCHA or the City for failure to meet these targets.

Several of the other types of properties that are excluded from coverage under Section 320 are regulated under a different part of LL97 known as Section 321. Section 321 covers the following types of properties, provided they meet the size threshold:[35]

1.
Buildings in which more than 35% of units are rent regulated;[36]

2.
Public houses of worship;

3.
Buildings owned by a housing development fund corporation; and

4.
Buildings that participate in a project-based federal housing assistance program.[37]

33. N.Y.C. Admin. Code § 24-803(b)(3). Note that some of NYCHA properties are required to make prescriptive upgrades under Section 321.

34. N.Y.C. Admin. Code § 24-803(b)(1). The law also sets an interim goal of reducing emissions by 40% below 2005 usage by 2025.

35. As with Section 320, Section 321 only covers buildings that exceed 25,000 square feet and properties with two or more buildings which combined exceed 50,000 square feet. § 28-321.1.

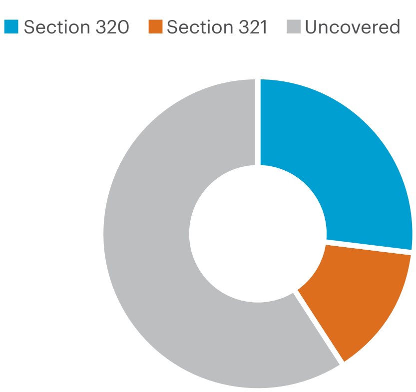
36. This covers units that are required by law or agreement with government to have their rents regulated in accordance with the Emergency Tenant Protection Act of 1974, the Rent Stabilization Law of 1969, and the Local Emergency Housing Rent Control Act of 1962. N.Y.C. Local Law No. 1947 (2020).

37. This provision covers buildings that participate in the federal low-income housing assistance program is detailed in 42 U.S.C. § 1473f.

Owners of properties covered under this section can choose between either demonstrating that their 2024 emissions "did not exceed what the applicable annual building emissions cap would be…if such building were a covered building as defined in Section 320"[38] or making specified "energy conservation measures" such as insulating hot water pipes.[39] If the building owners choose the latter path, they do not need to meet the performance targets.[40] The law does not set a specific penalty for non-compliance with the prescriptive mandates but the Department of Buildings has discretion to establish a penalty.[41] Importantly, buildings with rent regulated units make up the largest share of the properties subject to Section 321.

All in all, LL97 imposes mandatory emissions caps on approximately 11,800 properties, or 1.5 billion square feet of real estate (27% of the City's total square footage).[42] Section 321 covers an additional 14,700 properties, comprising 836M square feet (15% of the City's total square footage). Note that each property can have one or multiple buildings on it because property, as we use the term in this report, refers to individual tax lots defined at a "borough block lot" level.

Figure 4. Share of NYC real estate covered by LL97 mandatory emissions caps by square footage.



38. N.Y.C. Admin. Code § 28-321.2.1.
39. A full list of measures can be found in § 28-321.2.2.
40. N.Y.C. Admin. Code § 28.321.2.2.
41. N.Y.C. Charter ch. 26, § 651(a)(7).
42. This includes buildings covered by Section 320 but not NYCHA or city-owned properties.

B. What are the Options for Complying with the Law?

LL97 outlines several different paths that property owners can take to comply with their emissions caps. We detail these various compliance paths in the paragraphs below. Before doing so, however, it is necessary to describe how owners calculate their total annual emissions.

A property's emissions are calculated by summing the emissions attributable to onsite combustion of fossil fuels (typically for the purpose of producing heat or hot water) and emissions attributable to electricity that it purchases from the grid. The law establishes carbon intensity coefficients for the 2024–2029 period for several types of fossil fuels that can be burned onsite, as well as grid-tied electricity,[43] and tasks DOB with establishing coefficients for energy sources for the later years.[44] To figure out a property's total annual emissions, one multiplies the amount of each type of energy used by the relevant carbon coefficient. The resulting figure is what we will call the property's "base" emissions.

43. The law directly establishes carbon coefficients for natural gas, fuel oil #2, fuel oil #4, and district steam, but leaves it to DOB to establish the coefficients for other energy sources, including "campus-style electric systems," fossil-based distributed generation, and natural gas fired fuel cells. N.Y.C. Admin. Code § 28-320.3.1.1.
44. N.Y.C. Admin. Code § 28.320.3.2.1.

If a property owner anticipates that its property's base emissions will exceed its LL97 caps, the owner has three main options for how to comply with the law:

Direct emissions reductions. The first option for compliance is for the property to reduce its consumption of fossil-fuel based energy in the buildings through energy efficiency retrofits, fuel switching, or clean distributed generation.

Use deductions. LL97 also permits property owners to make certain "deductions" from their emissions for the first compliance period by purchasing renewable energy credits (RECs) from power sources that feed into Zone J, which is the area of the grid that serves NYC, purchasing offsets,[45] or using clean distributed energy resources.[46] Offsets can only be used to deduct up to 10% from a properties' base emissions. Importantly, LL97 does not specify which types of offsets could be used under LL97—it is up to DOB to decide that via rules.[47] And because there is no existing NYC-specific offset standard, money spent on offsets would most likely flow to projects outside the City's borders.[48] As it was initially passed, LL97 only authorized offsets to be used in the first compliance period. However, a subsequent law, Local Law 147 of 2019 instructs DOB to pass rules to make offset deductions available beyond the first compliance period.[49] It remains to be seen whether there will be any modification to the conditions under which they can be used. In our modeling exercises, we assumed that DOB would not make offsets available after the first compliance period in order to encourage investment and emissions reductions to stay local but would make RECs available in later compliance periods.

Pay a penalty. For buildings that exceed their emissions caps at the end of a compliance period even after taking any deductions into account, the law requires that they pay a penalty of *up to* \$268 per metric ton of CO_2e for any excess emissions.[50]

45. Buildings can only use offsets to deduct up to 10% of their emissions limits. N.Y.C. Admin. Code § 28-320.3.6.2. There are no restrictions on the use of deductions for using clean distributed energy—meaning, buildings can deduct the full extent of clean distribution energy they use from their reported emissions. N.Y.C. Admin. Code § 28-320.3.6.3.

46. Note that by using clean distributed generation, owners can both avoid adding to their base emissions and roll-back tabulated emissions from fossil fuel energy use.

47. The term "greenhouse gas offset" is defined in LL97 as "a credit representing one metric ton of carbon dioxide equivalent emissions reduced, avoided, or sequestered by a project," subject to independent verification and additionality requirements. N.Y.C. Admin. Code § 28-320.1. The term "project" is not defined in the law; however, there is language in LL97 that suggests that DOB's rules should "reference[]" offset standards. See N.Y.C. Admin. Code §§ 28-320.1, 28-320.3.6.2.

48. Other trading programs have introduced restrictions on where qualifying offset programs can occur, or where the majority of emission reductions can take place. California, for example, will only issue offset credits for qualifying emissions reduction projects if they occur in the United States, and, as of 2021, requires that at least 50% of offset projects provide "direct environmental benefits in the State." Cal. Code Regs. tit. 17, §§ 95972(c), 95854(e). Likewise, RGGI has five specific offset protocols, developed cooperatively by the RGGI states. Participating RGGI states will only issues offset allowances for projects that are designed to reduce or sequester emissions within the corresponding RGGI state, provided the majority of emission reductions occur within said state, or within other states or U.S. jurisdictions, provided that they have a Memorandum of Understanding with all participating RGGI states to carry out certain monitoring and auditing obligations related to offset projects. RGGI Model Rule § XX-10.3(a)(2); *see also*, e.g., N.Y. Comp. Codes R. & Regs. tit. 6, § 242-10.3(a)(2) (describing the location requirements for offset projects in New York State).

49. N.Y.C. Local Law No. 147 (2019) § 9 (amending N.Y.C. Admin. Code § 28-320.3.6).

50. N.Y.C. Admin. Code § 28-320.6. Note that this penalty is not indexed to inflation.

In addition to these three primary compliance options, the law permits owners to apply to the Department of Buildings to seek individualized variances based on hardship.[51] Finally, there are two categories of properties that are eligible for more generous treatment that should be noted: not-for-profit hospitals and healthcare facilities, and properties that exceeded their 2024–2029 cap by more than 40% in 2018 ("highest emitters").

Hospitals

Not-for-profit hospitals and healthcare facilities that apply for a special adjustment only have to reduce their emissions to 85% of their 2018 emissions during the first compliance period and 70% of their 2018 emissions during the second compliance period.[52]

Highest Emitters, Eligible for Adjustment

Buildings that exceeded their 2024–2029 cap by more than 40% in 2018 need only reduce their emissions to 70% of their 2018 emissions during the first period, provided they make certain other showings.[53]

51. N.Y.C. Admin. Code § 28-320.7.2.1.
52. N.Y.C. Admin. Code § 28-320.9.
53. N.Y.C. Admin. Code § 28-320.8.

C. The Stringency of the LL97 Emissions Caps

As noted above, the LL97 caps become progressively more stringent over time. The law creates three different compliance periods, spanning from 2024 to 2050, and prescribes different carbon intensity limits for each period. It sets specific carbon intensity limits for each building class for the first two periods and an average intensity limit for the third period. These limits are as follows:

2024–2029: For the first period, the law establishes building carbon intensity limits by building occupancy type.[54]

2030–2034: For the second period, the law establishes building carbon intensity limits by building occupancy type, but gives DOB the authority to adjust these limits so long as the average limit across all occupancy categories is no less strict than the average given in law.[55] DOB also has until 2023 to establish the carbon intensity coefficients for different energy sources for this period.[56]

2035–2050: For the third period, the law requires that the average intensity factor should not exceed a specified amount (0.0014 tCO_2e/sf/yr) by 2050 but leaves it up to the Department of Buildings to determine the rate at which the caps decline over the 16 years to achieve this average target.[57] DOB must set the annual building carbon intensity limits for these periods by 2023.[58]

54. N.Y.C. Admin. Code § 28-320.3.1.
55. N.Y.C. Admin. Code § 28-320.3.2.
56. N.Y.C. Admin. Code § 28-320.3.2.1.
57. N.Y.C. Admin. Code § 28-320.3.4.
58. N.Y.C. Admin. Code § 28-320.3.4.

As can be seen, much remains unknown about how buildings' emissions will be calculated after 2029. As such, the Study had to make a number of assumptions to conduct our modeling, including predicting the carbon intensity coefficients for energy sources beginning in 2030. In so doing, we assumed that the grid would fully decarbonize by 2040 in accordance with New York State's Climate Leadership and Community Protection Act (CLCPA) and that the carbon intensity coefficients would reflect this pace of decarbonization.[59] Unless otherwise specified, the compliance estimates provided in the remainder of this report assume this pace of decarbonization.

D. The Requirement for a Trading Study

LL97 requires MOC&S to "conduct a study on the feasibility of a citywide trading scheme for greenhouse gas emissions from buildings and submit a report and implementation plan with findings to the mayor and the speaker of the council."[60] While mandating the completion of this study, LL97 does not authorize the City to implement an emissions trading program. The City Council would need to adopt new legislation to implement a trading program.[61]

59. The State's CLCPA requires that at least 70% of New York's electricity come from renewable sources by 2030 and that 100% of electricity come from zero-carbon sources by 2040. Climate Leadership and Community Protection Act § 4, N.Y. Pub. Serv. Law § 66-p.

60. N.Y.C. Admin. Code § 28-320.11.

61. LL97 does not expressly authorize DOB to create a carbon trading program; rather, it calls for the City to conduct a study of whether or not a trading program should be developed. N.Y.C. Admin. Code § 28-320.11. Thus, additional legislation would probably be needed before DOB could implement a carbon trading program; otherwise, a court would likely consider the program to be ultra vires, meaning it is beyond the scope of an agency's authority, if it were challenged as such.

E. Defining Environmental Justice Communities for the Study

Given the Study's focus on developing a trading program that centers environmental justice,[62] it was important to define areas of the City that qualify as environmental justice communities (EJCs). Defining EJCs was a necessary first step to isolate the predicted impacts of trading for these communities.

Local Law 64 of 2017 defined "environmental justice areas" in New York City to be those areas in which at least 23.59% of the population has an annual income that is below the federal poverty line and/or 51% of the population is "Hispanic, African-American or Black, Asian and Pacific Islander or American Indian."[63] This definition is consistent with the idea that communities with a majority of low-income residents and/or communities of color have experienced a disproportionate share of poor environmental outcomes.[64] However, using racial criteria to identify areas that would receive different credit allocations under a potential trading program could introduce legal risk.[65] As such, the Study uses an alternative set of criteria for identifying EJCs.

62. N.Y.C. Local Law No. 64 (2017) defines environmental justice to mean, "the fair treatment and meaningful involvement of all persons, regardless of race, color, national origin or income, with respect to the development, implementation and enforcement of environmental laws, regulations, policies and activities and with respect to the distribution of environmental benefits. Fair treatment means that no group of people, including a racial, ethnic or socioeconomic group, should (i) bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal and commercial operations or the execution of federal, state or local programs and policies or (ii) receive an inequitably low share of environmental benefits."

63. N.Y.C. Local Law No. 64 (2017) § 3-1001.

64. See, e.g., Morello-Frosch et al, 2002.

65. See, e.g., Wynn v. Vilsack, 2021 WL 2580678 (M.D. Fla. June 23, 2021) (granting motion for preliminary injunction to prevent enforcement of a federal law that authorized the Secretary of Agriculture to use racial criteria to determine eligibility for preferential debt relief).

The criteria incorporate two metrics, one of which measures environmental vulnerability and the other which indicates social vulnerability. For the environmental criteria, we looked at the number of $PM_{2.5}$ attributable asthma emergency department visits for children.[66] Of course, air pollution causes a long list of other health impacts apart from childhood asthma. However, we focused on this metric because of the considerable neighborhood-level data that the City has available regarding the impact of $PM_{2.5}$ on asthma. For the social vulnerability criteria, we looked at the high school graduation rate.[67] Communities that ranked in the bottom 40% of Neighborhood Tabulation Areas for either criteria were defined as EJCs for the purposes of this study. These communities are colored in dark green in the map presented in Figure 5. Throughout the remainder of the report, when we describe impacts for EJCs, we are referring to the dark green areas.

Critically, the Study does not presume that the City would adopt these particular criteria in identifying EJCs in practice; quite to the contrary, MOC&S is leading a separate stakeholder process under LL64 of 2017 to officially map out EJCs.

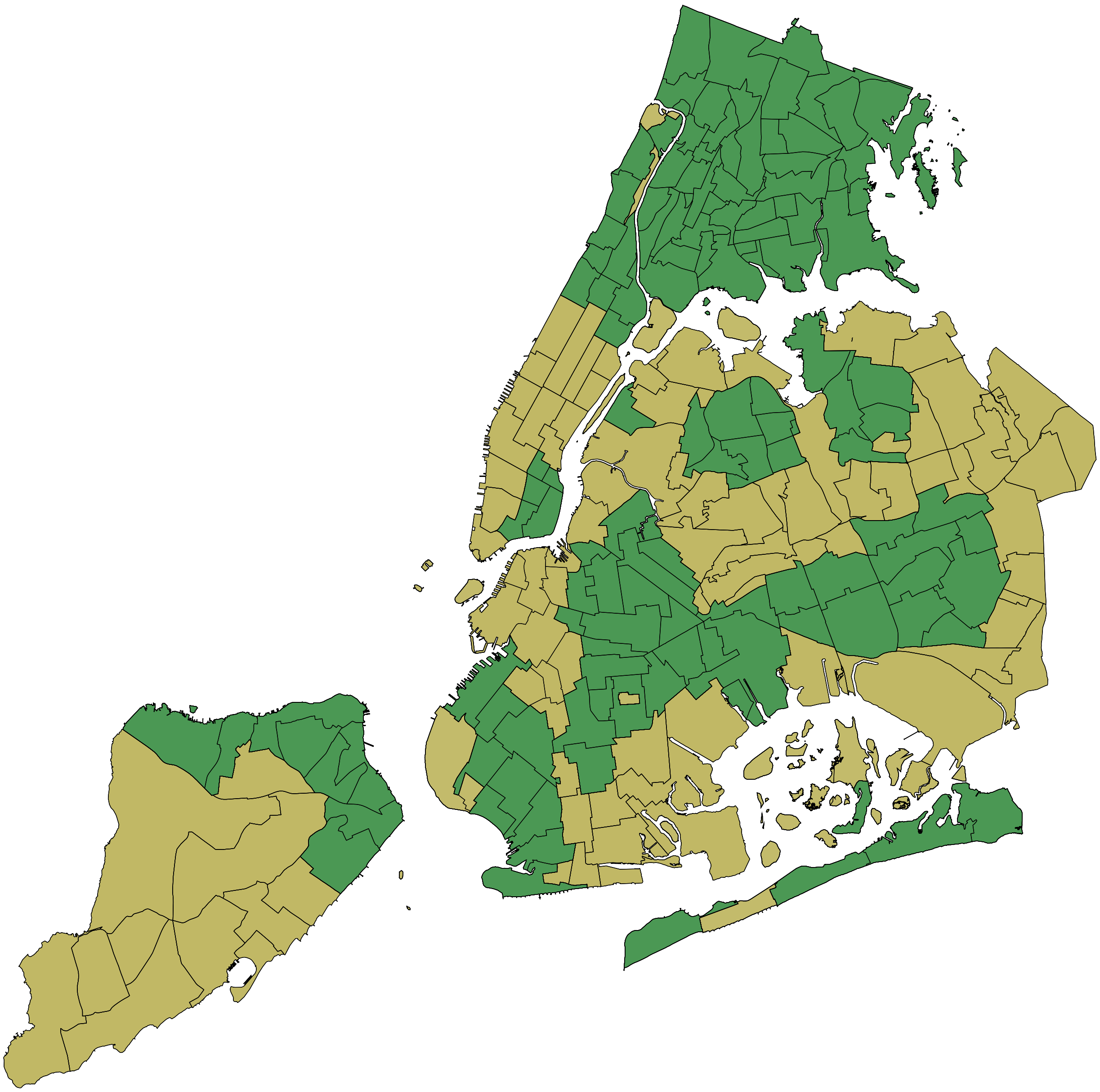
The building stock in EJCs differs from that in non-EJCs in ways that impact LL97's coverage. In particular, while nearly three-quarters of square footage covered by Section 321 is located in EJCs, only about one quarter of the square footage covered by Section 320 is located in EJCs (see Figure 6 and Figure 7). A major reason why Section 320 covers more square feet and properties in non-EJCs is that large commercial buildings and large market-rate residential buildings are concentrated in non-EJCs (see Figure 8).

66. Data sourced from N.Y.C. Department of Health and Mental Hygiene, n.d.a [Environment and Air Quality Data Portal]; U.S. Census Bureau; U.S. Environmental Protection Agency, n.d.a [EPA Air Quality System]; Ito et al., 2007.

67. The reason we were interested in high school graduation rate is that a study of the Acid Rain Program found that communities with low levels of educational attainment were more likely to experience a relative increase in pollution under that program. See Ringquist, 2011. In considering this result, the study's author hypothesized that poorly educated communities might have less capacity to monitor reallocations of emissions, which would make it less politically costly for firms in these areas to increase their emissions. Ringquist, 2011. This is, of course, just one study and we should be careful not to assume that its findings are generalizable to other contexts. Nevertheless, we thought educational attainment might be a proxy for vulnerability. High school graduation rate data was sourced from the N.Y.C. Department of Health and Mental Hygiene (DOHMH) Data Portal and was based on data from the U.S. Census Bureau American Community Survey 5-Year Series (2013–2017). U.S. Census Bureau, n.d.

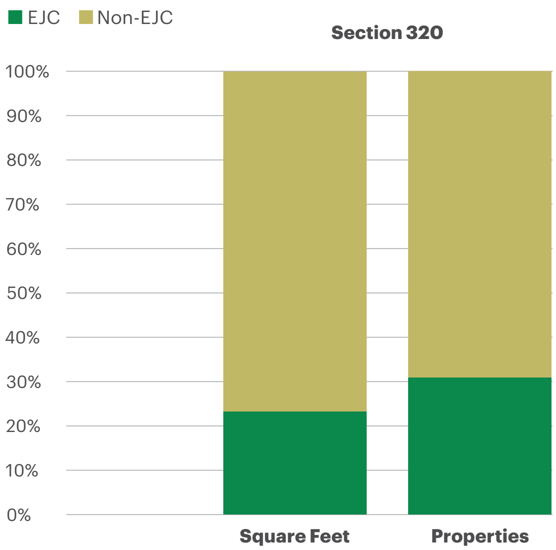
Figure 5. Map of illustrative environmental justice communities.

EJC Non-EJC



Geographies shown are Neighborhood Tabulation Areas (NTAs).

Figure 6. Section 320 quare footage and properties in EJCs vs. non-EJCs.



Section 320 buildings are required to meet LL97 caps; Section 321 buildings can choose whether to meet LL97 caps or implement a specified list of prescriptive measures.

Figure 7. Section 321 square footage and properties in EJCs vs. non-EJCs.

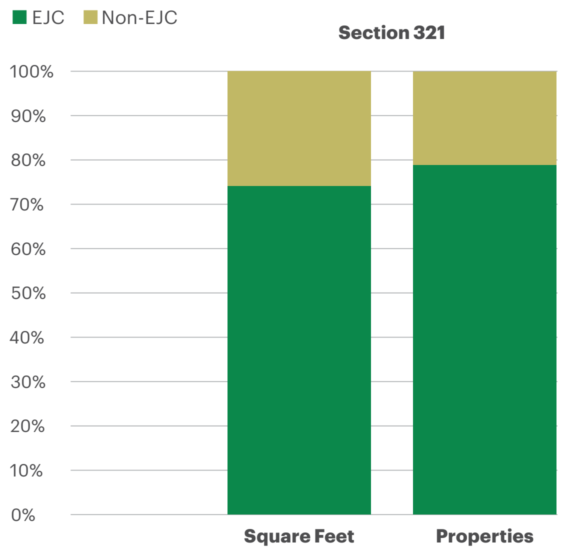
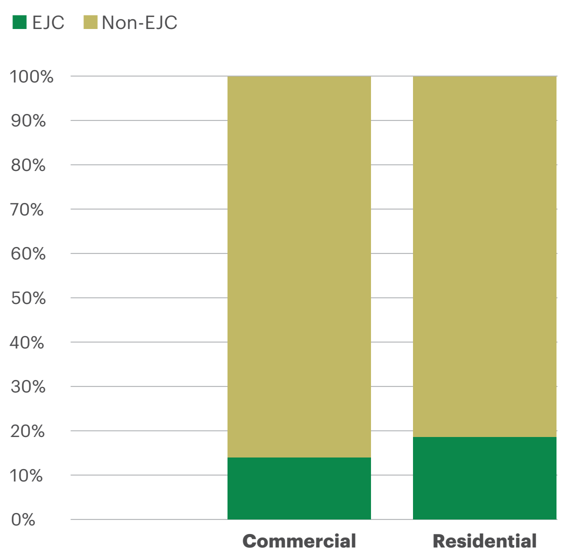


Figure 8. Shares of commercial vs. residential square footage in EJCs vs. non-EJCs for properties covered by Section 320.



3

A Look at the Theory and Empirical Evidence on Trading Programs

A Look at the Theory and Empirical Evidence on Trading Programs

Scholarship indicates that allowing emissions trading can lower the cost of pollution control compared to uniform performance mandates and incentivize firms to make earlier and deeper reductions than they otherwise would. However, a number of environmental justice groups, including members of our stakeholder groups, have expressed concern that emissions trading programs will shift pollution towards low-income communities of color. Two prominent existing trading programs—RGGI and the EU ETS—have also been criticized for not effectively incentivizing emissions reductions throughout the regulated region because emissions caps for the early years ended up being above actual emissions. This part reviews existing scholarship regarding the benefits of emissions trading as well as the concerns. We also review strategies that can be employed to avoid the challenges that some past programs have encountered. For example, regulators can avoid problems caused by lax emissions caps by ensuring that the emissions caps are subject to regular periodic review.

A. Benefits of Emissions Trading Programs

Emissions trading programs have become increasingly popular around the globe. First utilized on a large scale in the United States in the 1990s as part of the federal Acid Rain Program, there are now more than 20 active carbon emissions trading programs alone throughout the world, including the European Union (EU) Emissions Trading System (ETS), the California Cap-and-Trade Program, the Regional Greenhouse Gas Initiative (RGGI), the New Zealand ETS, the Korea ETS, and recently, the Chinese national emissions trading system.[68] Most of these programs target emissions from electricity generation, industrial sources, and/or the transportation system, but one major city—Tokyo—has adopted a carbon trading program that specifically targets commercial buildings.

The basic theory behind trading programs is that, in any given sector, some entities will be able to reduce their pollution more cheaply than others. Given this variation, to minimize the total cost of reducing emissions, environmental regulations can be designed to harvest the most reductions from sources that can cut pollution at the lowest costs. Trading makes this possible. Instead of requiring all sources to meet the same emissions standards, trading programs allow sources with higher abatement costs to pay for emissions reductions at facilities with lower abatement costs. Trading programs also provide an incentive for sources that can make low-cost reductions to reduce more than what is required and sell their surplus emission reductions to others who have only higher-cost options.[69] The result is the same or more total emissions reductions throughout the regulated emissions sources for a lower cost than if all sources were required to achieve the

68. International Carbon Action Partnership, 2021, p. 27.
69. Napolitano et al., 2007.

same emissions standard.[70] And by lowering the cost of emissions control, policymakers can free up resources to pursue other social goals or increase ambition to reduce pollution further.

Turning from theory to practice, several empirical reviews of trading programs indicate that such programs do indeed reduce compliance costs below what they would be if uniform emissions caps were in place.[71] This has been demonstrated in studies of the federal Acid Rain Program,[72] the Regional Clean Air Incentives Market (RECLAIM),[73] and others.[74]

The benefits of trading can go beyond just reducing costs.[75] Depending on how they are designed, trading programs can also incentivize firms to take earlier action than they otherwise would and generate revenue that can be used to make targeted investments, such as investments in environmental justice communities. If trading is substituted for alternative flexibility mechanisms, such as non-local carbon offsets, it can also increase the amount of investment that stays within the local economy, save lives, and improve public health locally.

A simple example shows how the addition of a trading program to LL97 could change outcomes in New York City. Imagine that there were only two buildings in the City that were subject to LL97:

Building A, which will exceed its cap for the first compliance period by 1,000 tons of CO_2e under business as usual, and

Building B, which will be able to comply with its LL97 cap for the first compliance period under business as usual, and therefore does not need to implement retrofits.

Imagine further that Building B could reduce its emissions in the first compliance period by 500 tons by investing $10,000 in retrofits, whereas it would cost Building A $10,000 to reduce the first 500 tons via some combination of retrofits, RECs and offsets, and $20,000 to reduce the second 500 tons because at this point only more expensive abatement options would be available to it.[76] Under LL97 as it is today, Building B will take no action to reduce its pollution and incur no additional costs. Building A, however, will have to spend $30,000 to reduce/offset its emissions by 1,000 tons.

Trading gives Building A another option: it could pay Building B $10,000 to reduce its emissions by 500 tons and spend $10,000 to reduce its own emissions by 500 tons. Taking this approach, Building A would only have to pay $20,000 and society would get the same 1,000 tons of total reduction. Moreover, unlike international offsets, which are another type of flexibility mechanism, the investment in Building B keeps funds local, where they can generate both local jobs and co-pollutant reductions. The diagram below illustrates how this could work pictorially.

70. This holds true if the emission caps are binding. If emission caps are not binding, a trading program may allow for increased system emissions if no additional policies are implemented. However, the root cause of such a situation is emission caps that are not stringent enough, not trading.

71. See, e.g., Schmalensee & Stavins, 2017; Schwartz, 2017; see also Tietenberg, 2006 (describing several studies evaluating cost savings from trading programs as compared to command-and-control programs).

72. Chan et al., 2012, p. 424 (describing the cost-effectiveness of the Acid Rain Program, as compared to a command-and-control regulatory approach) (citing Carlson et al., 2000, Ellerman et al., 2000, and Keohane, 2003).

73. Burtraw & Szambelan, 2009, p. 20 (citing a 1996 study [Johnson & Pekelney, 1996] that found that RECLAIM cost firms about 58% less over the first 6 years than a command-and-control regulation would have, but noting that these cost savings estimates "are undermined because of the difficulty of establishing a counterfactual baseline").

74. See, e.g., Farrell et al., 1999, pp. 119–120 (predicting up to $900 million in compliance cost savings from EPA's NO_x Budget Trading Program when compared to an assumed command-and-control alternative).

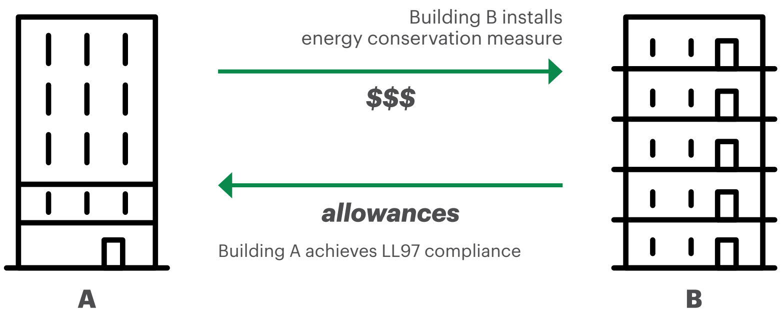
75. Some trading programs may also save on administrative costs. See Schwartz, 2017.

76. Marginal abatement costs tend to increase as pollution controls become stricter because owners "pick the lowest hanging fruit" first.

Figure 9. A building-level example under a hypothetical trading scenario:

Building A faces more expensive conservation measures, so it pays B to install an energy conservation measure.

Building B uses the money from A to undertake a cost-effective measure it otherwise would not have taken. It sells credits to A.



Building A owner better off because lower compliance costs

Building A tenants may be worse off because fewer energy savings and pollutant reductions

Building B owner better off because more energy savings

Building B tenants may be better off because more energy savings and pollutant reductions

The bottom line is that both parties benefit from the trade. Building A benefits from lower compliance costs while Building B earns net revenue from overachieving on abatement. Aggregated sector-wide, similar transactions unlock the benefits of driving investment to the lowest-cost emissions reduction opportunities, keeping the overall cost of GHG abatement low. Notably, however, trading can also redistribute where local air pollution reductions occur from what it would be under uniform standards. Depending on how the program is designed and other considerations, this can have positive or negative impacts for environmental justice communities.

B. Criticisms of Emissions Trading Programs

A number of criticisms and cautionary notes about emissions trading programs have also been raised. Three types of criticisms have been raised most often:[77]

1.
Emissions trading programs could further burden environmental justice communities, either by increasing pollution concentrations in these communities or failing to redistribute existing pollution burdens away from these areas;[78]

2.
Emissions trading programs do not effectively induce sources to control their emissions;

3.
Emissions trading programs can be complicated and costly for governments to administer, and these administrative costs exceed the benefits that they would otherwise provide. Some also suggest that it may be costly for regulated actors to participate in trading programs and comply with their requirements.

We take a look at each of these concerns and the available empirical evidence concerning them below.

77. Some commentators have also raised ethical concerns about the idea of commodifying pollution. See, e.g., Caney & Hepburn, 2011 (citing Sandel, 2005) ("Turning pollution into a commodity to be bought and sold removes the moral stigma that is properly associated with it…[and] may undermine the sense of shared responsibility that increased global cooperation requires.").

78. Notably, with respect to RGGI in particular, EJ groups have also expressed concerns that auction proceeds are not being appropriately directed towards those communities that are most in need. See, e.g., Environmental Advocates N.Y., 2020.

Environmental Justice Impacts of Emissions Trading

Concerns about the environmental justice implications of emissions trading go back at least to southern California's RECLAIM program. In 1993, following years of noncompliance with federal ambient air quality standards, the South Coast Air Quality Management District (SCAQMD) launched RECLAIM to reduce NO_x and SO_x emissions. RECLAIM mandated reductions only from stationary sources and was criticized for not covering emissions from mobile sources, which were major sources of air pollution in the region. As a result, SCAQMD developed a voluntary credit program that allowed "licensed car scrappers" that destroyed dirty old cars to generate emissions credits that could be used by regulated sources to comply with RECLAIM. In essence, this program allowed stationary sources to buy offsets from companies scrapping old vehicles. These offsets led to a concentration of pollution in certain areas because the pollution reductions that they conferred were dispersed across a large area, while the major stationary sources of pollution were concentrated in low-income communities of color.[79] The programs were thus criticized for creating pollution hot spots in already overburdened communities.[80]

79. Nash & Revesz, 2001.

80. See, e.g., Chinn, 1999 ("From the outset, environmentalists were concerned about whether actual pollution reduction could be achieved and whether pollution hot spots would form around facilities that choose to buy credits rather than reduce their own emissions."); Nash & Revesz, 2001 ("Environmental justice groups have assailed SCAQMD's emission trading regime. These groups allege, consistent with the general environmental justice criticism of trading, that areas immediately proximate to pollution sources have not seen improvement, or have experienced deterioration, in air quality. According to these groups, the adversely affected areas tend to be economically disadvantaged and contain relatively higher percentages of ethnic and racial minorities."). Environmental justice groups have also raised concerns about proposals to develop a trading program for transportation fuels, including that such a program might worsen or reinforce localized pollution disparities. Climate Justice Alliance, n.d. There have also been two Title VI complaints filed with EPA against California's Cap-and-Trade Program and RECLAIM invoking similar concerns. Coalition for a Safe Environment v. California Air Resources Board, Complaint Under Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d and 40 C.F.R. Part 7, (filed June 8, 2012); Nash & Revesz, 2001.

Beyond this concern that trading programs might produce hotspots, some environmental justice groups have expressed concerns that GHG trading programs do not guarantee pollution reductions in EJCs and could lead sources in EJCs to reduce their emissions by less than sources in non-EJCs. If this were to happen, it could shift pollution levels towards EJCs. Environmental justice groups have raised these concerns in criticisms of California's Cap-and-Trade Program and RGGI.[81]

Environmental justice groups have also criticized trading programs as lacking in transparency, or not providing accessible information to communities about their impacts on the environment and human health. For example, environmental justice groups have objected to California's Cap-and-Trade Program on the grounds that, among other things, it wrongfully denied the public "access to essential facility-specific compliance data."[82]

Recognizing the concerns about the environmental justice implications of emissions trading,[83] a growing number of scholars have sought to empirically assess whether emissions trading programs have in fact harmed EJCs.[84] We provide a high-level summary of the existing scholarship here. However, given the importance of this topic, we review the relevant empirical evidence in more detail in Appendix B.

81. Brooklyn Movement Center et al., 2017; Coalition for a Safe Environment v. California Air Resources Board, Complaint Under Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d and 40 C.F.R. Part 7, (filed June 8, 2012).

82. California Environmental Justice Advisory Committee, 2017.

83. Concerns about the disproportionate burden a trading mechanism could have on low-income communities and communities of color have been raised about the potential trading program under Local Law 97. See N.Y.C. Environmental Justice Alliance, 2020.

84. Notably, it is unclear to what extent the findings of this literature are relevant to NYC's likely experience under a carbon trading program for residential and commercial buildings, because all of the emissions trading programs studied have regulated industrial sources, which generally have a more significant impact on air quality in the surrounding area than individual residential or commercial buildings do. Cromar, 2018 (observing that "heating oil emissions from buildings represented a relatively small fraction of total pollution in New York").

There are at least nine empirical studies analyzing whether trading programs have increased the relative difference between the pollution burden in disadvantaged communities and other communities.[85] Most of these nine studies find that emissions trading programs have not increased the relative pollution burden in disadvantaged communities. In fact, only one of the nine studies found a general shift in pollution towards disadvantaged communities[86] and a subsequent study of the same program (California's Cap-and-Trade Program) found the opposite result.[87] Some of the difference in findings is likely due to different methodological approaches.[88]

85. Coburn, 2001; Cushing et al., 2018; Fowlie et al., 2012; Grainger & Ruangmas, 2018; Hernandez-Cortes & Meng, 2020; Mansur & Sheriff, 2019; Meng, 2019; Ringquist, 2011; Walch, 2018. These articles do not use a common definition of "environmental justice communities" or "disadvantaged communities;" some look at only at demographic criteria such as income and racial groups in isolation (e.g., Mansur & Sheriff, 2019), while others use aggregated metrics of social criteria and pollution exposure to identify disadvantaged populations (e.g., Hernandez-Cortes & Meng, 2020; Cushing et al., 2018). As used here, "disadvantaged communities" is a catchall of the populations of interests examined in these studies, whether the populations were identified by reference to demographic criteria alone or demographic and environmental criteria.

86. Cushing et al., 2018. Notably, two of the other studies among the nine found shifts towards poorly educated communities. (Grainger & Ruangmas, 2018; Ringquist, 2011). However, these studies did not find a shift towards Black and Hispanic communities. In his study of the Acid Rain Trading program, Ringquist finds no increase in the concentration of allowances in Black or Hispanic communities. In their study of RECLAIM, Grainger & Ruangmas found that Black communities saw larger reductions in pollution than white communities while Hispanic communities saw smaller reductions.

87. Hernandez-Cortes & Meng, 2020 (finding that emissions trading had narrowed the emissions gap between disadvantaged communities and other areas of the state).

88. For example, the study by Lara Cushing et al. has been criticized for not properly analyzing causation. In a subsequent study, the economist Ryan Walch wrote the following critique of the Cushing et al. study:

"The most simplistic approach to answering the research question posed in this paper would be to compare the mean emissions before and after the program. Many of the EJ groups concerned about cap-and-trade in California implicitly make such an argument and cite research such as Cushing et al. (2016) that follows this method. If I were to replicate this approach with my data, I would find a statistically insignificant decrease of 10.2 tons a year in NO_x and a statistically significant increase of 0.62 tons per year for SO_x. However, there are major concerns about the validity of this approach. It is impossible to separate the effect of the program from changes in co-pollutant levels that would have occurred anyway. To get proper estimates of the program's causal impact, we need to find a proper control group that would allow us to estimate what would have happened at the California plants under the no-program counterfactual." Walch, 2018.

In thinking about the implications of these studies for a potential NYC trading program, it is important to bear in mind that none of the trading programs that these studies analyzed specifically prioritized emissions reductions from regulated facilities in EJCs. It is true that the California program requires a proportion of auction revenue to be invested in GHG projects in EJCs,[89] but these investments will not necessarily translate into local pollutant emissions reductions at the *regulated* facilities in these areas.[90] And if they don't, the relevant reductions would likely not be captured in studies examining the change in emissions in EJCs that the California program has generated.[91]

This is a key difference between existing trading programs and the program that the Study has contemplated for NYC to adopt under LL97. Reflecting the priorities set by MOC&S, this study developed proposals that: 1) prioritize emissions reductions from buildings in EJCs, and 2) include safeguards to ensure that local air pollution would not increase in EJCs in any year under trading compared to LL97 without trading. We provide more detail on this and other aspects of the proposal designs in Part 8.

89. At least 25% of revenue generated from the auctioning of GHG allowances must be spent in "disadvantaged communities." California Environmental Protection Agency, 2017. New York State also requires a portion of the RGGI auction proceeds to be distributed to projects in disadvantaged communities—setting a goal for said communities to receive 40%, and no less than 35%, of the benefits from the investment of auction proceeds. This is a state regulation, and not endemic to RGGI itself. N.Y. Comp. Codes R. & Regs. tit. 21, § 507.4(d).

90. For example, California Climate Investments have been made toward providing rebates for clean vehicles, providing community composting programs in green spaces, or increasing the supply of affordable housing near jobs and transportation options. See California Climate Investments, n.d. None of these investments would directly manifest emissions reductions at regulated facilities because the program only directly regulates sources like petroleum refiners or cement producers that emit more than 25,000 tons of carbon dioxide equivalent per year.

91. See, e.g., Cushing et al., 2018 (noting that the study's emissions reduction analysis only considered the changes in emissions from regulated industries, and did not take into account the impacts of other emissions reductions, including those attributable to cap-and-trade revenue investments).

Effectiveness in Reducing Emissions

Another concern about emissions trading programs that is frequently raised is that they do not effectively induce firms to reduce their emissions. This criticism has been made about both RGGI and the EU ETS, particularly in the programs' early years.[92] In both instances, regulators set an emissions cap for the initial compliance periods that ended up being higher than actual emissions. As a result, allowance prices were low, which arguably undercut the effectiveness of the program in driving emissions reductions.[93] An alternative interpretation of the same evidence is that the cap-and-trade and complementary policies incentivized early action at low cost.[94] The federal Acid Rain Program, for instance, delivered a 36% reduction in SO_2 emissions from power plants between 1990 and 2004, while electricity generation increased by 25% during the same time period,[95] and for most of the program's existence, it has featured very low allowance prices.[96]

There is a risk that LL97 (with or without trading) might not induce significant emissions reductions in its early years given the relatively lenient emissions caps that the law sets for the first compliance period. As discussed further in Part 6, approximately 91% of square feet in covered properties are already predicted to be below their 2024 caps (see Figure 11). The illustrative design proposals outlined in Part 8 utilize best-practices approaches to restrict the supply of credits to guard against the risk that a trading program would fail to induce significant emissions reductions.[97]

92. Schmalensee & Stavins, 2017; European Commission, 2012.

93. Chang, Spees, & Lee, 2016. On the problems created in emissions trading programs by overallocation, see McAllister, 2009, p. 397 (discussing "low allowance prices, delays in emissions reductions, and the buildup of large allowance banks"). *See also* Schmalensee & Stavins, 2017, p. 583 ("It is clear from basic economic theory and is now validated by experience that a robust market requires a cap that is significantly below BAU emissions.").

94. See, e.g., Borenstein et al., 2019.

95. Schlamensee & Stavins, 2017, p. 62.

96. Hitaj & Stocking, 2016.

97. These approaches include disallowing the use of international offsets and strictly defining the baseline below which owners must reduce emissions to obtain credits. If LL97 uses an auction-based approach, a credit price floor can be utilized as well to ensure that low-cost abatement opportunities are pursued prior to purchasing credits.

The City should also adopt mechanisms for periodic review of the LL97 emissions caps, whether or not it proceeds with trading. The main reason that RGGI did not drive emissions reductions in the early years is because policymakers overestimated what business-as-usual emissions would be over the next decade and therefore set the cap at a level that ended up being too generous relative to actual emissions to induce savings.[98] The emissions caps that the City Council established in LL97 are vulnerable to similar miscalculations, especially given the dramatic decline in retail and commercial occupancy since the COVID-19 pandemic as well as significant reductions anticipated in the emissions intensity of the electricity sector.[99] If the LL97 caps end up being above business-as-usual emissions, the law will not drive change with or without a trading system and will not be worth the administrative costs involved with monitoring compliance. Periodic review could reduce this risk.

Administrative Complexity and Transaction Costs

Another concern that has been raised about emissions trading programs is that they will be costly for the government to administer and will impose substantial transaction costs on regulated entities who find it more challenging to participate in the program. If these costs are high, they could substantially decrease the economic efficiency of trading programs, thus weakening the case for their adoption.[100]

Experience to date suggests that emissions trading programs impose manageable administrative and transaction costs. For instance, an EPA review of the federal Acid Rain Program (ARP) determined that private transaction costs were only 0.1% of the cost of an allowance.[101] The same study also stated that administering the ARP's trading market required less than one full-time EPA employee.[102] This does not, of course, mean that administration of the acid rain trading program as a whole required only one staff member; by contrast, at the time that EPA published its review, 50 employees were staffed on the program.[103] But most of these employees were engaged in administrative tasks such as monitoring and verifying the veracity of emissions levels, which would have been required irrespective of whether trading was permitted.

98. Schlamensee & Stavins, 2017, p. 66. Emissions forecasts that were estimated when RGGI was designed did not foresee the recession brought about by the 2008 financial crisis or the drastic drop in natural gas prices.

99. Haag & Rubinstein, 2020 (noting that nearly 14% of offices and more than 33% of storefronts were empty, as of December 2020).

100. Heindl, 2015.

101. Napolitano et al., 2007.

102. Napolitano et al., 2007.

103. Napolitano et al., 2007.

In managing California's greenhouse gas market, the California Air Resources Board does devote several full-time-equivalent staff to implementation and oversight, and in particular to monitoring relationships between market participants to prevent any possible market manipulation. New York City could hire experienced contractors to manage tasks such as market registration, monitoring, and administration of any auctions or trading platforms or databases. We have separately undertaken an analysis of existing trading programs to understand a range of empirical costs to setting up and operating a trading program, and these have revealed a range of onetime investments and ongoing expenditures that all lead to a wide range of costs over time. Onetime investments include initial market research and design, upfront rulemaking, and the design and launch of registries and auction platforms for trading. Ongoing investments include registry and auction management, market monitoring and reporting, training and technical assistance to trading entities, and periodic evaluation of market performance. The ultimate cost of a trading system will also depend on the systems developed for LL97 through DOB, which have not been set. For example, covered buildings may be required to report using an updated system (as opposed to the current EPA Portfolio Manager) or to submit reports more frequently.[104,105]

Nonetheless, to keep administrative costs as low as possible, the City should take full advantage of third-party assistance and various cost-minimizing features of the market-based structure. For example, the City should hire experienced contractors to manage potentially costlier tasks like tracking affiliations between market participants and monitoring the auctions and trades for manipulations. Registration fees, especially perhaps from non-regulated financial entities seeking to participate in the market, could potentially help offset such monitoring costs. When possible, the City should borrow and adapt infrastructure from existing, proven regulatory markets, including appropriate regulatory text and relevant guidance from other programs, and adaptable software used by other programs to track credits or run auctions. Furthermore, the City should allow brokers to enter the market to help facilitate the participation of smaller or less sophisticated buildings without the need for as much additional guidance from the City. Finally, the City should take advantage of the features of the market-based approach (i.e., allow trading) that will reduce the need to grant variances to regulated entities, which would save the City the costs of reviewing as many applications for adjustments to emissions caps or penalty rates.

104. Critically, we have examined only the incremental costs of adding a trading program to the existing administrative infrastructure. Furthermore, because many aspects of LL97 are novel within the American context, including the number of regulated sources—LL97 covers far more sources that RGGI or California's Cap-and-Trade Program regulates—and the type of regulated sources (buildings), the Team had limited comparable examples to draw from in arriving at its estimates.

105. More detail on these calculations is provided in the Implementation Plan.

4

Goals for a Trading Program Under LL97

Goals for a Trading Program Under LL97

The City identified a number of goals that a trading program should advance both for the City as a whole and EJCs in particular. On a city-wide basis, a trading program should lower the cost of compliance with LL97 while yielding earlier and deeper GHG emissions reductions. With respect to EJCs, a trading program should drive *additional* investment towards the local building stock and ensure that there is no increase in any local air pollutant in any year compared to what would occur if LL97 were implemented without trading.

LL97 says fairly little about the goals that a trading program should advance. It calls for the Study to include "methods to ensure equitable investment in environmental justice communities that preserve a minimum level of benefits for all covered buildings and do not result in any localized increases in pollution"[106] but does not define what "equitable investment" means, nor provide any temporal or geographic criteria for determining whether an increase in local air pollution has occurred. The law also does not clearly state whether a trading program would need to meet these criteria to be adopted or if the Study is merely supposed to examine the options for achieving these results.

MOC&S provided a number of more specific goals for a trading program and criteria that such a program must meet. On a citywide basis, MOC&S determined that a successful program would lower the cost of compliance with LL97 and encourage earlier and more substantial GHG reductions than would otherwise result under LL97 without trading.

To promote environmental justice, MOC&S determined that a trading program should generate *more* investment in EJCs than would otherwise occur under LL97 without trading. In addition, MOC&S interpreted the requirement in LL97 that the Study "include methods...that...do not result in any localized increase in air pollution"[107] to mean that a successful program would not just avoid increases in air pollution compared to LL97 without trading on a citywide basis, or in EJCs from 2024 to 2050, but would not increase *any* local air pollutant ($PM_{2.5}$, SO_x, or NO_x) in EJCs in *any* given year between 2024 and 2050 compared to LL97 without trading. Thus, the Study was not just focused on maximizing total benefits throughout the 26 years during which LL97 applies (for example, maximizing total premature deaths avoided from local air pollution reductions) but was also concerned with the rate of emissions across time; If trading yielded an increase in any local air pollutant or emissions in EJCs during any year, this would violate MOC&S' interpretation of LL97, even if the total amount of pollution reduced would be greater than under LL97.

Once these more specific goals for a trading program had been determined, the Study developed a decision-matrix for evaluating the extent to which a given program advanced the City's goals. This matrix includes eight different categories of metrics that can be used to assess a program's performance. The categories include net benefits, overall emissions reductions, timing of emissions reductions, environmental justice, owners' costs, simplicity of use for property owners, implementation complexity for the City, and robustness of the results to changes in external conditions. The full matrix with all of the evaluative sub-categories is reproduced in Appendix D.

106. N.Y.C. Admin. Code § 28-320.11.

107. N.Y.C. Admin. Code § 28-320.11.

Given the importance that the Study placed on environmental justice, it is worthwhile to review some of the specific criteria that were developed to evaluate the proposals' environmental justice performance. As with the other aspects of the decision-matrix, all metrics were decided in consultation with MOC&S, which set the policy preferences. We used six metrics to assess a program's ability to drive investment into EJCs:

1.

Total investment in buildings subject to emissions caps under Section 320 in EJCs compared to non-EJCs per square foot. A program would do well under this metric if it increased investment in EJCs compared to LL97 without trading and there were more investment in EJCs than non-EJCs.

2.

Additional investment in buildings subject to prescriptive requirements under Section 321 in EJCs. A program would do well in this category if there were a substantial increase in investment in Section 321 buildings compared to LL97 without trading. Again, particular weight was placed on whether there was an increase in investment in 321 buildings located in EJCs.

3.

Participation by square foot by EJ status. A program would do well on this metric if it incentivized a large number of square feet to participate. This metric indicates if property owners find it beneficial to reduce emissions below their baseline levels and participate in a trading program. It suggests how much additional investment the program could be expected to generate.

4.

Trade revenue flows to EJCs. The more trade revenue that flowed towards EJCs, the better a program would score on this metric.

5.

Cost reductions for EJC property owners. The more a program reduced EJC owners' costs compared to LL97 without trading, the better it would score on this metric.

6.

Energy cost reductions for EJCs. This metric indicates whether trading would generate energy cost savings for owners and residents in EJCs.

The Study included several pollution-oriented metrics to evaluate environmental justice as well.

1.

GHG reductions in EJCs. For a program to do well on this metric, it should decrease GHGs originating in EJCs below that which would occur under LL97 without trading. A good rating on this metric indicates whether properties in EJCs are meeting their obligations by investing in energy efficiency, which produces localized benefits, as opposed to purchasing RECs or offsets.

2.

Change in local pollutant emissions ($PM_{2.5}$, NO_x, SO_x) in EJCs. For a program to score well on this metric, it should incentivize a decrease in each local pollutant in EJCs compared to LL97 without trading. Program designs that increase any pollutant in any year would be disqualified from further consideration.

3.

$PM_{2.5}$-related mortality in EJCs. The greater the reduction in mortality compared to LL97 without trading in EJCs attributable to $PM_{2.5}$, the better a program would score on this metric.

As will be described in Part 8, we believe that a carefully designed trading program could advance these environmental justice goals as well as the City's general environmental and economic goals.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5

Overview of Study Methodology

Overview of Study Methodology

The Study used an optimization model to approximate the decisions that building owners would make under different program designs. This model assumes that owners would choose the lowest cost means of complying with the law each year, whether that be investing in an energy conservation measure, investing in electrification or fuel-switching, buying a REC or offset, installing distributed generation, paying a penalty or buying a carbon credit. The outputs of the optimization model were then used to evaluate the costs and benefits of LL97 with and without inclusion of a trading program.

The Study focused on the potential to design a trading program to amplify the benefits and reduce the costs of LL97. To establish a base case for assessing the incremental benefits and costs of different trading designs, the Study began by analyzing the impacts of LL97 without trading. Once the base case was established, the Study used an iterative modeling process to assess the impacts of different trading designs. The impacts of LL97 and various trading designs were analyzed over a 26-year period from 2024 to 2050.

The underlying model used to analyze the impacts of LL97 without trading, and to evaluate and test different trading scenario designs, was The Brattle Group's Decarbonized Energy Economy Planning (DEEP) optimization model approximates building owner behaviors by assuming that building owners rationally choose the lowest-cost compliance pathway in each year, whether that be investing in an energy conservation measure, buying a REC or an offset, installing distributed solar, or paying a penalty.

With the introduction of trading, owners also have the option of buying credits to comply or selling excess credits if a building has a cost-effective measure. The model dynamically solves for the market value of credits in each year based on the supply of and demand for credits from building owners.

To populate this model, we segmented the NYC building stock into distinct typologies that varied along several categories of attributes: physical attributes such as building size and age, energy attributes such as baseline systems and emissions intensity, and real estate attributes such as ownership type and rent levels. This segmentation exercise yielded roughly 200 segments that each represent a tranche of owners that are modeled to behave in the same way. For each segment, we calculated baseline emissions levels based on LL84 data and emissions targets based on LL97 emissions caps by occupancy code. For each segment, we also determined a set of applicable energy retrofit measures and estimated the installation costs and energy savings benefits of these measures. These costs and savings estimates drew from past estimates developed by the NYC Technical Working Group, LL87 building audit data, and other reports and contractor data.

Additional inputs into the model included energy cost and emissions forecasts. Non-electricity future energy costs were estimated using a mix of near-term futures and long-term forecasts of energy commodities, and assumptions about the energy delivery charges based on historical trends and forecasts. Emission factors for non-electricity fuels were provided in LL97. Electricity costs and emissions were informed by Brattle's New York capacity expansion modeling results,[108] where costs and emissions were estimated for Zone J based on the capacity buildout costs, expected generation costs, and expected zero emission electricity delivered to Zone J to be achieved at pace with the CLCPA schedule for grid decarbonization.[109] Renewable energy credit (REC) costs and supply were based on estimated above-market costs to deliver renewable energy to Zone J (based on public sources of Zone J energy prices, levelized energy costs related to offshore, Tier 4 and local clean generation) and expected clean supply based on expected procurements.

Additional detail on the building segments and other model inputs is available in Appendix B.

The outputs of the optimization model were then used to evaluate the costs and benefits of LL97 and of additional trading programs. During the post-processing of model results, we calculated the net present value of owner costs (including measure installation costs, penalty payments, offset and REC purchases), owner energy costs and savings, and tenant energy costs and savings. We also calculated GHG and local pollutant emissions reductions, and monetized the value of these reductions, including by using the EPA's societal cost of GHG emissions and the monetary value of lives saved from lower concentrations of pollutants.

Notably, in the fall of 2020, as the Team was approaching the end of its modeling work, the City Council passed a law that expanded the number of properties subject to the mandatory emissions caps set out in Section 320. Initially, all buildings with one or more rent regulated units were excluded from Section 320 and covered by Section 321 instead. Under the new law, only properties with more than 35% rent regulated units were excluded from Section 320. Due to resource constraints, we could not redo all of our initial model runs to reflect this change. However, we did include the change in our final modeling runs, to evaluate the no trade scenario and the two illustrative proposals. Overall, the legislative change had only minor impacts on our modeling, as the affected square footage was less than 5% of total covered square footage.

108. Lueken et al., 2019.

109. The electricity emission factor from 2024–2029 was kept constant at the emission rate written in LL97. After 2029, the electricity emission factor was adjusted.

6

The Base Case: LL97 without Trading

The Base Case: LL97 without Trading

Our modeling projects that LL97 without trading will reduce GHG emissions, improve local air quality, and reduce energy costs for building owners across the City. The law will lead to greater reductions in local air pollution in non-EJCs than EJCs because the emissions caps cover substantially more square footage in non-EJCs than EJCs. The law will also impose higher average compliance costs on residential buildings on a $ per square foot basis, so the average compliance costs for building owners are higher in primarily residential areas than primarily commercial areas. This leads to lower average compliance costs for buildings in non-EJCs because these areas have the highest concentration of commercial buildings. The major reason that the average cost of compliance is lower for commercial buildings is that their emissions decline the most as a result of grid decarbonization.

This part describes the predicted benefits and costs of LL97 without trading so that we have a baseline against which to estimate the impacts of trading. Unless otherwise stated, all estimates that we present derive from modeling conducted for the purposes of this study.

LL97 will reduce GHG emissions, improve local air quality, and reduce energy costs for building owners. These benefits accrue to the City as a whole as well as to EJCs in particular. And while the law will require many owners to spend money to bring their properties into compliance with the law, especially after 2029, the value of energy savings will generally exceed the cost of these initial outlays over the course of the 26 years in which LL97 will operate.

There are some differences in the magnitude of these benefits and costs between EJCs and non-EJCs. Looking first at the pollution impacts, LL97 leads to larger reductions in local air pollution in non-EJCs. The reason for this is that the law regulates more square feet of real estate in non-EJCs, which leads to more total retrofits in non-EJC buildings and therefore more local air pollution reductions. However, because most neighborhoods in the City have been classified as EJCs, more people live in EJCs, which means the reduction in pollution that does occur is likely to produce more health benefits for EJCs.

The costs of LL97 are different for EJCs and non-EJCs as well. In particular, the law generally imposes higher compliance costs on buildings in EJCs. The difference results from the fact that commercial buildings, which rely mostly on electricity for their energy needs and therefore benefit substantially from grid decarbonization, are concentrated in non-EJCs.[110]

Importantly, the magnitude of the benefits and costs that LL97 will have depends to a large extent on the pace at which the New York State electricity grid decarbonizes. If the grid decarbonizes at the pace that the State mandates in the CLCPA, and the coefficients DOB assigns for grid-tied electricity reflect this pace,[111] the aggregated LL97 emissions caps will not be much below buildings' estimated future emissions until 2050.[112] And if the caps are not much below "business-as-usual" emissions, neither the additive GHG benefits nor the costs imposed on owners to meet the law will be very large. This is especially true of the commercial sector because, as described above, electricity accounts for a greater percentage of the source energy that commercial buildings use than in other sectors. If, however,

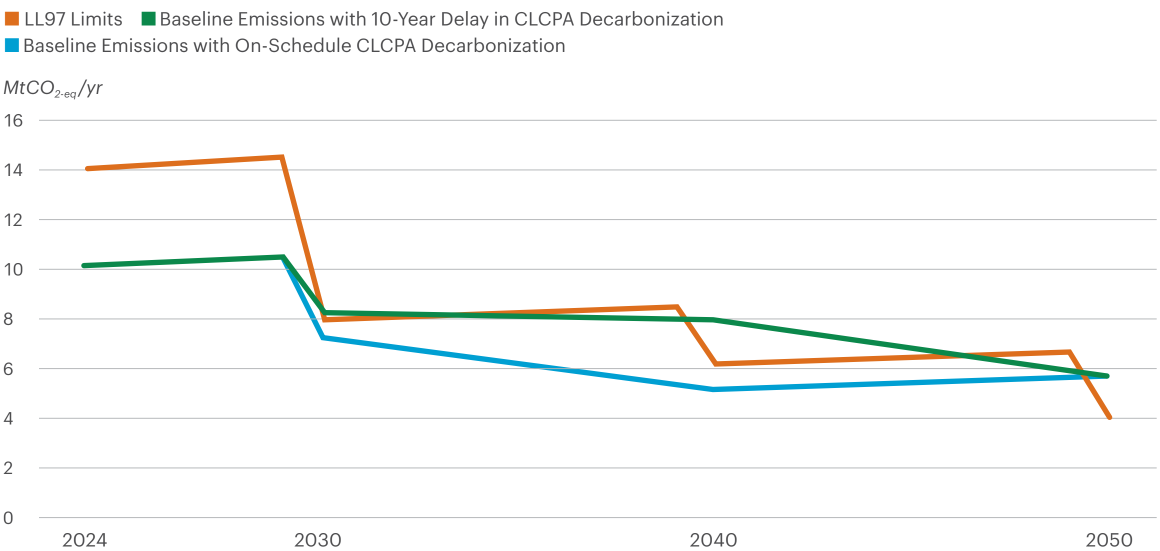
110. See Part 6.B for more details on this dynamic.

111. DOB may rely on grid studies by NYISO, NYSERDA, or other state and/or City agencies to inform the carbon coefficients for grid-tied electricity. It is important that the coefficients reflect expected decarbonization and are also provided with enough lead time to allow building owners to plan investments.

112. By 2050, when the most stringent caps are in place, LL97 itself will require building owners to take significant action, even if the grid has been decarbonized.

Figure 10. Reduction in covered buildings' emissions attributable to CLCPA grid decarbonization.

Baseline emissions until 2030 reflect the electricity emission coefficient in LL97. The coefficient for electricity is adjusted after 2030 to reflect grid decarbonization at pace with CLCPA or 10-year delay. Gradual increase in emissions after 2040 reflects building growth.



grid decarbonization is delayed, then LL97 will drive more substantial changes. In developing a base case of LL97 without trading, we assume that the grid will decarbonize at pace with the CLCPA, since this is what is written in the law today. Figure 10 above indicates how CLCPA decarbonization impacts covered buildings' emissions; by 2040, if the grid decarbonizes at pace with CLCPA, covered buildings' emissions will fall by 50% relative to 2024 without having to invest in any abatement. If CLCPA is delayed by 10 years, covered building emissions will fall by only 20% during the same time period.

A. Benefits of LL97 without Trading—Citywide and for Environmental Justice Communities

LL97 without trading is predicted to confer a variety of environmental and economic benefits.

Looking first at the environmental benefits, LL97 is expected to reduce emissions by 14 million metric tons of CO_2e (in addition to emission reductions from grid decarbonization) of the covered building stock over the 26-year study period compared to business as usual. For context, these buildings emit roughly 9 million metric tons of CO_2e *annually*, and grid decarbonization is estimated to reduce over 50 million metric tons of CO_2e from LL97 covered buildings over the 26-year study period if CLCPA is met.

Most emission reductions occur due to adoption of cost-effective efficiency measures such as plug load efficiency improvements, insulation upgrades, or boiler and distribution optimization, which, along with a few electrification measures, make up 11 million metric tons of reductions. Beyond those measures which are very cost effective, few retrofit measures are uptaken in the early years where owners instead choose to use cheaper deductions from offsets and RECs to comply. Offsets reduce 0.5 million metric tons of emissions in the first compliance period, and RECs reduce emissions by 1.8 million metric tons.

LL97 is also predicted to improve local air quality. Both EJCs and non-EJCs see reductions in local air pollution emissions (see Table 4). These emissions are reduced due to a mixture of efficiency measures, which reduce the burning of liquid and gaseous fuels on-site, and electrification measures, which replace on-site fossil fuel burning with electricity use. LL97 leads to more total reduction in local air pollution in non-EJCs than EJCs because Section 320 covers many more square feet of real estate in non-EJCs.[113]

The law is predicted to provide economic benefits as well. As we describe in more detail below, we estimate that LL97 will actually *save* property owners money because the energy efficiency improvements that the law induces owners to make will generate energy cost savings over the study period that exceed the cost of the initial investment.[114] The results for tenant energy bill costs are mixed. We forecast that tenant energy bills will increase citywide by $6 million over the study period, but tenants in EJCs will see $26 million in energy bill increases while tenants in non-EJCs will see savings of $20 million. This increase in tenant energy bills results primarily from modeled increased electrification investments in EJCs, as electrification is modeled to increase tenant costs while reducing emissions. Critically, however, these estimates do not account for certain legal protections that might be in place to protect tenants in rent regulated units from building owners shifting utility expenses towards tenants as the buildings electrify.[115] Thus, the modeled tenant impacts are fairly crude estimates.

The model projects that LL97 could generate penalties in the amount of $224 million (2020 $, 2020 NPV over the course of the Study period).[116]

Note that our Study did not estimate the potential for LL97 to create new jobs in the building retrofit sector, such as building engineers and HVAC contractors, which is another important economic benefit.

The table below summarizes the predicted benefits and to whom they accrue.

113. LL97 covers 1.4 billion non-EJC square footage and 0.4 billion EJC square footage.

114. Savings across EJCs and non-EJCs are similar on a $/sqft basis; however, absolute values are larger for non-EJCs because Section 320 covers more square feet of properties in non-EJCs. See Table 4.

115. A common cause of increased energy bills is electrification, as electricity is often costlier than natural gas to operate common appliances and heating equipment. For buildings where owners pass on the costs of energy to tenants, owners make decisions in the modeling without consideration of the potential energy bill changes. Notably, there are a number of legal protections in place that restrict landlords' ability to shift energy costs to tenants when converting from centralized heating to a submetered electric heating system. Urban Green Council, 2020b. Moreover, New York State Homes and Community Renewal (HCR) policies prohibit landlords from charging tenants in rent regulated units for their heating; thus, tenants of rent regulated properties should not see their utility costs rise as a result of heating electrification. Urban Green Council, 2020b. Some of such units are captured in our sample because Section 320 of LL97 covers buildings with more than 25,000 square feet in which fewer than 35% of units are regulated.

116. In this modeling exercise, penalty revenues begin in 2030 at around $5 million per year and grow to $50 million per year by 2040. Given the modeling of averaged segments, penalty revenues may be underestimated, especially in the early years, as averaging masks high-emitting and high-cost buildings which may face penalties even in the first compliance period. Over the course of the study period, $840 million (in nominal dollars) in penalty revenues is projected to be generated.

Table 4. Citywide benefits of base-case LL97 without trading from 2024 to 2050.

GHG Emission Reductions	14 million metric tons CO_2e
Pollutant Reductions	**In EJCs:** 9,167 metric tons primary $PM_{2.5}$ 11,543 metric tons NO_x 1,170 metric tons SO_x **In non-EJCs:** 13,511 metric tons primary $PM_{2.5}$ 15,459 metric tons NO_x 1,590 metric tons SO_x
Owner Net Savings	$2.032 billion (2020$, 2020 NPV)
Tenant Bill Costs	$6 million (2020$, 2020 NPV)
City Revenues from Penalties	$224 million (2020$, 2020 NPV)

B. Costs of LL97 without Trading—Citywide and for Environmental Justice Communities

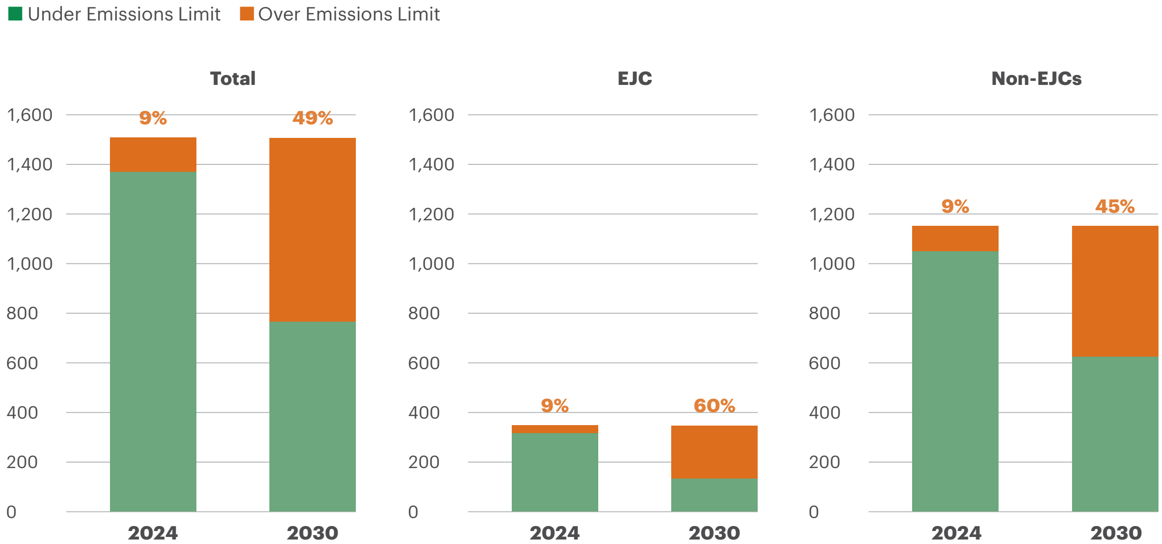
Of course, LL97 will also impose costs on many building owners who will need to spend money to bring their properties into compliance with the law. Broadly speaking, there are two different ways that one can think about the costs that LL97 imposes on property owners. First, one could simply calculate the total amount that owners must spend on retrofits, RECs, offsets, and penalties to bring their properties into compliance with the law. We refer to this figure as "compliance costs." Second, one can calculate compliance costs and then subtract the expected energy savings that owners will reap as a result of their investment. We refer to this figure as owners' "net costs" (or "net savings," if the savings exceed the costs).

We find that while LL97 imposes modest compliance costs on property owners, it actually produces modest net *savings* on average. The idea that an energy efficiency regulation could produce net savings for owners is consistent with the scholarly literature that suggests that property owners often fail to implement cost-effective energy efficiency improvements.[117]

To understand why we predict LL97 will only have modest impacts on owner costs, it is important to note that most properties are unlikely to have to take any action to meet the 2024 caps. Only about 9% of square feet subject to emissions caps under section 320 are expected to be over their emissions caps in 2024 if they maintain emissions at 2018 levels. The picture changes in 2030. At this point, about 49% of square feet will be over their caps if they maintain emissions at 2018 levels. As the grid decarbonizes, GHG emissions from buildings will decline because electricity from the grid is a significant source of emissions today. While EJCs have a much lower volume of square feet covered by Section 320, a higher share of this square footage will be over the 2030 emissions limits: 60% compared to 45% in non-EJCs.

117. Gerarden, Newell & Stavins, 2017.

Figure 11. Share of square footage whose 2018 emissions exceed LL97 caps for 2024 and 2030.



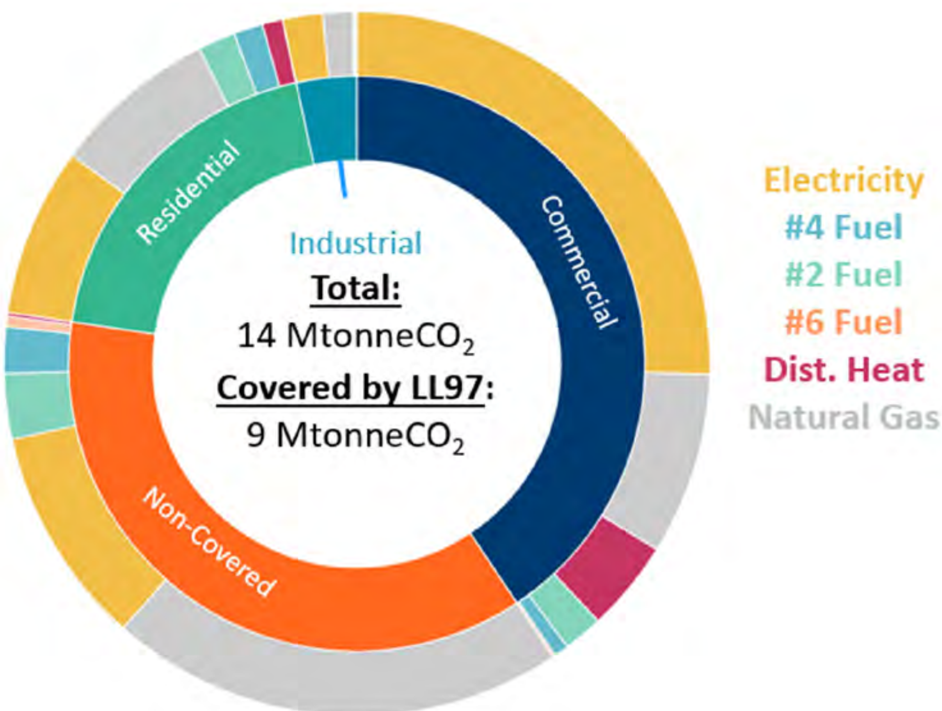
Commercial and institutional properties today are better positioned to meet their emissions targets than residential and industrial properties. Looking at commercial properties' 2018 emissions, only 8% of square footage exceeded the 2024 caps, compared to 17% of residential properties. Commercial buildings' relative compliance advantage grows in subsequent periods as the grid decarbonizes: if all buildings maintained 2018 emissions levels but the grid decarbonizes on pace with the State's goals, by 2040, only 7% of commercial square footage would be emitting more than its LL97 caps, compared to 73% of residential square footage. We provide more detail on the precise types of buildings within the categories below (residential, commercial, industrial, and institutional) in Appendix B.

Table 5. Share of square footage whose 2018 GHG emissions exceed LL97 caps after CLCPA grid emission reductions for 2024, 2030, and 2040 by segment.

	2024	2030	2040
Residential	17%	64%	73%
Commercial	8%	29%	7%
Industrial	8%	100%	100%
Institutional	2%	32%	18%

The varying stringency of the LL97 caps for different sectors results from the disparate impacts of grid decarbonization on the emissions levels of different building segments. Electricity accounts for a larger share of total energy use in commercial buildings than residential buildings, as a higher share of residential buildings' energy use comes from the combustion of onsite fossil fuels for heating and hot water (see Figure 12). Because commercial buildings are generally more electrified, they will benefit more from the State's plans to decarbonize the electricity grid. As will be described below, the fact that compliance costs are generally higher for residential buildings impacts the geographic distribution of the costs that LL97 imposes with higher costs in the more residential parts of the city, which include most environmental justice communities. Notably, LL97 was passed before the State's CLCPA, so City lawmakers may not have anticipated the full extent of the State's commitment to decarbonize the grid when they set the LL97 caps.

Figure 12. Annual emissions by building sector and fuel type in 2018.
As used here, non-covered buildings include those that are subject to prescriptive measures under Section 321 but not subject to emissions caps under Section 320.



Turning specifically to owners' compliance costs, we estimate that, citywide, building owners will have to spend $1.24 billion USD to meet their LL97 obligations (represented as the net present value in 2020 of costs over a study period of 2024–2050), or an average of $46 million USD per year over the study period.

On a per-square-foot basis, compliance costs average approximately $0.53 per square foot over the 2024–2050 study period—or roughly $53,000 for a 100,000 square foot building. These compliance costs are low, especially when compared to the typical operating expenses for a residential or commercial building. For example, average *annual* operating expenses for market-rate multifamily were calculated to be around $6.75 to $9.80 per sq. ft. for non-utility costs, including repair and maintenance costs and insurance costs.[118] However, while these costs appear low when considered over the entire study period, investment will be concentrated in the years preceding a decrease in emissions limits.

The optimization model developed for this Study[119] assumes varying utility costs using today's electricity and fuel rates, with a weighted average utility cost of roughly $7 per sq. ft. per year. This means that a 26-year NPV cost of $0.53 per square foot amounts to about a tenth of a percentage point of annual operating expenses, on average.

This is an important dynamic to keep in mind when interpreting the additive benefits of trading: if LL97 without trading will not impose very significant costs on owners, then the amount of money that trading can save property owners is necessarily limited. Of course, this does not mean that trading cannot provide significant benefits to other stakeholder groups or even to individual property owners that deviate substantially from the mean, because modeling segments that average many buildings likely reduces the actual cost saving potential. Additionally, trading can lead to increased air quality and reduced GHGs from early action. But the dynamic does suggest that trading will not provide very substantial cost savings to the average covered building owner.

When we consider owners' "net costs," LL97 becomes even less costly. In fact, when accounting for energy savings from retrofits, owners are expected to see total net *savings* of $2.03 billion USD over the 2024–2050 study period, or $0.87 per square foot on average. In other words, the modeling done for the Study predicts that over the entire 26 years between 2024 and 2050, LL97 should generate modest savings for buildings on average.[120] Of course, most owners and tenants will have shorter planning horizons than the 26 years of accrued benefits we report here. Moving beyond citywide average net costs, there are notable variations in costs based on building typology. Overall, the cost of complying with LL97 is higher for residential buildings than commercial buildings. This is due to the effect of grid decarbonization described above.

The following table presents per-square-foot costs by segment. Note that most segments are expected to reap savings as a result of LL97 once energy savings are taken into account (red = net savings).

118. Operating cost data were retrieved from the Real Property Income and Expense (RPIE) statements submitted by property owners to the Department of Finance annually. RPIE statements are filed by all income-producing properties.

119. The optimization model is described in Part 5 and Appendix B.

120. Notably, not included in the analysis of owners' costs are the lost benefits to owners from replacing building systems in advance of the end of their useful life, given the difficulty of creating a standardized estimate of these costs.

Table 6. Average per-square-foot costs of base-case LL97 without trading by building segment assuming grid decarbonization at pace with CLCPA.

	Total (unit/sqft)							
					Reduction in on-site emissions			
Segment	**Upfront Cost** *($/sqft)*	**Net Costs** *($/sqft)*	**Penalties** *($/sqft)*	**Emissions** *(tonne/sqft)*	**CO_2** *(tonne/sqft)*	**$PM_{2.5}$** *(grams/sqft)*	**NO_x** *(grams/sqft)*	**SO_x** *(grams/sqft)*
Resi Condo	$0.96	($0.22)	$0.32	0.14	0.007	18.17	23.08	2.23
Resi Market-Rate	$0.95	$0.14	$0.26	0.13	0.009	15.05	13.80	1.54
Affordable Housing	$0.07	$0.04	$0.00	0.15	0.001	6.77	11.72	1.04
Office	$0.40	($1.57)	$0.02	0.11	0.003	5.65	6.58	0.67
Industrial	$0.81	$0.39	$0.39	0.07	0.003	3.66	1.76	0.35
Retail	$1.19	($3.58)	$0.05	0.14	0.010	10.09	2.88	0.82
Hotel	$0.83	($3.37)	$0.05	0.18	0.008	9.45	4.60	0.79
NYCHA	$0.02	$0.05	$0.00	0.14	0.001	10.51	19.19	1.69
Institutional	$0.92	($4.21)	$0.03	0.18	0.010	10.71	4.43	0.86
Total ($M or Mtonne)	$1,240.56	–$2,031.88	$250.52	322.15	10.05	22,678	27,002	2,760

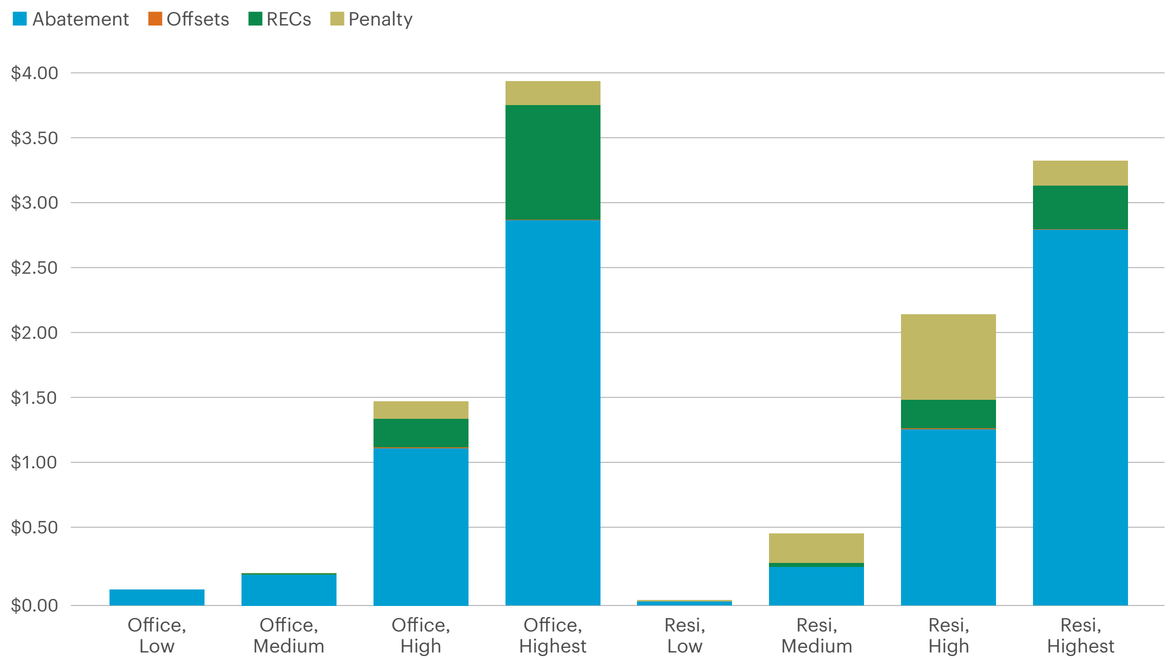
Notes: **Upfront Cost** = NPV of Investment in Abatement Measure + Penalty Cost.
Net-Costs = NPV of Upfront Cost – Energy Savings from Abatement Measures.

Within each segment, costs also vary considerably based on the emissions intensity of the individual property. This matters because it indicates that while LL97 may not impose very substantial costs on the average property, LL97 does impose somewhat substantial costs on the highest emitters.

Table 7. Per-square-foot gross compliance costs of base-case LL97 without trading assuming grid decarbonization at pace with CLCPA.

	Low Emitters (2018 emissions <2030 caps)	**Medium Emitters** (2018 emissions <2024 caps)	**High Emitters** (2018 emissions >2024 cap)	**Highest Emitters** (>40% over 2024 cap)
Office	$0.12	$0.24	$1.53	$3.93
Residential	$0.04	$0.54	$2.19	$3.34

Figure 13. Composition of average per-square-foot compliance costs by segment by emissions tier (low, medium, high, highest).



"Low" indicates properties whose 2018 emissions are already compliant with the relatively strict 2030 emissions caps. "Medium" indicates those that are compliant with 2024 caps, but not with 2030 caps. "High" indicates those not yet compliant with even the 2024 caps, but excluding "highest" emitters. "Highest" are properties not yet compliant with 2024 caps and emitting over 40% above the 2024 emissions caps.

Each segment's costs are comprised of quite different types of expenditure as well. As Figure 13 indicates, a larger share of the residential sector's costs come from penalty payments to the City's General Fund, which are priced at $268 per ton of excess emissions. Note that the figure above assumes that offsets are only available in the first compliance period; if DOB makes offsets available for the second and third compliance periods as well, which LL147 of 2019 instructs the Department to do, then offsets would comprise a larger share of the adopted compliance measures because they are expected to be cheap.[121]

A 2019 Retrofit Market Analysis produced by Urban Green Council estimated that LL97 would require $20 billion worth of retrofits in nominal dollars.[122] By contrast, this Study calculated that LL97 would impose compliance costs of $3.22 billion in nominal dollars ($1.24 billion in NPV). The present Study used similar inputs around retrofit costs and potential but shows a lower cost due to methodological differences.[123]

121. Modeled offset costs are roughly over $3–$4/metric ton CO_2, assuming international offsets from any source are eligible. These costs are based on recent historical offset costs from voluntary carbon markets. See Donofrio et al., 2020.

122. Urban Green Council, 2019. By "nominal dollars," we mean not adjusted for inflation.

123. There were three main methodological differences between our study and the Urban Green Council (UGC) study: (1) UGC did not adjust the coefficients for grid-tied electricity over time to reflect decarbonization outlined in the CLCPA, which we do in our analysis; (2) our study focuses only on the compliance costs of properties covered under LL97 Section 320 and subject to emissions limits, which excludes thousands of properties covered under Section 321 that had been included in UGC's higher-level calculation; and (3) UGC did not model the full suite of lower-cost compliance pathways available to owners, which includes RECs, offsets, and penalty costs in addition to retrofits. Instead, UGC's cost estimate assumed that only retrofits would be used to comply with emissions caps. See Urban Green Council, 2019.

Table 8. Share of square footage whose 2018 emissions exceeded LL97 caps for 2024, 2030, and 2040 by EJC status, assuming grid decarbonization at CLCPA pace.

	2024	2030	2040
EJC	9%	60%	53%
Non-EJC	9%	45%	38%

The different emissions profiles of commercial and residential buildings affect the geographic distribution of the costs and benefits that LL97 imposes. Because commercial buildings are heavily concentrated outside of EJCs,[124] non-EJC areas have a higher percentage of properties that are expected to meet their LL97 emissions targets under business as usual, meaning they would be in compliance with the law without having to invest in retrofits or purchase offsets or RECs. This is an important dynamic because it explains the finding that non-EJC buildings are more likely to sell credits, while EJC buildings are more likely to buy credits, if trading is introduced. It also explains why a trading program does more to lower the compliance costs of building owners (and tenants) in EJCs than non-EJCs. Stated differently, under LL97 as is, buildings in EJCs generally will have higher compliance costs than buildings outside EJCs.

124. 86% of commercial space covered under Section 320 is located outside of EJCs.

7

The Building Blocks of a Tailored Emissions Trading Program for LL97

The Building Blocks of a Tailored Emissions Trading Program for LL97

Emission trading programs can be designed in a number of different ways. Among the most consequential decisions is whether to freely distribute the credits that regulated entities need to meet their obligations or to require entities to purchase a portion of these credits at auction. The decision that is made in this respect impacts how stringent the emissions caps are; the more credits entities are given for free, the less they have to pay for their total emissions. There are many other variable elements of trading programs as well, including whether to allow entities to bank credits for use in future compliance periods, whether to set a minimum price at which credits can be purchased, whether to direct auction proceeds (if any) to particular purposes, such as investing in EJCs, and more.

The Study varied several of these elements in a series of initial modeling runs. Each of the initial runs produced larger emissions reductions (in terms of GHGs and local air pollutants) over the course of the study period than LL97 compliance without trading and lowered owners' costs. However, several scenarios showed increases in some pollutants in the early years, when the LL97 cap is relatively loose. The illustrative program proposals that were ultimately designed for the City to consider include complementary policy interventions to mitigate these negative outcomes.

The first step in designing an emissions trading program for LL97 is to identify which elements of a trading program are fixed by LL97 and which remain open to choice. As such, this part begins by reviewing the elements that the Study considered to be fixed and those that were considered variable. From here, we highlight key findings from the initial model runs that adjusted several of the elements that were considered to be open to choice. These findings informed the development of two illustrative design proposals which are discussed in Part 8.

Before reviewing the findings of our initial model runs, it is important to recall that the goal of the Study was to examine the *incremental* costs and benefits of adding a carbon trading program as a compliance mechanism under LL97. In other words, the Study focuses on whether a trading program would augment the net benefits that the law is expected to provide and, if so, how these additional benefits would be distributed among different stakeholders such as property owners, tenants, the public at large, and the City government. Therefore, the findings that we present in the rest of this report focus on describing the differences between a world in which LL97 proceeds as is and a world in which a trading program is added to it. We are not comparing LL97 with trading to a world in which there were no LL97 at all.

A. Fixed and Variable Elements

Policymakers have a number of choices as to how to design any particular emissions trading program. In developing a potential program for NYC to implement under LL97, the Study assumed that key features of LL97 would not be changed if a trading program were adopted pursuant to new legislation, and thus that certain parameters for a trading program were already set by LL97. Below, we outline key elements of trading programs, as well as which elements we assumed were fixed by LL97 and which were open to choice.

Caps. Trading programs typically are premised on a cap on allowable emissions. The stringency of the cap is an important decision. The cap also may be applied in different ways. For example, the cap could be sector-wide (e.g., a total value for all buildings), or it could be the product of individual caps for each regulated actor (e.g., individual building caps add up to an implied cap on overall building emissions).

The Study assumed that the building emissions caps in LL97 for each compliance period (2024–2029; 2030–2034; 2035–2050) are fixed and will not be tightened or relaxed.[125] We also assumed that there will be no explicit building sector-wide cap, since LL97 is structured to impose caps on individual buildings. We assumed that new buildings will receive the same emissions caps as equivalent existing buildings of the same occupancy type.[126] And we assumed that property owners would be allowed to use the deductions for RECs and clean distributed energy use that LL97 currently permits.[127]

Allocation Method. Trading programs require officials to allocate credits equal to the total amount of emissions that regulated entities can release. In some programs, such as the EU Emissions Trading System, a government entity creates the emissions credits centrally and then distributes them to regulated entities, which can then trade credits among themselves.[128] In other programs, such as the Tokyo ETS, the regulated entities themselves generate tradable credits in a decentralized manner by reducing emissions below a specified emissions limit.[129] Under the first approach, the government explicitly distributes credits equal to the total amount of emissions regulated entities can emit, whereas the second approach simply allows these entities to emit up to the emissions limit without penalty. (The second approach can be described as implicitly allocating credits up to the baseline since entities can emit up to that amount without further action.). If the government chooses to allocate credits centrally, it may allocate them for free, by auctioning them, or through a combination of free allocation and auctions.

LL97 authorizes buildings to emit up to their building emission caps for free. However, LL97 does not currently allow buildings to sell credits for excess emission reductions, and thus does not address how credits would be allocated if buildings were allowed to sell credits for such emissions reductions under an emissions trading program. Thus, the Study assumed that the method of allocating credits under an emissions trading program is subject to choice.

125. LL97 itself does not set caps for building emissions limits for individual types of buildings for 2035–2050. Instead, it instructs the DOB to issue rules by January 1, 2023 that specify limits for the periods between 2035–2039 and 2040–2049. However, the law says that the average carbon intensity for all covered buildings during these years should be 0.014 tCO_2e/sf/yr or less by 2050. For the purposes of this study, MOC&S provided a set of interim emissions limit assumptions for the years between 2034 and 2049. MOC&S instructed the study team to assume that the emissions limits for 2035–2039 would be the same as those listed in LL97 for 2030–2034. For the 2040–2049, MOC&S calculated an indicative emissions limit as follows: 1) they found the variance of each of the occupancy group targets from the average overall GHGI in 2030; 2) these variances were applied to the 2050 average GHGI included in the text of LL97; and 3) the half-way point between the 2030 and 2050 targets were determined and assigned to the 2040–2049 compliance period.

126. More precisely, the Study modeled each building segment as a group without explicitly distinguishing new and existing buildings with the segment. The total square footage of each segment grew over time, and so the associated emissions and abatement opportunities grew with the segments, but identifiable buildings were not added.

127. REC prices and availability were determined using forecasts of clean energy deliveries to Zone J, load serving entity demand for RECs, and above market costs for clean energy delivery to Zone J.

128. The number of allowances to be issued under the EU ETS has been set by the EU Commission. European Commission, 2020.

129. Tokyo Metropolitan Government, 2015.

The Study assumed that credits could either be allocated centrally, via auctions and/or free distribution, or in a decentralized manner by buildings generating credits for reductions below a baseline. If an auction is used, the Study assumed that the City would seek State legislative authorization in keeping with past practice.[130] The Study also assumed that revenues that the City generates from auctioning credits could be "earmarked" and directed to specific policy priorities, such as promoting environmental justice. While there does not appear to be a specific legal impediment to such earmarking, the City has a longstanding policy that revenues go to the general fund to preserve fiscal soundness and stability.[131]

Since LL97 does not presently provide for a trading program, it does not spell out how many credits would be distributed if allocated centrally, or the baseline emissions level below which a building would have to reduce its emissions to generate tradeable credits. The Study assumed that if credits were created centrally and then given out to buildings, buildings would only be given credits equal to the lesser of their LL97 emissions cap and their actual 2018 emissions (adjusted for electricity decarbonization after 2029). If the buildings themselves generate credits, the Study assumed that buildings would have to reduce their emissions below the lesser of their LL97 emissions caps and their actual 2018 emissions (adjusted for electricity decarbonization after 2029) to generate a credit.[132]

Banking. In designing an emission trading program, it is necessary to choose whether to allow credits to be banked for use in future years. If banking is permitted, the trading program may regulate it further, for example by setting time limits on the use of banked credits or devaluing credits over time to prevent regulated actors from accumulating large banks of credits. Again, because LL97 does not currently authorize emissions trading, it does not speak to whether credits could be banked, and the Study examined various approaches to banking.

Price floor. A price floor establishes a minimum price that must be paid for credits. If the government auctions credits, it can also relatively easily implement a price floor because it can decide not to sell the credits for less than a specified price. (It may also be possible to implement a price floor without auctions by requiring a fee equal to the price floor be paid upon surrender, but this has not been a common approach in precedent trading markets and may introduce added administrative complications.) The amount of the price floor is a key variable when price floors are used. Given that LL97 does not speak to whether there would be a price floor, and if so, how much it would be, the Study assumed this is subject to choice and modeled different options.

130. In the past, the City has sought prior State legislative authorization when auctioning regulatory instruments for more than the cost of administering the relevant regulatory program.

131. In the past, the City's budgetary processes have been subject to State oversight and control. For example, the New York State Financial Emergency Act for the City of New York, passed in 1975 in response to the City's debt crisis of the 1970s, established a series of budgeting restrictions, many of which are no longer in force today. Although § 5411(1) provides for the establishment of a "board fund" where "all revenues received or to be received by the city…shall, unless exempted by order of the board, be revenues of the board fund and shall be for the account of the city," this provision was only effective "for the duration of a control period." N.Y. Unconsol. Law ch. 22, § 9(1). This provision should be inapplicable as today the City is not in a control period, although the Financial Control Board does reserve the ability to reinstate a control period at any time.

132. This is necessary to ensure that building owners do not get a windfall and/or flood the market with credits, which would lead to low prices and weak incentives to invest in retrofits. Building baselines for credits also should be updated to account for electricity decarbonization after the first compliance period to further prevent windfall, which was done in the modeling after the first compliance period.

Offsets. An important consideration in designing an emissions trading program is whether to allow the regulated actors to use offsets to comply with emissions caps. LL97 allows covered buildings to use offsets to comply with up to 10% of their emissions caps in the first compliance period. It delegates to DOB to determine which offsets will be eligible for compliance. LL147 of 2019 instructs DOB to further extend the use of offsets beyond the first compliance period, although again, the eligibility rules for offsets are not known.

With one exception,[133] the Study's initial modeling assumed that offsets, including offsets from outside the United States, would be allowed in the first compliance period. The later modeling of the two illustrative proposals assumes that offsets will not be allowed. The reason for this is that trading itself would be a form of NYC-offset program, which makes some of the flexibility afforded by an offset program duplicative. A trading program also provides a tight geographic restriction to keep both investment and local emissions reductions within the city.[134]

Environmental Justice Policies. Trading programs can be designed to prioritize emissions reductions in environmental justice communities and/or install safeguards against localized emissions increases in EJCs. However, few existing trading programs have been designed with the specific goal of targeting benefits towards EJCs.[135]

133. One of the banking scenarios that the Study modeled excluded offsets.

134. See Part 6 above for more discussion on this point.

135. Two programs—RGGI and California's Cap-and-Trade Program—have adopted a form of EJ support. Both operate in a similar way, by allowing revenue to be directed toward EJCs, and both operate ex post. California requires that at least 25% of revenue generated from the auctioning of GHG allowances is spent in disadvantaged communities. California Environmental Protection Agency, 2017. RGGI allows for states to direct their revenue generated from the program toward EJCs, and New York State includes a goal in its regulations that disadvantaged communities receive 40%, and no less than 35%, of the benefits from the investment of the auction proceeds—bringing the program into alignment with the CLCPA. N.Y. Comp. Codes R. & Regs. tit. 21, § 507.4(d). Here, the Study wanted to explore alternative options for providing benefits to EJCs.

Trading market rules can be designed to encourage (or discourage) purchases of credits from EJCs. For example, credit holders outside EJCs could be required to include a percentage of EJC credits upon surrendering credits for compliance; credits from EJCs could entitle holders to emit more emissions than credits from non-EJCs (or conversely, credits from non-EJCs could be discounted); or only actors from EJCs could be allowed to bank credits or voluntarily opt into a trading program. Centrally allocating credits opens up options for promoting environmental justice that are not available if credits are distributed in a decentralized manner by buildings reducing emissions below a baseline. If some or all credits are auctioned, the auctions could potentially create a pool of funds that could be directed to funding retrofits or other investments in EJCs. If credits are distributed centrally, stakeholders in EJCs potentially could be distributed credits for free while non-EJC stakeholders are required to pay for some or all credits.

LL97 does not speak to how a trading program should promote environmental justice. The law requires this Study to "include methods to ensure equitable investment in environmental justice communities that preserve a minimum level of benefits for all covered buildings and do not result in any localized increases in pollution"[136] but does not provide more details on what gauges whether these goals are met. The Study analyzed multiple options for achieving these general goals as they were further specified by MOC&S.[137]

136. N.Y.C. Admin. Code § 28-320.11.

137. See Part 7.

The diagram in Figure 14 illustrates some of the key levers that policymakers can adjust to design a trading program that appropriately furthers their particular goals.

Table 9 provides a summary of some of the key variables that we assumed were fixed and those that we assumed could be adjusted in designing a trading program.

Figure 14. Summary of key variable elements of trading programs.

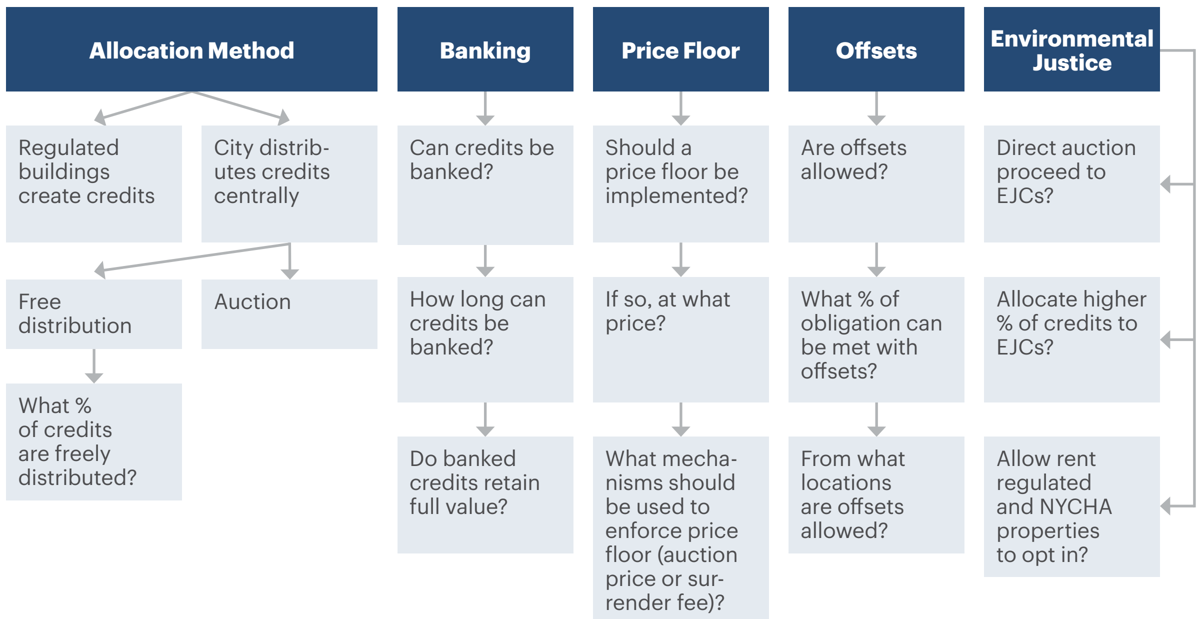


Table 9. Summary of key variable elements of trading programs.

Design Element	Fixed or Variable
Building caps	Fixed
REC availability	Fixed
Timing of compliance periods	Fixed
Pace at which emissions caps decline	Fixed
No sector-wide cap (i.e. building-specific caps utilized instead)	Fixed
Ability to pay penalties in lieu of reductions	Fixed
Section 321 properties can opt-in	Variable
Program price floor	Variable
Ability to bank credits	Variable
Ability to utilize carbon offsets	Variable
Trading program start date	Variable
Use of auction revenue	Variable
% of credits auctioned vs. freely allocated	Variable
Policies to promote environmental justice	Variable

B. Iterative Modeling Process

With these constraints and options in mind, the Study used an iterative modeling process to identify illustrative proposals that would effectively further the City's goals. The Study had to be judicious about the options it tested because resource constraints limited the Study to 15 model runs. Eight modeling runs were allocated to explore individual policy levers to understand the isolated impacts of each policy. One run was allocated for simulating the program without trading, and six were allocated for simulating two versions of multi-policy program designs under three different input scenarios.

After simulating LL97 without trading, we first modeled a "simple trading program" (e.g., no banking, no price floor, no particular support for EJCs) to understand the general directional impacts of introducing trading. From here, we conducted a number of model runs that varied individual elements of the simple trading design (e.g., banking vs. no banking, price floor vs. no price floor, earmarking auction proceeds to subsidize investments in EJC buildings vs. no subsidy) one at a time to isolate the impact that each change would have on the results. Finally, with these findings in hand, we developed two illustrative proposals that we believe would effectively advance the City's goals. These illustrative proposals combine several of the elements that we explored in isolation in the initial runs. The runs explored were:

1.
No Trading

2.
Simple Trading

3.
Price Floor ($25, $50, and $75 per MTCO$_2$e price floors tested)

4.
Banking without Restrictions

5.
Banking with Restrictions (restrictions investigated were no banking in the first compliance period and no ability to use offsets to build up a bank)

6.
Banking with a $25/metric ton price floor

7.
Section 321 Building Opt-in

8.
Trading Delay to 2030

9.
EJC Support—20% capital expenditure reduction

Critically, each of the different design elements presents tradeoffs. For example: allowing regulated entities to bank credits for use in future compliance periods provides incentives for early action and can help prevent price shocks.[138] However, banking can also cause a cap to be "too loose" to induce effective emissions reductions where large surpluses of banked credits enter the market in the later years of a program.[139]

138. RECLAIM, for example, did not initially allow regulated entities to bank allowances, which posed a significant problem during California's electricity crisis in 2000. Generation at some regulated entities sharply increased, causing them to exceed their allocations—and in part because there was no supply of banked allowances, allowance prices spiked dramatically. Schmalensee & Stavins, 2017. In the EU ETS, initial allocations during Phase I were based on estimates of emissions rather than historical data, leaving an over-allocation of allowances. Since there was no banking allowed, and since regulated entities were already able to meet their compliance obligations and could not save allowances for future compliance obligations, the value of allowances dropped. Environmental Defense Fund, 2012.

139. In Tokyo, regulators aimed to address this problem by only allowing banked credits to be used in the following compliance period, after which they expire. Thus, regulated entities cannot bank credits indefinitely, reducing the risk that large surpluses of banked credits will enter the market in later compliance periods. Wakabayashi & Kimura, 2018, p. 1034 (noting that "[w]hile banking serves to increase price stability, the accumulation of very large surpluses can cause future prices to be highly discounted"). In California, banked allowances do not expire, but the state places holding limits on the number of allowances that an entity can bank at any one time. Cal. Code Regs. tit. 17, §§ 95920, 95922.

C. Key Findings from Initial Model Runs

A few major themes cut across the results of the different initial model runs.

First, aggregating our results to the highest level, every trading element that we modeled yielded higher monetized net benefits than LL97 without trading.[140] What this means is that when we monetized the predicted impacts that trading would have on owner costs, tenant costs, city penalty revenues, GHG emissions, and local air pollution levels over the 26 years and then added these monetized benefits and costs together, each trading program design that we tested produced more net benefits than LL97 as is without trading. Every trading scenario also reduced GHGs across the study period by more than LL97 as is.[141]

Looking at how these incremental benefits are distributed across time and stakeholder groups, there are some further themes that cut across the different elements:

Avoided premature deaths generate the most benefits. In every scenario besides unrestricted banking, the biggest share of the incremental benefits comes from avoided premature deaths due to local air pollution reductions. Owner benefits, by contrast, are typically more modest, at least when we look at the value of the savings for the average building in our segments.[142] This finding is not particularly surprising given the relatively low net costs we predict LL97 will impose on owners; if one believes that the base case will not be particularly costly, trading can only save owners a modest amount of money.

Pollution levels can increase in the first compliance period without careful program design. Several scenarios see small increases in local pollutants compared to base case in the first compliance period, when the LL97 caps are more lenient. The reason this increase occurs is that when the LL97 caps are lenient, there is little demand for credits, and credit prices will be low. If credit prices are low, those owners who would have otherwise had to invest in their buildings will buy credits instead. The low credit prices also fail to incentivize would-be sellers of credits to invest in their properties for the purpose of selling credits to others. This problem can be fixed by setting a minimum price for credits, and, indeed, our model shows that a $25 price floor is enough to solve it. Removing international offsets from the equation would also mitigate the problem by increasing demand for credits. Beginning in the second compliance period, when LL97 caps are tighter, even a "simple trading" program design without a price floor reduces local air pollution by more than LL97 without trading.

140. See Appendix D, Table 1.

141. See Appendix D, Table 1.

142. Given that modeling was done with averaged building segments, cost savings from trading may be larger, as modeling the segments does not capture the spread in costs across individual buildings within each segment.

Trading increases investment in the local building sector compared to LL97 as is. Each modeled program design indicated that allowing owners to trade under LL97 would increase the amount of investment in the local building stock. The increase in building investment results from a shift away from REC purchases towards retrofits. The magnitude of the increased investment ranges from $200 million NPV under simple trading, to over $750 million NPV under $75 price floor. Removing offsets, as the illustrative design proposals do, would increase local investment further.

Trading reduces owners' net costs in EJCs more than non-EJCs. A final theme pertains to the geographic distribution of costs throughout the City. Because commercial properties are concentrated in non-EJC areas, which benefit more from electricity decarbonization, and residential buildings in EJC areas, which will require more substantial retrofits to reduce non-electricity emissions, LL97 is more costly for buildings in EJCs. Thus, without targeted EJC interventions, trading reduces compliance costs for buildings in EJCs more than for buildings outside EJCs, but that is done through EJC buildings deferring investment and buying credits from non-EJC buildings on average.

The next two sections present key results from each of the specific runs that we conducted prior to developing the illustrative proposals.

D. Simple Trading Program versus LL97 without Trading

The first program design that we tested was a "simple trading" program. The simple trading program assumed the following terms:

- Property owners can generate credits if they emit less than their LL97 caps and their 2018 emissions. Emissions must be below LL97 caps and 2018 emissions to avoid giving a windfall to properties that already emitted less than their LL97 caps before the law was passed;

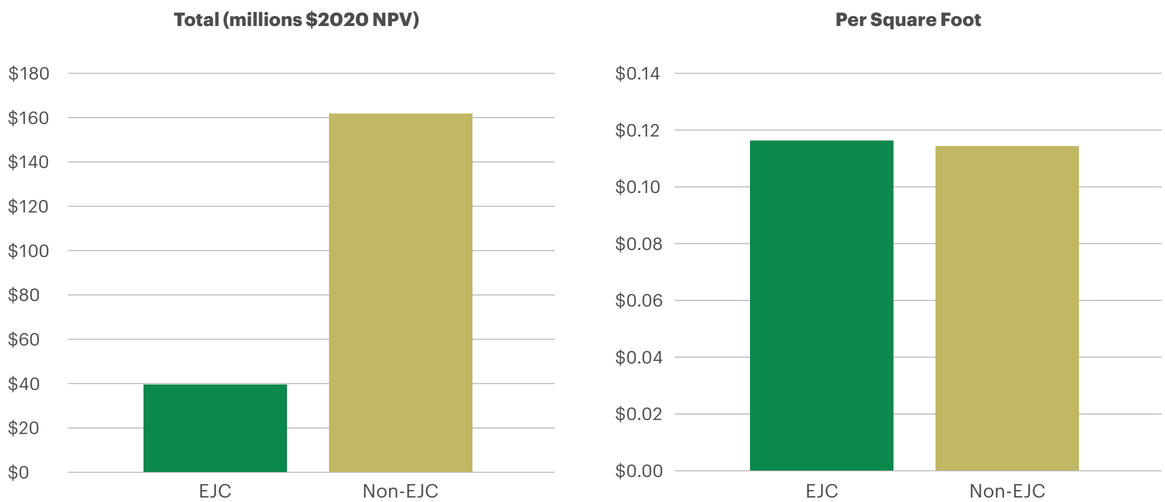
- No banking is allowed;

- Offsets up to 10% of a properties' LL97 cap are allowed in the first compliance period;

- No policy specific for EJCs.

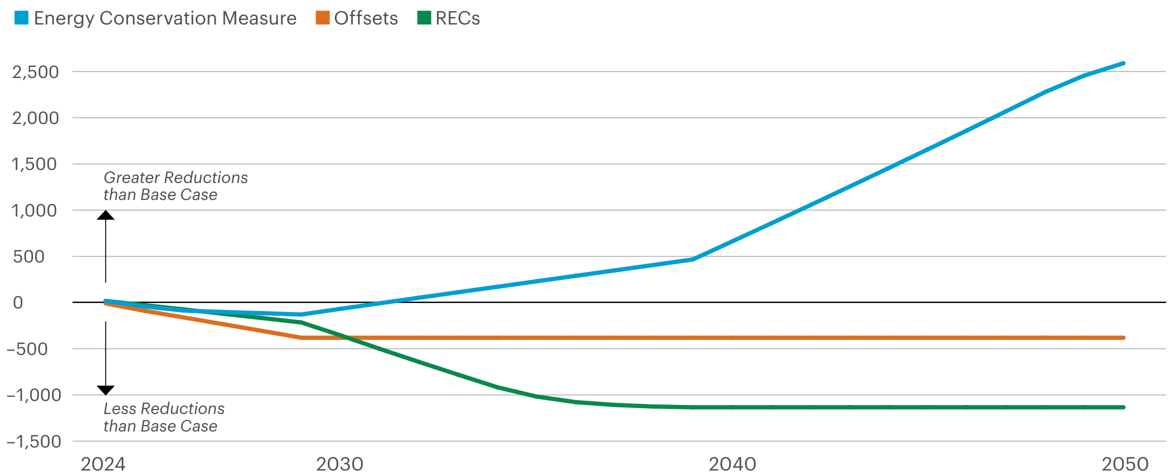
The modeling indicates that a simple trading program offers a number of advantages compared to LL97 as is. It materially increases investment in retrofits in EJCs and non-EJCs, reduces total GHG emissions over the study period (by reducing REC and offset use while increasing retrofits), improves air quality over the 26-year study period, and reduces premature deaths due to air pollution, especially in EJCs. A simple trading program also reduces the money spent on offsets and RECs, which would not result in local investment in NYC as RECs can be acquired from generators importing energy into the City and offsets are awarded for projects undertaken outside of NYC. These findings are presented in Figure 15, Figure 16, and Table 10 below. Note that the x-axis in both graphs reflects the base case of LL97 without trading; the bars and lines represent deviation from the base case.

Figure 15. Additional investment in improving building energy efficiency under simple trading (relative to base case LL97) (NPV, in millions of 2020 dollars and in 2020 dollars per square foot).*



*Per square foot building investments are calculated by dividing the capital costs of building retrofits in EJCs and non-EJCs by covered square footage in EJCs and non-EJCs, respectively. While the rounded values of per-square-foot investment in this graph are the same ($0.12 each), per square foot investments in EJCs are very slightly higher: $0.116/SF compared to $0.115/SF in non-EJCs.

Figure 16. Cumulative GHG emissions reductions with simple trading (relative to base case LL97) by compliance pathway.



As shown in Figure 16, trading lowers the amount of RECs and offsets used and substantially increases the energy efficiency measures to comply with LL97. This exemplifies how trading can incentivize owners to uptake retrofits in a greater amount than without trading to sell credits for revenue. Without trading, however, no such incentive exists. Moreover, without trading, buildings are left to comply with the law on their own, which increases the use of RECs and offsets from buildings without cost-effective retrofit measures.

Table 10. Cumulative change in local pollutants and avoided premature deaths from pollution from simple trading, relative to base-case LL97 without trading.

	Pollution Reductions (metric tons)	Additional Avoided Deaths from $PM_{2.5}$*
EJCs	+ 445$PM_{2.5}$ + 21SO_x – 42NO_x	132
Non-EJCs	+ 813 $PM_{2.5}$ + 60 SO_x + 56NO_x	88

*We computed avoided deaths of total $PM_{2.5}$ emissions, which are composed of primary $PM_{2.5}$ (directly emitted) and secondary $PM_{2.5}$ (formed through chemical reactions of NO_x and SO_x emissions in the atmosphere).

However, there are also some drawbacks to a simple trading program compared to LL97 as is. In particular, simple trading increases GHG emissions by 0.8–2.2% between 2024–2035 compared to LL97 as is. Moreover, while simple trading improves air quality over the length of the study period compared to LL97 as is, it also increases pollution relative to LL97 in the first compliance period across the city by 7% for $PM_{2.5}$, 0.04% for NO_x, and 2.4% for SO_x.[143]

Across the whole 26-year study period, simple trading also leads to a 1.6% increase in NO_x in EJCs compared to LL97 without trading. This result has to do with the lenient emissions caps in the first compliance period combined with the timing of the mandatory phase out of fuel oil #4 and the locations in which buildings using fuel oil #4 are concentrated. The dynamics that create this result warrant some elaboration because they are complicated and specific to the local regulatory context and building stock.

Compared to other fuels used in the housing sector, fuel oil #4 is a heavy emitter of NO_x emissions. Recognizing this potency, the NYC Clean Heat Program requires buildings to stop using fuel oil #4 by 2030 and replace it with a cleaner fuel source.[144]

The model projects that without trading, buildings that currently burn fuel oil #4 invest in fuel switching in 2024 in order to comply with LL97 and to get ahead of their obligation to phase out fuel oil #4 by 2030. These properties then make relatively minor further changes to their properties in 2030 to meet the tightening LL97 caps. With trading, these buildings, which are concentrated in EJCs, take a less incremental approach. Instead of investing in fuel switching in 2024, they buy credits from other buildings in the first compliance period, when credits are cheap, and then invest in electrifying their heating systems for 2030. Electrification gets these properties below their 2030 emissions caps, which lets them sell credits at a time when prices should be higher. In essence, with trading, these owners think, "why invest in fuel switching in 2024 if I am going to electrify my heating in 2030 anyway?" Stated otherwise, instead of making a small change in the first compliance period that gets them to the 2024 caps, trading leads these buildings to do nothing in the first period and then make big changes in the second period. As a result, trading produces more investment in these properties over the duration of the study period but less investment in the first period.

Because properties that use fuel oil #4 are concentrated in EJCs, their decision to purchase credits during these early years instead of reducing emissions manifests as an increase in ambient emissions in EJCs relative to LL97 without trading. And because NO_x is effectively eliminated from direct building emissions after 2030, when fuel oil #4 will be phased out, these initial increases relative to no-trade cannot be offset by the subsequent building efficiency improvements (and emissions reductions) that trading induces.

143. This is due to the relaxed early caps and the presence of very cost-effective efficiency measures (that are taken up during the first compliance period with or without trading), which result in low credit prices. As a result, buildings that would have chosen to abate their emissions without trading can now buy cheap credits to defer their investments.

144. NY.C. Rules, tit. 15, § 2-15(d); NY.C. Department of Environmental Protection, 2011.

In our model, five building segments are causing approximately 95% of the increased NO_x emissions in EJCs during the first five years. Together, these segments, which are listed below, make up only approximately 60 properties.

- High Emitter (not yet 2024-compliant), Pre-1980 Market-Rate Rental Multifamily, 4 to 7 stories, low-rent tier
- Highest Emitter (2018 emissions exceeded 2024 cap by >40%), Post-1980 Market-Rate Rental Multifamily, 4 to 7 stories
- Highest Emitter (2018 emissions exceeded 2024 cap by >40%), Pre-1980 Market-Rate Rental Multifamily, 4 to 7 stories
- Highest Emitter (2018 emissions exceeded 2024 cap by >40%), Post-1947 Office, Class C
- Highest Emitter (2018 emissions exceeded 2024 cap by >40%), Public Assembly

Notably, because the reduction in $PM_{2.5}$ and SO_x emissions across the study period is expected to be larger than the increase in NO_x (recall that we estimate a 0.1% increase over the study period compared to LL97 as is), simple trading is still predicted to reduce pollution-related deaths in EJCs across the study period. Nonetheless, the relative increase in NO_x results violate the condition that a trading program not lead to more emissions of any local air pollutant in EJCs compared to LL97 as is.[145]

145. See Part 4 for the goals established by MOC&S for a trading program.

Table 11. Summary of benefits of simple trading, relative to base-case LL97 without trading.

	LL97 without trading	LL97 with simple trading
GHG Emissions Reductions (metric tons CO_2e)	14 million	+ 1 million metric tons CO_2e **+ 7% more CO_2e reductions**
Pollutant Reductions (metric tons)	**In EJCs:** Primary $PM_{2.5}$: 4,023 NO_x: 2,638 SO_x: 376 **In Non-EJCs:** Primary $PM_{2.5}$: 10,974 NO_x: 11,520 SO_x: 1,234	**In EJCs:** + 445 metric tons primary $PM_{2.5}$ reduction increase **+ 11% more primary $PM_{2.5}$ reductions** – 42 metric tons NO_x reduction decrease **– 1.6% less NO_x reductions** + 21 metric tons SO_x reduction increase **+ 5.7% more SO_x reductions** **In non-EJCs:** + 813 metric tons primary $PM_{2.5}$ reduction increase **+ 7.4% more primary $PM_{2.5}$ reductions** + 266 metric ton NO_x reduction increase **+ 2.3% more NO_x reductions** + 60 metric tons SO_x reduction increase **+ 4.9% more SO_x reductions**
Owner Net Savings (2020$, 2020 NPV)	$2.032 billion	+ $395 million **+ 19% more owner net savings**
Tenant Bill Savings (2020$, 2020 NPV)*	– $6 million	– $49 million
Penalties Paid (2020$, 2020 NPV)	$224 million	– $153 million **– 68% less revenues from penalties**

*See Appendix B for additional information on tenant costs and savings. **change relative to LL97 without trading

E. Variations upon a Simple Trading Program

With the results of the simple trading program run in mind, the Study turned to model several variations of the basic program, varying one individual policy lever at a time to isolate its effects. The goal of this process was to deduce whether including a given lever would further the City's goals.[146]

Before reviewing the specific policy levers that we modeled, it is important to note that they each present tradeoffs. In general, the fewer restrictions that the regulator imposes on where and when credits can be used, the lower the cost of compliance will be. But fewer restrictions also create the potential for there to be more significant variation in the distribution of emissions across time and space. In short, there is not one type of trading program design that best suits all desired policy outcomes; the best approach depends on the policymakers' particular priorities.

We explored three types of policy levers in this batch of model runs:

1.

Price Floors. The Study examined the impact of establishing a minimum price at which credits could be purchased. We considered three different price floor levels: $25, $50, and $75 per $MTCO_2e$. Notably, in February 2021, the Biden Administration set the federal social cost of carbon at $51 per $MTCO_2e$.[147]

2.

Banking. The Study evaluated the impact of allowing owners to bank credits for use in a future compliance period. We also looked at the interaction between banking and offsets, including one run in which banking was allowed but offsets disallowed.

3.

Environmental Justice Policies. The Study evaluated a number of interventions designed to increase investment in EJCs. Specifically, we modeled the impact of allowing Section 321 buildings to opt in to a trading program and earmarking auction proceeds for direct investment in EJC buildings. We also examined the impact of delaying the onset of trading until the second compliance period, at which point fuel oil #4 will be phased out, to see if this eliminates the increase in NO_x in EJCs that occurred under simple trading.

The impact of credit allocation approaches was investigated in the modeling post-processing. As described above, the City can either create credits centrally, and then give them out to owners, or it can leave it to property owners to create the credits in a decentralized manner by reducing emissions more than they are legally obliged to do. In the first option, the City explicitly distributes credits equal to the total amount of emissions property owners can emit, whereas the second approach implicitly allocates credits by allowing owners to emit up to their LL97 caps without penalty.

146. See Part 4 for the goals established by MOC&S for a trading program.

147. U.S. Interagency Working Group on Social Cost of Greenhouse Gases, 2021.

So long as owners are allowed to emit up to their LL97 caps for free, the method of allocation (explicit versus implicit) itself should not impact either total benefits or the distribution of benefits as the economic incentives for any one owner is the same. However, if the City were to give out credits equal to something less than 100% of LL97 caps for free and auction off the remainder, which is possible under an explicit allocation approach, the design choice could create meaningfully different outcomes because then the City could direct the proceeds of its auctions to advance its policy goals, such as investment in EJCs. The City could vary the percentage of credits that different types of building owners are given for free to give credits for free to building owners in EJCs in particular.

Auctions also provide the most effective means of implementing price floors, which can strengthen the incentives for building retrofits. Thus, both the runs with price floors and the run that subsidized retrofits in EJCs assumed that at least a portion of credits would be created centrally and auctioned off. The other policy designs (banking vs. no banking, opt in vs. no opt in, delay vs. no delay) could be implemented with or without auctions. Recall, however, that the City would likely need to seek State legislative authorization to implement an auction approach. Using auctions to sell credits instead of distributing them for free (either implicitly or explicitly) will also raise the cost of compliance for building owners.

Below, we describe the result of our model runs examining the extent to which the different policy levers advanced the City's goals.

Price Floors

The Study's central price floor estimate was $50/metric ton of CO_2, which reflects EPA's Social Cost of Carbon estimate.[148] We also modeled $25 and $75 price floors (50% increase and decrease from the central case).

Adding price floors to a trading program confers a number of benefits compared to simple trading. Of principal importance, price floors incentivize earlier and more investment in energy conservation measures, which reduces GHG and pollutant emissions in all years, increases overall investment, reduces net owner costs, and increases energy savings and air quality benefits in both EJCs and non-EJCs. The higher the floor, the more action taken. Price floors also decrease $PM_{2.5}$ and SO_x emissions in all years in both EJCs and non-EJCs, and can stabilize credit prices, providing more certainty for investment decisions.

But there are some drawbacks to price floors as well. In particular, because price floors would be implemented through an auction as a minimum sale price, the City may need to seek State authorization for policies that include price floors.[149]

Price floors alone also do not cure the NO_x emission increase in EJCs, and do not reduce the abatement cost discrepancy between EJCs and non-EJCs present in LL97 as is, meaning that it is still generally less expensive for buildings in non-EJCs to comply with LL97 than buildings in EJCs. (Again, this cost difference is due to the fact that commercial buildings, which include the fewest high emitters, are concentrated in non-EJCs.) As a result of the cost imbalance, EJCs buy more credits from non-EJC buildings than vice versa, even after price floors are introduced. Neither

148. In late February of 2021, the Biden Administration increased the estimate to $51 per ton of carbon dioxide for year 2020 emissions. United States Interagency Working Group on Social Cost of Greenhouse Gases, 2021. Notably, New York State has adopted a Social Cost of Carbon of $125 for 2020, although it allows agencies to use alternative values. N.Y.S. Department of Environmental Conservation, n.d. Thus, $50 is a conservative estimate.

149. See Part 7 for further discussion of this issue.

of these last two points are arguments against price floors; they simply suggest that price floors have to be combined with other interventions to achieve the full suite of the City's goals.

Banking

The Study modeled four different banking scenarios in our initial runs:

- Simple banking (i.e. banking is allowed starting in the first compliance period and banked credits can be used in any future period);
- Simple banking with a $25/metric ton of CO_2 price floor;[150]
- Simple banking with no offsets allowed;
- Banking allowed only after 2029.

All forms of banking lead to more GHG reductions over the study period than LL97 as is. The reason for this is that banking incentivizes early action to build up a bank to offset more costly abatements during later periods. While not modeled, banking can also be used by owners during compliance period transitions, where a bank can create a credit buffer and add flexibility to install retrofit measures as caps tighten. Earlier action, all other things constant, leads to more GHG reductions over the study period as the benefits of energy efficiency improvements made early on continue to pay dividends throughout the study period.

All forms of banking also reduce owners' net costs compared to simple trading and LL97 as is, especially in the later years when an owner can use a bank to defer expensive abatement measures and/or non-compliance penalties, and decrease tenant energy bills compared to simple trading due to reduced energy bills from early action.[151]

But banking introduces certain challenges as well, especially when we look at unrestricted banking. When banking is unrestricted, property owners build up a large bank of credits in the early years, when credits are cheap, and then use these banked credits to defer investments after 2040. The result is that GHG emissions increase after 2040 relative to no trade. (Cumulatively, GHG emissions still go down compared to LL97 without trading because of the early investments.). The primary driver of this effect is the ability to use offsets and RECs to build up a bank. If offsets and RECs are more cost effective than the abatement measures required to meet the limits in later compliance periods, building owners will maximize uptake of offsets and RECs (which only have temporary emission impacts on emission inventories) to build a bank early to defer expensive in-building investments (which would have long-lasting impacts on emission inventories) later. This effect can also lead to criteria pollutant emission reductions not being as large relative to LL97 without trade in the years when investment is deferred. As a result, banking restrictions can help prevent such unwanted effects while maintaining the major flexibility benefits of banking.

150. A price floor can help prevent excess allowance banking in early years from diluting carbon abatement achieved in future years. Banking with $25 per metric ton was chosen to evaluate the minimum impact from pairing banking with a price floor, and before the decision to use $50 per metric ton in the illustrative design proposals.

151. We do not analyze other tenant impacts, such as impacts on rent, building amenities, living conditions, etc.

Unrestricted banking leads to citywide increase in $PM_{2.5}$ emissions compared to LL97 without trading over the study period, and small increases in NO_x and SO_x emissions in EJCs. The negative $PM_{2.5}$ and SO_x impacts can be negated by only allowing banking after 2029, adding a $25 price floor, or allowing banking without offsets. However, for the reasons described above, the NO_x emissions remain slightly higher than under LL97 without trading even with these adjustments.

In short, banking effectively incentivizes early action and lowers costs, but can lead to emissions increases post-2040 relative to no trade if it is not combined with other restrictions. Adding a price floor, delaying the onset of banking, and removing offsets all help to mitigate the relative emissions increases after 2040. However, no combination of policies prevented banking from deferring investment after 2040 and resulting in more co-pollutant emission compared to LL97 as is after 2040. As a result, we concluded banked credits would need to be devalued to prevent excess and long-term banking that can lead to early (cheaper) banked credits significantly affecting investment action after 2040.

Environmental Justice Policies

Working with input from stakeholders,[152] the Study identified a number of potential policy options that could be explored to prioritize investment and emissions reductions in EJCs. We modeled several of these options, which are described below.

Opt-in

The first policy that the Study modeled to try to drive investment and emissions reductions towards EJCs was to allow NYCHA properties and those properties subject to prescriptive requirements under Section 321 to opt in to the program.[153] The reason that the Study hoped that this intervention would increase investment in EJCs is that NYCHA and Section 321 buildings are concentrated in EJCs.

Allowing 321 and NYCHA properties to opt-in to a trading program provides two distinct but related benefits compared to simple trading and LL97 as is: 1) it increases investment in retrofitting City-owned buildings, both in EJCs and non-EJCs, and; 2) as a result of this increased investment in retrofits, opt-in improves local air quality and reduces premature deaths. Allowing NYCHA to opt in to the trading program could also provide a valuable source of revenue to finance the improvements that LL97 instructs the Authority to make across its portfolio.

The main foreseeable drawback to allowing opt-in is that it could increase monitoring costs for the City. However, given that these properties were already subject to alternative LL97 obligations, the incremental administrative costs may be quite small. Given the relatively significant upside to opt-in, and the seemingly low costs it imposes, we decided to include opt-in in both of the illustrative

152. Throughout the study process, MOC&S organized 8 formal meetings between the Study Team and external stakeholder groups.

153. Baselines for Section 321 buildings were determined after the application of prescriptive measures. This effectively incentivizes these buildings to go beyond what would be required under LL97 as-is, which ensures additional emissions are reduced with opt-in beyond what would occur with LL97 as is.

designs. However, on its own, allowing buildings to opt-in does not negate the increase in NO_x that occurs during the first compliance period.

Retrofit Subsidy for EJCs

The second EJ-oriented policy that the Study explored was to earmark revenue from the sale of credits at auction to directly invest in retrofits in EJC buildings.[154] Specifically, this run assumed that the City would use auction revenue to pay 20% of the cost of retrofits in EJCs.[155] To be clear, this approach assumes that the City would adopt an explicit allocation approach that centrally creates credits and would only give property owners credits equal to a portion of their LL97 caps for free; owners would have to purchase the remainder of the credits they need from the City at auction.

Using auction revenue to subsidize retrofits in EJCs significantly increases investments in and into EJCs, meaning that owners in EJCs increase investment in their own properties and more capital is transferred from non-EJCs into EJCs. This shift also results in lower air pollutant emissions in EJCs for all emissions including NO_x in all compliance periods; however, it also leads to less reduction in air pollution in non-EJCs than would occur under LL97 without trading due to the investment shift away from non-EJCs into EJCs. Moreover, the approach increases costs for owners of non-EJC building owners compared to simple trading or LL97 as is. It is also premised on a share of credits being auctioned off, which as mentioned above likely would require State legislative authorization. Given the considerable pros and cons that this option presents, we decided to include it in one, but not both, of the illustrative proposals.

154. Given the favorable results of the opt-in run, we also included opt-in in this run, so it combined the two interventions.

155. Specifically, the run assumed that auction revenues would fund 20% of the cost of retrofits in buildings in EJCs with caps under Section 320 and buildings regulated under Section 321.

Trading Delay

The third EJ-oriented policy that we explored was to delay the onset of trading until 2030. The motivation for exploring this option was to avoid the increase in localized emissions that occurred during the first compliance period under prior policy designs (and in the case of NO_x, were not offset by improvements in subsequent periods). As noted in Part 7.D, the pollutant increases that were observed in the first compliance period under prior designs were due to the combined effects of the relaxed LL97 caps in the early years and timing of the fuel oil #4 phase out. We hoped to mitigate these undesirable outcomes by delaying trading until 2030, when fuel oil #4 will be phased out and the LL97 caps will be tighter.

The modeling results did not align with this expectation. Delayed trading increases early action compared to Simple Trading (and LL97 without trading), lessens the increase in $PM_{2.5}$ in the first compliance period relative to Simple Trading, and eliminates the relative increase in SO_x. However, the NO_x results persist, as building owners are presented with the same opportunity to wait and electrify right before the decrease in emission caps in 2030 as with Simple Trading (discussed above). Moreover, the delay led to several undesirable outcomes. Of principal importance, delay reduces flexibility in the early years and locks buildings into higher cost compliance pathways, which reduces the ability for trading to reduce costs over the study period. It is also possible that if trading does not commence until 2030, we will forego an opportunity to incentivize owners of new buildings planned or under construction to be more efficient than they are required for the purpose of selling credits into the market.[156] For both of these reasons, the Study did not include a delay in the illustrative designs.

The table below summarizes the pros and cons of the various policy adjustments that we explored in our initial modeling runs.

156. Urban Green Council, 2020a.

Table 12. Summary of modeled EJC policy levers and their impacts.

	Increased Investment in EJCs	Remedies NO_x Increase in EJCs in Early Years?	Negative Impacts
Opt-in	Yes	No	Increases City's administrative costs
Retrofit subsidy for EJCs	Yes	Yes	Increases non-EJCs owners' costs and local air pollution levels in non-EJCs relative to LL97 without trade
Trading delay	No	No	Raises owners' compliance costs in EJCs and non-EJCs; may disincentivize new buildings from reducing emissions below LL97 caps

Other EJ Policies Considered

Notably, stakeholders raised a number of other potential policy options for prioritizing investment and emissions reductions in environmental justice communities that we ultimately decided not to model. Given resource constraints, which prohibited us from conducting more than 15 total model runs, we needed to be judicious about which policies we tested. Therefore, after extensive internal deliberations and consultations with stakeholders, we did not consider the following options for the reasons described:

1.

Impose geographic limits on credit use: Under this option, EJC building owners would not be able to use credits created by non-EJC buildings, but buildings in non-EJCs would be able to use credits created by any building. This option would prohibit EJC buildings from meeting their caps by paying for emissions reductions in non-EJCs. The idea of geographic restrictions was rejected due to concerns about increasing the relative compliance costs for EJC building owners relative to non-EJC owners. If only credits from EJCs can be used by property owners anywhere in the City, demand for EJC credits should increase, which should increase emissions reductions and investment in EJCs. However, this approach could also increase the cost of compliance for EJC building owners because many cost-effective measures are in non-EJC buildings. This predicted increase in compliance costs rendered geographic restrictions undesirable.

2.

Multiplier for EJC credits: Under this option, credits produced by buildings in EJCs would receive a bonus multiplier. For example, each EJC credit purchased and used by a non-EJC building owner might count as 1.2 non-EJC credits and therefore count towards 1.2 tons of excess emissions upon surrender. We rejected the idea of multipliers because it violates the requirement that a trading program not reduce the total emissions reductions that would otherwise be achieved under LL97. Enabling a building to release more than the seller had reduced its emissions would lead to more emissions overall than allowed under LL97 (unless other buildings were required to reduce by more than their caps to compensate for the excess emissions). The credit multiplier approach would further introduce economic inefficiencies that would reduce the economic benefits of the trading mechanism.

3.

Discount on non-EJC credits: For example, non-EJC credits used by EJC building owners might count for 0.8 tons of emissions per credit as opposed to 1 ton for EJC credits. This would discourage the sale of credits by non-EJC building owners to EJC building owners and could raise the cost of compliance for owners. We rejected the idea of discounts on non-EJC credits as this is effectively reducing the emission caps passed in LL97.

4.

EJC support standard: Under this option, non-EJC building owners would be required to include a given percentage of EJC credits in their total surrendered credits. This would create two sub-markets for credits, EJC-generated credits that could trade at a higher price and general LL97 credits that would trade at a lower price. We rejected this option largely due to the economic inefficiencies that could be created, and a concern that building owners in EJCs (rather than building residents) might enjoy the majority of the benefits from the support standard. There was also a concern that setting the minimum percentage for EJC credits at an appropriate level would require substantial finesse and potential guesswork; if the percentage were set too low, it would not drive meaningful additional investment in EJCs. But if the City set too high a percentage, non-EJC building owners would just do more to invest in their own buildings instead of EJC buildings. This would undercut the goal of shifting investment towards EJCs.

5.

Delay trading but allow early EJC banking: Another option is to launch trading in 2030, but allow early, indefinite banking of credits generated only in buildings in EJCs starting in 2024. While the Study did consider a delay in trading, it did not consider allowing for early EJC banking. This option does not clearly increase demand for EJC-generated credits beyond regular trading with banking, and also risks reducing action in EJCs later in the program.

With the results of these initial model runs in mind, the Study proceeded to develop two illustrative proposals that incorporate and refine a selection of the levers tested. These illustrative proposals and their predicted impacts are described in the next Part.

8

Two Illustrative Trading Proposals for LL97

Two Illustrative Trading Proposals for LL97

After completing the initial modeling runs, the Study developed two illustrative trading program proposals that include complementary policy interventions. We believe either of these proposals could advance the City's goals. These complementary interventions—the development of an investment program (funded by credit auctions under Proposal #1) and the acceleration of the phase-out of fuel oil number 4 (under Proposal #2)—could be pursued alongside or independently of a trading program.

Under Proposal #1, properties in non-EJCs would have to purchase a percentage of the credits needed to meet the LL97 caps at auction. Proposal #2 assumes that all property owners can emit up to their LL97 caps for free. Buildings that would like to sell credits would generate credits by reducing their GHG emissions below both their LL97 caps and their 2018 emissions. Modeling indicates that both proposals would amplify the benefits of LL97. However, each scenario contains its own challenges.

Proposal #1 leads to higher net benefits and more investment and emissions reductions in EJCs, driven in part by the investment of auction revenue into buildings in EJCs. However, this proposal imposes more net costs on buildings in non-EJC neighborhoods and also leads to a small increase in air pollution in non-EJCs after 2029 compared to Local Law 97 alone, because fewer retrofit projects are done in non-EJC areas and more are done in EJCs.[157]

Proposal #2, which assumes a phase-out of fuel oil #4 (currently scheduled for 2030, accelerated in this scenario to 2025), is substantially less administratively complex. This acceleration shifts behavior in the model, discouraging building owners, particularly in EJCs, from delaying investments in reducing fuel oil #4 usage, which might otherwise cause an increase in emissions during the first compliance period when limits are relatively lenient.

The Study developed two illustrative proposals of market designs that we believe would effectively advance the City's goals. The two illustrative designs represent two sides of a spectrum of the types of programs that the City might wish to pursue. Our goal in presenting two fairly distinctive designs is to give future policymakers a wide array of options that they could choose from to match their particular policy goals.

Below we outline the elements of the two illustrative design proposals and then evaluate these proposals using the eight categories of metrics that the Study defined to measure the extent to which the trading designs would advance the City's goals. The key features of the two design proposals are summarized in Table 13.

157. Note that the evaluative metrics that were developed with MOC&S did not consider the temporal distribution of pollution in non-EJCs, but instead only required that there not be an increase in pollution in non-EJCs aggregated over the 26-year study period. Therefore, the small increases in pollution in non-EJCs after 2029 were not considered a disqualifying feature of Proposal #1. As indicated in Appendix D, local air pollution is reduced under Proposal #1 over the entire study period in non-EJCs, notwithstanding the increases after 2029.

Table 13. Elements of the two illustrative trading program proposals

Design Element	Proposal #1	Proposal #2
Credit Allocation Method	This proposal uses a combination of free allocation and auctions of credits. Buildings in EJCs are freely given credits equal to 100% of their LL97 cap or 2018 emissions, whichever is less. Buildings in non-EJCs are freely given credits equal to 70% of their LL97 cap or their 2018 emissions, whichever is less. The City auctions off credits equal to 30% of the non-EJC buildings' caps. 2018 emissions are adjusted for grid decarbonization after 2029.	This proposal does not include an auction. All buildings can emit up to their LL97 caps without having to purchase any credits; buildings can generate credits if they emit less than both their LL97 cap and 2018 emissions. 2018 emissions are adjusted for grid decarbonization after 2029.
EJ Policies	All Section 321 and NYCHA buildings are eligible for opt-in. Section 321 buildings are freely given credits equal to their 2018 emissions minus projected emissions savings provided by the prescriptive measures listed in Section 321. NYCHA buildings are freely given credits equal to their 2018 emissions. Buildings that opt in can sell excess credits. 2018 emissions are adjusted for grid decarbonization after 2029. Auction proceeds fund 20% of the cost of retrofits in EJCs. EJC buildings get 100% free allocation up to lesser of 2018 emissions or LL97 cap.	All Section 321 and NYCHA buildings are eligible for opt-in. Section 321 buildings generate credits that they can sell if they emit less than their 2018 emissions minus projected emissions savings provided by the prescriptive measures listed in Section 321. NYCHA buildings generate credits that they can sell if they emit less than their 2018 emissions. 2018 emissions are adjusted for grid decarbonization after 2029. Assume accelerated phase-out of fuel oil #4 by 2025 instead of 2030.
Price Floor	$50 price floor	None
Banking	Banking is allowed but credits decrease in value by 20% each year.	Banking is allowed but credits decrease in value by 20% each year.
Offset Eligibility	Offsets are not allowed in any compliance period.	Offsets are not allowed in any compliance period.

A. Elements of the Illustrative Proposals

As explained in Part 7, the Study presumed that LL97 sets the caps for a trading program in the form of the individual building GHG emission caps that the law establishes.

The illustrative proposals focus on five broad categories of features of a trading program: credit allocation method, environmental justice policies, price floor, banking, and offsets.

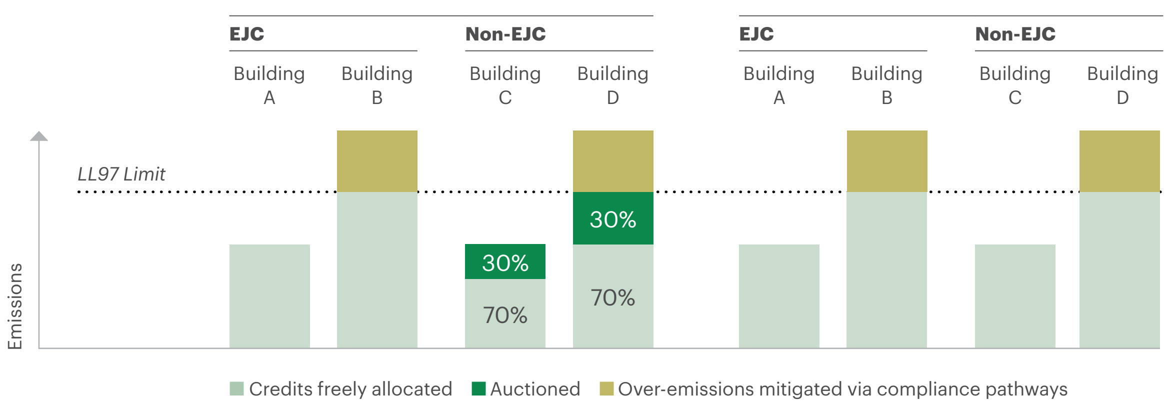
Allocation Method

A key initial choice in designing a trading program is how the credits that will be traded will initially be allocated.

The core distinction between the two designs concerns the method of initial credit allocation. Under Proposal #1, the City would centrally allocate credits to all buildings with LL97 emission limits through a combination of free allocations and auctions. Under Proposal #2, building owners would choose whether they wanted to generate credits for sale. Buildings that want to sell credits would generate credits by reducing their GHG emissions below their LL97 building emissions limits and their 2018 emissions (adjusted for decarbonization after 2029).

Figure 17. Credit allocation method in the two illustrative proposals.

	Proposal #1 Auction	**Proposal #2** Non-Auction
Credit Allocation Method	Under an auction scenario, all credits would be freely allocated to EJCs, whereas non-EJC buildings would need to purchase 30% of their required credits at auction.	Under a non-auction scenario, all non-EJC and EJC buildings would be allowed to emit up to their LL97 limit without purchasing credits. Buildings that emit less than their LL97 limit and 2018 emissions can choose to sell credits.



Specifically, under Proposal #1, buildings in non-EJCs would be freely given the credits that they require to cover 70% of the lesser of their LL97 building caps or their 2018 emissions (adjusted for decarbonization after 2029).[158] Seventy percent free allocation for non-EJCs was determined in post-processing to ensure that enough emissions need to be auctioned to ensure that the auction price floor drives cost-effective abatement measures. Non-EJC buildings would have to purchase any credits that they require to cover their remaining emissions at an auction or in the secondary market. EJC properties would be freely allocated credits equal to 100% of the lesser of their LL97 building caps or their 2018 emissions (adjusted for decarbonization after 2029). Free allocation to buildings in EJCs may induce capital to flow from non-EJCs into EJCs. Free allocation to EJC building owners also addresses the concern that these owners would pass on the additional costs of buying credits at auction to tenants, thus raising EJC tenant costs. As described further below, there would be a minimum price of $50 per credit to purchase credits at auction.[159]

Auctions provide a number of advantages, including the ability to implement price floors, which incentivizes greater investment in energy conservation measures, and generating revenue that can be used to advance City goals. But auctions also present certain drawbacks. Of principal importance, the study assumed that the City would seek and receive State legislative authorization to implement an auction.[160] Thus, Proposal #1 may not be entirely within the City's discretion to pursue on its own. Given this, the Study also considered a proposed program design that does not include an auction, which the City could implement independently without State authorization.

Under Proposal #2, credits would be allocated in a decentralized manner, and only to buildings that choose to sell credits. All properties would be allowed to emit up to their LL97 building caps for free. Buildings would generate credits that they could trade by reducing their emissions below the lesser of their LL97 building caps or 2018 emissions (adjusted for grid decarbonization after 2029). It is important to ensure that buildings can only generate credits if their emissions are below both the LL97 caps and 2018 emissions to avoid granting a windfall to properties whose emissions were below their LL97 cap to begin with. It is necessary to adjust 2018 emissions to reflect electricity grid decarbonization after 2029 to ensure that building owners do not generate credits based on reductions attributable to grid decarbonization without investing in energy efficiency measures. One credit would be generated for every ton of excess GHG emission reductions.

158. As stated in the text, building credit allocation is determined by the lesser of the building's LL97 caps or 2018 emissions (adjusted for decarbonization after 2029). This is done to prevent windfall allocation for buildings whose actual emissions in 2018 fall below their LL97 cap. Failure to adjust 2018 emissions to reflect the effects of decarbonization also could create a windfall for building owners who could see their emissions fall as the electricity grid decarbonizes without investing in energy efficiency improvements.

159. The amount of credits auctioned must be large enough to ensure that the price floor remains binding. As an example, if enough free credits are provided such that trading of freely allocated credits combined with low-cost abatement measures (that have abatement costs below the price floor) can satisfy the citywide emission cap, then nobody will need to buy credits from the auction and the price floor will not be effective. Therefore, the portion of credits that is allocated freely (70%) was estimated by first simulating the emissions that would result from a scenario with a price floor and then ensuring that less than that amount of credits are freely allocated.

160. In the past, the City has sought State legislative authorization when auctioning regulatory instruments for more than the cost of administering the relevant regulatory program.

Environmental Justice Policies

Both proposals include a number of levers to promote environmental justice.

Both proposals permit Section 321 and NYCHA buildings to opt into a program and sell credits. These buildings are concentrated in EJCs. The mechanisms through which these buildings would obtain credits would differ slightly under Proposals #1 and #2, reflecting the central allocation of credits under the former and the decentralized allocation of credits under the latter. Under Proposal #1, Section 321 buildings would be allocated credits for free equal to their 2018 emissions minus the anticipated savings that they receive from implementing their prescriptive measures; Section 321 buildings' 2018 emissions also would be adjusted for decarbonization after 2029. Using the Section 321 buildings' emissions after the prescriptive measures as the baseline for allocating them credits would ensure that opt-in generates more emission reductions than LL97 as is. NYCHA buildings that opt in would receive credits for free equal to their 2018 emissions, as adjusted for decarbonization after 2029. Under Proposal #2, Section 321 buildings that opt into the trading program would generate credits by reducing their emissions below their 2018 emissions minus the anticipated savings from their prescriptive measures; 2018 emissions would be adjusted for grid decarbonization after 2029. NYCHA buildings would generate credits by reducing their emissions below their 2018 emissions, adjusted for decarbonization after 2029. NYCHA building baselines are not adjusted for prescriptive measures, and can sell credits if their emissions fall below their baseline. The benefits of driving additional potential investment towards Section 321 and NYCHA properties seem to outweigh the predicted increase in administrative costs.

Proposal #1 includes a number of additional levers for promoting environmental justice. As mentioned above, EJC building owners (with building caps under LL97) would be freely allocated credits up to the lesser of their LL97 caps or their 2018 emissions.

To increase investment in EJCs and mitigate the risk of NO_x emissions increases relative to no trade in these areas,[161] Proposal #1 also assumes that a portion of the auction proceeds are used to directly invest in retrofits of buildings in EJCs (including NYCHA buildings within EJCs), offsetting 20% of the cost of such improvements.

As for Proposal #2, this option assumes that the City pursues an accelerated phase out of fuel oil #4 as part of its Clean Heat program. Legislation to this effect has been introduced. If the City were to move ahead with the accelerated phase out, it would eliminate the risk that trading would lead to an increase in NO_x in EJCs compared to LL97 as is. Effectively, the accelerated phase out would eliminate the possibility that a building segment could increase NO_x emissions in EJCs compared to LL97 as is by using trading to defer action in 2024 and then electrifying in 2029.[162] This auxiliary policy change would therefore solve the mismatched timelines between LL97 and the Clean Heat program. An alternative option to address the NO_x emissions is a targeted program to fund the conversion of approximately 60 properties in EJCs with LL97 caps from fuel oil #4 to fuel oil #2.[163]

161. See Part 7 for discussion of the concerns about NO_x emissions.

162. See Part 7 for further discussion of this issue.

163. Notably, the study team proposed to model a scenario in which the City would fund the conversion of a select number of buildings in EJCs from fuel oil #4 to fuel oil #2; our initial estimates suggested it would take between one and two million dollars of direct investment to convert enough buildings to avoid a NO_x increase in EJCs under trading.

Price Floor

Proposal #1 includes a $50 price floor for the initial sale of credits at auction.[164] The minimum price incentivizes building retrofits and ensures that trading does not lead to localized pollution increases in the first compliance period, when emissions caps are lenient. Fifty dollars is roughly in line with the Social Cost of Carbon that the Biden Administration approved in late February of 2021.[165]

There is no price floor in the second proposal given the difficulty of applying a price floor in the absence of auctions.

Banking

Both proposals would allow credits to be banked for use in a future compliance period. However, the value of banked credits would decline by 20% each year. By allowing banking, but devaluing banked credits over time, policymakers can stimulate early action without weakening owners' incentives to invest in their properties towards the end of the study period, which is a problem that unrestricted banking can cause.

The devaluation rate was determined by running multiple sensitivities that explored devaluation rates in 5% increments. A 20% devaluation was determined to provide enough banking incentives and flexibility for owners to benefit while also preventing excess banking from resulting in deferral of investments in later compliance periods.

Offsets

To augment local investment and local emissions reductions, both proposals assume that offsets are removed as a compliance option, as a tradeoff for the increased flexibility that the trading program itself provides. The main justification for allowing offsets is to provide owners additional flexibility, such that they are not obliged to either make cost-prohibitive retrofits or pay a $268 penalty if there are no eligible RECs available for purchase. But there are some significant downsides to allowing offsets. For one, due to challenges with verifying the baselines and actual emissions for offset projects, there are often serious questions about whether offsets actually provide the additional GHG reductions that they claim to generate.[166] For another, if offsets were allowed to be generated by projects that are outside of New York City, allowing building owners to meet their obligations with offsets deprives the local population of the reductions in co-pollutants and investment that retrofits provide. And because offset prices are generally quite low—when the Study conducted its modeling, the average price for energy efficiency carbon offsets was about $4 per tonne—owners who exceed their LL97 caps will generally look to buy offsets to meet their obligations before turning to other mechanisms such as purchasing credits from other owners. As a result, if offsets are allowed, demand for carbon credits will be low. Moreover, since establishing a carbon market would provide owners with an additional flexibility mechanism—indeed, the program would essentially create a local offset market for retrofit projects in NYC buildings—there would be little justification for allowing owners to meet their obligations by purchasing offsets from projects outside of NYC. For all of these reasons, both proposals envisage that LL97 will be amended to disallow offsets if trading is pursued.

164. The price floor would be adjusted for inflation on an annual basis.

165. U.S. Interagency Working Group on Social Cost of Greenhouse Gases, 2021. Note, however, that the Interagency Working Group considers the estimate to be a conservative underestimate and will be updating the value in the near future.

166. It is often hard to verify that the sources generating offsets are making GHG reductions that they would not otherwise be making (i.e. that the reductions are truly additional). Thus, projects generating offsets are often criticized as generating "phantom reductions." Carbon Market Watch, 2014; Metcalf, 2019.

B. Impacts of the Illustrative Proposals

The Study assessed the two proposals against a range of quantitative and qualitative metrics. These metrics describe the ways in which the illustrative proposals would advance the City's policy goals compared to the implementation of LL97 without trading.

We used eight categories of metrics to assess the two proposals:

1. Net benefits
2. Overall emissions reductions
3. Timing of emissions reductions
4. Environmental justice
5. Owners' net costs
6. Simplicity of use
7. Implementation complexity
8. Robustness

We describe the components of each of these categories in more detail below.

Our assessment indicates that both proposals would amplify the benefits of LL97. However, the qualitative and quantitative evaluative metrics generally point in different directions. Thus, neither option is strictly superior to the other. Proposal #1 scores better on most of the quantitative metrics. It leads to higher net benefits and more investment and emissions reductions in EJCs than Proposal #2, although Proposal #1 imposes more net costs on non-EJC building owners and also leads to a small increase in air pollution in non-EJCs after 2029 relative to LL97 as is.[167] Proposal #2 scores better on qualitative metrics such as the complexity of implementation and use (see Table 14). Proposal #2 could be implemented by the City on its own, without the State, whereas Proposal #1's auction likely requires State legislative authorization. Proposal #2 also relieves the City of the obligation to design and administer an auction for credits. However, Proposal #2's approach would have to be pursued in concert with an accelerated phase out of fuel oil #4 to ensure that there are no increases in NO_x under trading compared to LL97 as is. Thus, both approaches may involve legislative action outside of the amendments to LL97 itself.

Below we describe how each design proposal scores on the quantitative and qualitative metrics. Consistent with the Study's focus on the incremental benefits of adding a trading program to LL97, the information below identifies the additional benefits that Proposals #1 and #2 would bring compared to LL97. A more detailed description of our calculations is provided in Appendix D.

167. Note that the evaluative metrics that were developed with MOC&S did not consider the temporal distribution of pollution in non-EJCs, but instead only required that there not be an increase in pollution in non-EJCs aggregated over the 26-year study period. Therefore, the small increases in pollution in non-EJCs after 2029 was not considered a disqualifying feature of Proposal #1. As indicated in Appendix D, local air pollution is reduced under Proposal #1 over the entire study period in non-EJCs, notwithstanding the increases after 2029.

Table 14. Summary comparative assessment of two illustrative trading program designs.

	Proposal 1	Proposal 2
Net Benefits	✓	
Overall Emissions Reductions	✓	
Timing	✓	
Environmental Justice	✓	
Owners' Net Costs		✓
Simplicity of Use		✓
Implementation Complexity		✓
Robustness	—	—

A check mark means a program is superior in that criteria. The dash indicates that neither program was superior in that category.

Net Economic Benefits to New York City

Table 15 summarizes the net economic benefits to New York City of the two illustrative proposals. We measured the expected monetized benefits and costs of each program design for property owners, tenants, City agencies and offices, and society in the form of GHG emission reductions and lives saved compared with LL97 as is. We looked separately at how these benefits and costs are distributed between stakeholders in EJCs and non-EJCs.

In total, Proposal #1 leads to about $4.5 billion additional net benefits compared to the LL97 without trading over the study period, and Proposal #2 leads to about $3.0 billion additional net benefits compared to LL97 without trading. The added net benefits under Proposal #1 are mostly driven by the auction-based method incentivizing more and earlier investment in energy efficiency, and, hence, reducing local air pollutants more.

Table 15. Cumulative quantified net benefits of illustrative proposals, relative to base-case LL97 without trading between 2024 and 2050 (NPV, in millions of 2020 dollars).

	Proposal 1	Proposal 2
Net Benefits	4,547	3,015

Table 16. Breakdown of quantified net benefits by group between 2024 and 2050 (NPV, in millions of 2020 dollars).

Group	Proposal 1	Proposal 2
Property owners	$304	$854
City Agencies and Offices	$450	–$251
Tenants	$98	$107
Society: Avoided GHG emissions	$100	$20
Society: Avoided deaths*	$3,595	$2,285

*To compute and monetize avoided deaths, we followed a two-step approach. First, we estimated mortality impacts associated with $PM_{2.5}$ (both directly emitted and associated with NO_x and SO_x emissions) using InMAP, a reduced-complexity air-quality model. See Tessum, Hill & Marshall, 2017. This model yields $PM_{2.5}$ concentrations in a fine 1-kilometer grid, which the study team used to separately estimate concentrations inside and outside EJCs. To translate concentrations into pollution-related deaths, we used the dose-response function proposed by Krewski et al. (2009), following the approach of the N.Y.C. Department of Health and Mental Hygiene in its Environment and Health data portal. N.Y.C. Department of Health and Mental Hygiene, n.d.b. ($PM_{2.5}$-Attributable Deaths). Second, we monetized this estimated mortality using the Value of Statistical Life determined by the EPA, which amounts to 9.7 million in $2020. U.S. Environmental Protection Agency, n.d.b (Mortality Risk Valuation).

Table 16 shows the breakdown of net benefits by group. As the breakdown shows, the majority of the added benefits the proposals provide come from avoided $PM_{2.5}$-attributable premature deaths, with Proposal #1 leading to about 60% more benefits in this category than Proposal #2. Given the greater $PM_{2.5}$ reductions under Proposal #1, the unquantified public health benefits of lower pollution are likely to be higher under Proposal #1 as well.

Direct benefits to property owners are higher under Proposal #2 than Proposal #1, although they are still relatively small when considered on a per-square-foot basis ($0.4/sq. ft. under Proposal #2 vs $0.1/sq. ft. under Proposal #1).[168]

Proposal #2 reduces penalty payments compared to the LL97 base case without trading, while Proposal #1 leads to additional net revenues compared to the no-trade base case, even after reinvested auction revenues are taken into account. The reason for this is that the auction produces more revenue than is needed to fund 20% of retrofit costs for section 320 and 321 and NYCHA buildings as currently formulated.[169] Many experts consider the Interagency Working Group's (IWG) Social Cost of Carbon estimates, which we used here to monetize the value of avoided emissions, to reflect a conservative estimate of the true costs of GHG emissions. These estimates omit key damage categories, and there are additional unquantified benefits.[170]

168. See Appendix D.

169. Mechanisms could be implemented to return auction proceeds beyond funding requirements if desired.

170. In addition, after our analysis was completed, the New York State Department of Environmental Conservation released "Establishing a Value for Carbon: Guidelines for Use by State Agencies," which recommends significantly higher values than the IWG estimates. Therefore, the estimates of avoided GHG emissions in this analysis should be taken as conservative estimates. N.Y.S. Department of Environmental Conservation, n.d.a.

Table 17. Avoided deaths by EJC status between 2024 and 2050, relative to base-case LL97 without trading.

Area	Proposal 1	Proposal 2
EJCs	+485	+270
Non-EJCs	+119	+110
Total	**+604**	**+380**

Similarly, because we are estimating only mortality-related benefits of local air pollution reductions, the societal benefits from reduced local air pollutants are also underestimated. In this analysis, we do not quantify many important benefits such as non-mortality benefits of reduced $PM_{2.5}$ including reduced incidence of heart attacks and respiratory diseases, benefits related to reduced exposure to ozone such as fewer hospital admissions and emergency department visits, and benefits from reduced exposure to ambient SO_x and NO_x. Table 17 shows the number of averted deaths under Proposals #1 and #2 with respect to a scenario with LL97 without trade (total and broken down by EJC status).

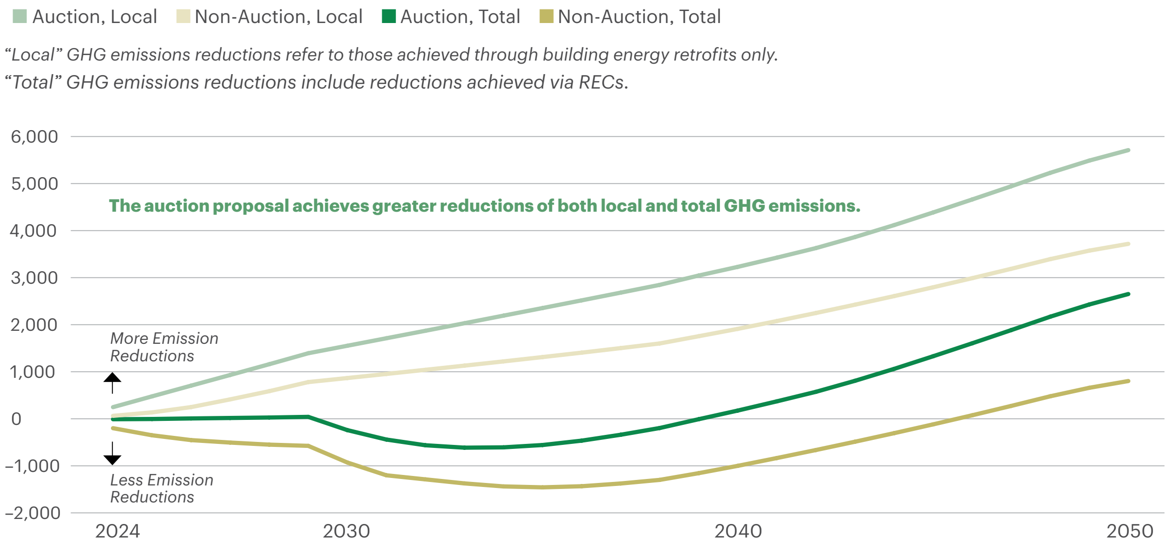
Table 18 shows the breakdown of net benefits by EJC status. Under both proposals, EJC areas benefit more than non-EJC areas, both on a NPV basis and a per-square-foot basis. Under Proposal #1, a significant portion of the incremental net benefits of the policy accrues to EJC groups. The majority of this difference is due to Proposal #1 leading to more $PM_{2.5}$ reductions in EJC areas as a result of reinvesting the auction revenue in EJC areas, and reducing $PM_{2.5}$-related deaths. Under Proposal #2, the distribution of the net benefits between EJC and non-EJC areas is more equal.

Table 18. Breakdown of quantified net benefits by EJC status between 2024 and 2050 (NPV, in millions of 2020 dollars).

Area	Proposal 1	Proposal 2
EJCs	$3,323	$1,790
Non-EJCs	$773	$1,476

This analysis comes with an important caveat. The net benefits analysis above does not take into account costs related to the implementation of a carbon trading program. Setting up new institutions and developing new capacity to monitor and enforce regulations associated with carbon trading will lead to additional costs for the City agencies and offices. However, unless these costs are expected to be in billions of dollars over the study period, both proposals are still expected to be net beneficial. Comparing the two proposals, Proposal #1 is likely to lead to higher implementation costs than Proposal #2 due to the need to set up and administer an auction system. The costs of implementing a trading program are addressed in the Implementation Plan.

Figure 18. Local and global GHG emissions reductions of two illustrative proposals vs. LL97 without trading, 2024–2050 (thousand metric tons CO_2eq).



Overall Emissions Reductions

The second metric the Study examined was whether, and to what extent, trading would further reduce GHG emissions and local pollutant emissions over the study period compared to LL97 without trading.

Both proposals generate more GHG reductions than LL97 without trading. The reason for this is that both proposals stimulate more investment in energy efficiency and electrification than LL97 as is. While owners purchase fewer RECs and offsets than under the no-trade base case, the increase in energy efficiency and electrification investments more than compensates for this decline, leading overall greenhouse gas emissions to go down. Affordable housing units and institutional and office sectors increase abatement, while retail, market-rate residential, and industrial sectors reduce abatement.[171]

On a citywide basis, both proposals also reduce local air pollution more than the LL97 without trading aggregated over the course of the 26-year study period and in each year. Proposal #1 leads to greater reductions of $PM_{2.5}$ and SO_x than Proposal #2 while Proposal #2 leads to greater reductions of NO_x than Proposal #1. Both proposals also lead to relative reductions in local air pollutants in EJCs in all years. By contrast, non-EJCs see a slightly more local air pollution under Proposal #1 after 2029 than would occur under LL97 without trading.[172] This is because Proposal #1 shifts investment in retrofits from non-EJCs to EJCs.[173]

Timing

The third metric the Study considered in evaluating the two proposals was the timing at which GHGs emissions reductions occur. Timing matters because if properties invest in electrification and energy efficiency improvements early on, these investments will continue to pay dividends in the form of emissions reductions throughout the remainder of the study period. Thus, the earlier properties invest in improvements the better. Both of the illustrative proposals incentivize earlier emissions reductions than the no-trade base case, but Proposal #1 scores slightly better in this regard.

171. See Appendix D.

172. See Appendix E.

173. Still, over the 26-year study period, non-EJCs still see greater local pollutant reductions under Proposal #1 than under LL97 without trading. See Appendix D for more details. As noted above, the evaluative metrics that were developed with MOC&S did not consider the temporal distribution of pollution in non-EJCs, but instead only required that there not be an increase in pollution in non-EJCs aggregated over the 26-year study period. Therefore, the small increases in pollution in non-EJCs after 2029 were not considered a disqualifying feature of Proposal #1.

Environmental Justice

The Study considered nine separate factors to assess the extent to which each proposal would advance environmental justice. These nine factors were:

1.

Change in the proportion of investment per square foot in EJCs versus non-EJCs compared to LL97 base case. This metric compares the degree to which the two illustrative proposals shift investment in non-EJCs to EJCs compared to the base case.

2.

Change in investment in Section 321 and NYCHA buildings compared to LL97 base case. This metric indicates the degree to which the two illustrative proposals encourage additional investment from properties that are not covered or currently subject to prescriptive measures.

3.

Reduction in owners' costs compared to LL97 base case by EJ status. This metric indicates whether a trading program reduces costs for property owners in EJCs and non-EJCs.

4.

Reduction in GHGs resulting from localized investment by EJ status. This metric indicates how properties are choosing to comply in EJCs and non-EJCs, and whether the trading program results in localized building investments.

5.

Change in pollutants compared to LL97 base case by EJ status. This metric measures whether the illustrative proposals would lead to increased or decreased air pollution compared to the base case.

6.

Projected $PM_{2.5}$ related mortality compared to LL97 base case by EJ status. This metric measures whether the illustrative proposal would lead to improved health outcomes compared to the base case.

7.

Projected reductions in energy consumption compared to LL97 base case by EJ status. This metric indicates projected energy cost savings that owners and tenants could expect to receive.

8.

Square footage participating in trading in EJCs versus non-EJCs. This metric measures how many properties would participate in the illustrative proposals in trading to take advantage of the flexibility that trading provides.

9.

Net trade revenue into EJCs. This metric measures how much trade revenue flows into EJCs.

The first seven environmental justice metrics all compare outcomes under the illustrative proposals to LL97 without trading. Both illustrative proposals outperform LL97 in each of the seven metrics: they both increase the share of investment that goes into EJCs, lower costs for building owners, and produce more local GHG reductions, less air pollution, fewer $PM_{2.5}$ related mortalities, and less energy consumption.

As between the two proposals, Proposal #1 generally scores higher than Proposal #2, meaning the differences from the base case are larger.[174] But this comes at the cost of non-EJCs. In particular, Proposal #1 leads to higher costs for owners in non-EJCs than LL97 as is and a small increase in local air pollution after 2029 (see Appendix E).

The remaining metrics—square footage participating in trading and net trade revenue—present a mixed picture as well. Proposal #2 leads to slightly more NYCHA and Section 321 buildings participating in the trading program (in EJCs and non-EJCs), which indicates that more of these properties find it cost-beneficial to reduce emissions below their baseline under this scenario. The reason this occurs is that credit prices are a bit higher under Proposal #2 than Proposal

174. As for the last two metrics—square footage participating and net trade revenue—Proposal #2 leads to more participation in EJCs, while Proposal #1 leads to more trade revenue flowing into EJCs.

#1 towards the end of the study period, which increases participation incentives. As for net trade revenue, Proposal #1 causes more trade revenue to flow into EJCs. However, this comes at the expense of non-EJCs, which see less revenue (and investment) than under the base case in which LL97 is implemented as is without trading.

Owners' Net Costs

One of the key arguments for emissions trading is to provide regulated entities with the flexibility to reduce emissions where and when it is most cost-effective to do so. Thus, the next evaluative metric considered whether, and to what extent, the two illustrative proposals would lower owners' costs compared to the no-trade base case. In calculating owners' net costs, we included trade revenues and costs of compliance measures less the associated savings in energy costs net of savings passed on to tenants, trading costs, and penalties.

Both proposals generate cost savings for owners compared to the LL97 without trading, however the savings are modest on a per square foot basis. As described above, because our model looks at the cost savings that would accrue to the average building in each segment, it underestimates the savings that would accrue to the buildings within each segment that have higher-than-average emissions or retrofit costs. As such, our estimated cost savings are conservative.

Comparing the two proposals against each other, Proposal #2 yields higher incremental benefits for owners than Proposal #1, primarily due to additional auction costs in Proposal #1. These cost savings are not uniformly distributed across different sectors of geographies. In particular, under Proposal #1, retail and residential sectors see *higher* net costs compared to the no-trade base case.[175] Under Proposal #2, however, only affordable housing and retail sectors see net cost increases. Under both proposals, as with LL97 without trading, owners of office buildings benefit the most; this is a result of the fact that commercial buildings primarily use electricity for their energy needs and the base case modeling assumes that the grid will decarbonize at pace with the CLCPA timeline.[176] This reduces commercial building emissions significantly, and allows them to use their cheapest retrofits to reduce emissions below their caps to sell credits.

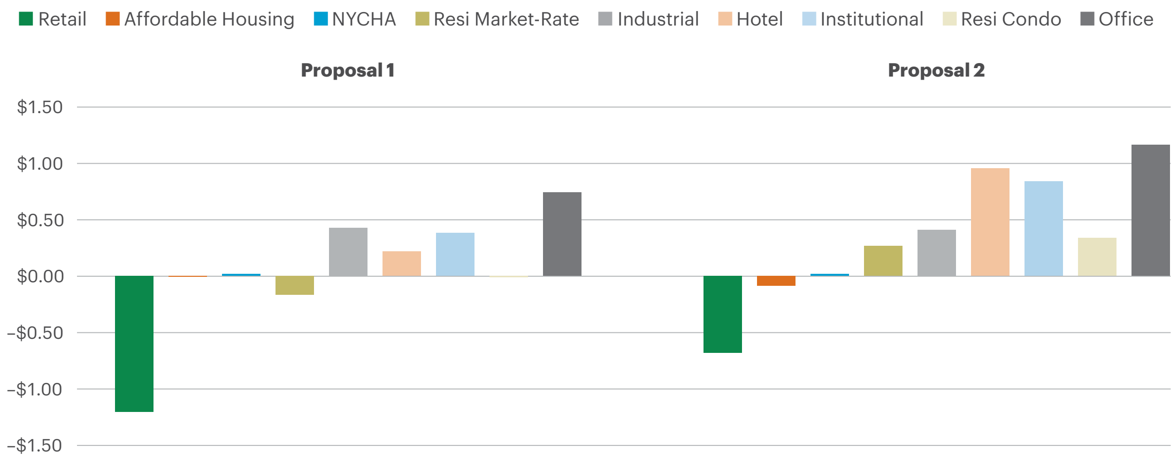
Comparing EJCs to non-EJCs, EJCs see significant cost savings in both Proposal #1 and #2, though savings are greater in Proposal #1 due to the increased uptake of measures that lower energy bill costs and reduction in upfront costs.

Geographically, both proposals reduce costs for owners in EJCs while only Proposal #2 reduces costs for owners in non-EJCs. However, due in part to the price floor, Proposal #1 produces more stable credit prices across the 26-year study period (see Figure 21). Overall, Proposal #2 scores better in the "owners' net costs" category.

175. This is partly explained by increased costs from auctions and owner short-sightedness, where some owners choose not to invest in energy saving measures that would have reaped energy bill savings in the long term. Under Proposal #1, affordable housing also sees slightly higher net costs compared with no trade, but the net cost increase is so small on a per square footage basis that it is not shown in Figure 19 due to rounding. See Appendix D (Metric 5.1).

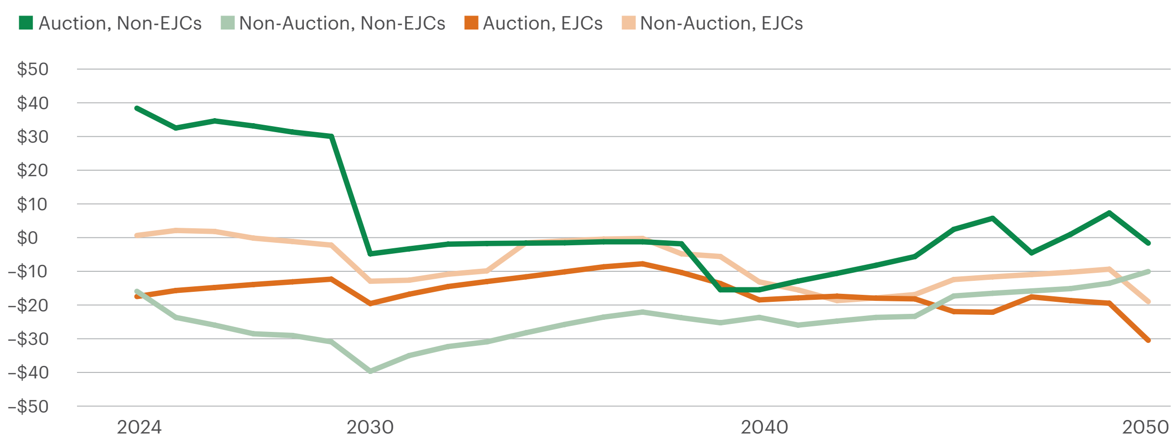
176. See Part 6 for more discussion of the interplay between CLCPA grid decarbonization and LL97.

Figure 19. Change in net owner cost savings by sector vs. LL97 without trading, 2024–2050 (2020 NPV $/SF).



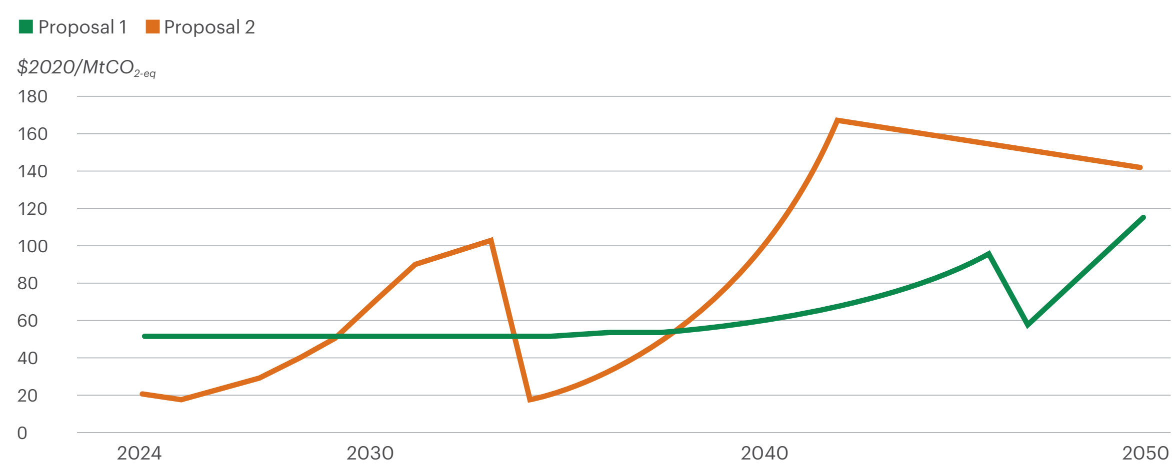
Net owner costs are calculated as the sum of compliance costs (building investments, RECs, offsets), trade costs, auction costs, and penalties *minus* trade revenue and energy savings. The x-axis represents LL97 without trading.

Figure 20. Net owner cost savings by year vs. LL97 without trading, 2024–2050 (2020 NPV $millions).



Net owner costs are calculated as the sum of compliance costs (building investments, RECs, offsets), trade costs, auction costs, and penalties *minus* trade revenue and energy savings. The x-axis represents LL97 without trading.

Figure 21. Fluctuation in credit prices under the two illustrative proposals.



Simplicity of Use

For a trading program to be successful, it must be simple enough to be widely utilized and understood. Therefore, the Study also considered the relative complexity of the two illustrative proposals from the perspective of building owners.

Proposal #2 scored better in this category. The auction in Proposal #1 is the key complicating factor as owners may require additional training to understand and participate in auction(s), as well as additional time and resources to participate. Moreover, under Proposal #2, owners who fear that participating in a trading market would be overly complicated can simply choose not to participate in the market because no one is obligated to purchase credits at auction in order to be able to emit up to their LL97 caps.

Implementation Complexity

If a trading program imposes substantial costs on the City government to establish or administer, it would decrease the program's efficiency. Therefore, the Study also evaluated the two proposals to compare the relative costs they would impose on the City government.

Proposal #1 likely imposes more substantial administrative costs on the City than Proposal #2. There are additional upfront costs involved with establishing an auction-based program as well as additional on-going costs to administer the auction. In terms of the upfront costs, the City will need to invest in developing a more elaborate program infrastructure if it is to add an auction to the compliance mechanisms. The City will also want to seek new State legislation authorizing an auction in addition to City legislation, while Proposal #2 could more straightforwardly be implemented with City legislation alone. Proposal #1 also requires the City to concretely define the environmental justice communities that are eligible to receive targeted investment, and in which regulated buildings would be freely allocated credits up to the lesser of their LL97 building emissions or 2018 GHG emissions (adjusted for decarbonization after 2029). The definition of EJCs must be done with consideration for many issues, including legal risks. In terms of ongoing costs, administering the auction under Proposal #1 would require some additional annual expenditure as well, though, as discussed in the Implementation Plan, these costs may not be very substantial.

Robustness

After evaluating the two proposals against each of the metrics described above, the Study conducted two final model runs, which we referred to as "sensitivity analyses," to assess how robust our findings were. The overarching goal of the sensitivity analysis was to see whether our directional findings—for example, that trading would generate more local investment than would occur under LL97 without trading—would hold up even if we varied our assumptions about the state of the external world. If one of the proposed program designs was more robust, meaning the direction of results was less likely to change under varied assumptions, it would rank higher on the metric of "robustness."

In the sensitivity runs, the Study modified three of the assumptions regarding the external world that we had used in our prior runs. The assumptions modified were:

1.
The pace at which the CLCPA's targets for grid decarbonization were achieved

2.
The cost of retrofits

3.
The cost of electricity and RECs

Ideally, we would have modified only one assumption at a time in our sensitivity runs so that we could isolate the impact of each assumption. However, due to constraints on the total number of runs that we could complete, we grouped the changes into two runs: one "optimistic case" and one "pessimistic case." In the optimistic case, we assumed that CLCPA targets were achieved on time (same as base case), that retrofit costs declined more quickly than assumed in the base case, and that both electricity prices and RECs were less expensive than assumed in the base case as well. In the pessimistic case, we assumed that CLCPA targets were delayed by ten years, that retrofit costs were the same as in the base case, and that both electricity prices and REC prices were higher than in the base case. Table 19 presents an overview of our two sensitivity runs.

Table 19. Inputs adjusted in robustness checks.

Input	Base Case	Optimistic/ Easy to Decarbonize	Pessimistic/ Difficult to Decarbonize
CLCPA	100x2040	100x2040 **(Base input)**	100x2050 **(10-year delay)**
Capital Cost	Base Inputs	**Reduction** of 25% by 2030, 35% by 2040, and 50% by 2050.	**Base Inputs**
Electricity and REC Cost	Base Inputs	**Reduction** of 10% by 2030, 15% by 2040, and 20% by 2050.	**Increase** of 10% by 2030, 15% by 2040, and 20% by 2050.

Importantly, in scoring the two proposals for robustness, we were not concerned with whether the magnitude of the change from base case remained constant, but rather whether the direction of the change, positive or negative, remained constant. Thus, if Proposal #1 was scored as +10 on a given metric compared to LL97 without trade under the base case assumption and scored + 12 on the same metric under the optimistic case; that would be ranked as a "no qualitative" change because the direction of the result (positive) remains the same.

Using these evaluative criteria, the two illustrative proposals scored almost identically in terms of robustness. Both proposals continue to be net beneficial under both of the sensitivity scenarios analyzed, meaning that the total monetized benefits compared to LL97 without trading exceed the monetized costs compared LL97 without trading. Stated simply, when we change our assumptions regarding the pace of electricity grid decarbonization and the cost of retrofits, RECs and electricity, the proposals still generate more benefit than harm. However, as expected, the proposals' performance is sensitive to the external factors analyzed (i.e., changes in the pace of grid decarbonization, retrofit capital costs, and electricity and REC). For some metrics, the direction of these changes compared to the base case is counterintuitive. For example, Proposal #2 leads to higher net benefits relative to LL97 without trading under the pessimistic scenario than the base case scenario.[177] This counterintuitive finding highlights the complicated dynamics underlying property owners' compliance decisions under the proposals and the no-trade LL97 scenarios. Further, some of the key metrics such as the timing and the location of the reductions in local air pollutants change qualitatively under both proposals. A full accounting of the results of these robustness checks is provided in Part 8 of Appendix D. Given that the changes in the qualitative results are similar with both of the designs, we rank them equally under this category.

177. External factors affect both the no-trade base case and the outcomes with trading. For example, the no-trade outcomes under pessimistic assumptions would be worse relative to the no-trade outcomes under base case assumptions. As a result, there would be more opportunities for trading to improve the outcomes, especially costs. Thus, net benefits from trading would be higher in the pessimistic scenario than the base case scenario.

9

Conclusion and Next Steps

Conclusion and Next Steps

Modeling suggests a trading program for buildings in New York City could generate more GHG reductions, more investment in the local economy, and less local air pollution over the course of the study period than would occur if LL97 were implemented without trading. If paired with complementary policies, a trading program can also be designed to avoid an increase in NO_x emissions in EJCs in the first compliance period compared to no trading, thus meeting MOC&S' criteria that LL97 not lead to an increase in any pollutant in EJCs in any year compared to LL97 without trading. There are several types of complementary policies that should achieve the desired reduction in NO_x during the first compliance period. One option, which we modeled in Proposal #1, is to auction off some credits and use a portion of the proceeds from this auction to invest in retrofits of EJCs building. Another option, which was modeled in Proposal #2, is to accelerate the phase out of fuel oil #4, as the City is already contemplating. A third option would be to use an alternative (non-auction) source of funding to subsidize the conversion of certain buildings in EJCs from fuel oil #4 to lower emitting fuels.[178]

Had the LL97 emissions caps for the first compliance period been tighter, credit prices during the first compliance period would have been higher, which would have removed the need to pursue complementary policies to reduce fuel oil #4 use in the first compliance period. These findings are consistent with the conclusions of prior studies of existing trading programs: trading works best when the emissions caps are set to a level that is considerably lower than business-as-usual emissions. Even with the LL97 caps as they are today, the complementary policies would likely not have been needed to achieve MOC&S' local air pollution goals if the timing of LL97 and the City's phase out of fuel oil #4 more closely coincided. Thus, the modeled outcomes for the first compliance period reflect a very particular set of circumstances and may not apply in other contexts.

If the City decides to move forward with a trading program, there are several potentially lengthy preparatory steps that need to be taken. A trading system would require a new local law, and accelerating the phase-out of fuel oil #4 would require a separate new law as well. A design that involves auctioning off a portion of allowances likely requires State legislative authorization.[179]

178. The Study did not fully model this option. However, preliminary analysis indicated that the requisite reduction in NO_x emissions could be achieved by making a limited investment to convert some properties in EJCs from fuel oil #4 to fuel oil #2.

179. See footnote 160 with accompanying text for more discussion on this point.

As described further in the Implementation Plan, the City may also want to enter into contracts with one or more third-parties to help administer a trading market. There are a number of advantages to delegating to third-party administrators that have prior experience running other emissions trading markets: such firms can likely perform technical tasks more efficiently than the City, thus lowering the program's administrative costs, and would likely be able to design and implement the program more quickly. Stakeholders may also have more faith in the ability of experienced third-parties to run the market, which could encourage more market participation.

In conclusion, adding a trading mechanism for emission reductions could offer New York City an opportunity to reduce compliance costs and deepen the sustainability benefits of LL97. No other city in the world has developed a carbon trading program of a similar scale and New York City and the uncharted nature of this endeavor also breeds uncertainty. The Study has conducted extensive research, modeling, and analysis to try to predict how different trading program designs would impact different stakeholder groups and policy goals.

Still, questions remain for future research. For example, we would have also liked to have dug deeper into optimal outreach strategies, including conducting focus group meetings with owners of mid-sized residential apartment buildings, coops, and condos, and would encourage future researchers to examine this issue.[180] Despite these lingering uncertainties, the research conducted throughout this Study provides a solid foundation for understanding the benefits that trading could provide, as well as the costs and complications.

180. There were several further analyses that we would have liked to have conducted but were unable to do so due to resource constraints. In particular, we would have liked to have conducted more sensitivity analyses to isolate the impact of different external assumptions on our findings and to have disaggregated building segments into individual buildings to observe building-level behavior. We would have liked to have examined second-order effects on various key housing metrics, such as impacts on rent, prices as well. We encourage future researchers to pick up where we left off.

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APPENDIX A—Review of Economic Literature on the Environmental Justice Implications of Emissions Trading

Environmental justice groups have expressed concerns that emissions trading programs will widen the pollution exposure gap between disadvantaged communities[1] and others beyond that which it would be under an approach that requires uniform emissions reductions from all sources. As the economist Ryan Walch has observed, "the core distributional concerns of the EJ groups could be valid if firms with relatively high marginal abatement costs are more likely to be located in disadvantaged communities."[2] (Walch, 2018). Alternatively, it is also possible that, "the flexibility inherent in market mechanisms may allow plant managers to make pollution control decisions on the basis of informal political or discriminatory, rather than purely economic, motives." (Masur & Sheriff, 2019) This appendix reviews the economic literature on this question and specifically asks whether empirical evidence suggests that trading programs have increased the relative difference between the pollution burden in disadvantaged communities and other communities.

Major Findings

Most studies that have examined the distributional impacts of prior cap-and-trade programs fail to find that such programs have increased the relative pollution burden in disadvantaged communities. Below, we review the leading studies of the distributional effects of three prior cap-and-trade programs: the federal Acid Rain Trading program implemented pursuant to the Clean Air Act, the RECLAIM program in the Los Angeles region, and California's Cap-and-Trade Program for greenhouse gases (GHGs) administered pursuant to AB 32.

In addition to the studies that we review of individual trading programs, Joseph Shapiro and Walker Reed recently published an analysis that traces the dispersion of Clean Air Act Emissions Reductions Credits, which they call "offsets," in 12 markets in California and Texas. Similar to most of the studies of cap-and-trade markets, Shapiro & Walker "find little association of offset prices or offset-induced movements in pollution with the share of a community that is Black, Hispanic, or with mean household income." (Shapiro & Walker, 2021).

Acid Rain Program:

In an early study of the distributional effects of the federal acid rain trading program, Jason Coburn, who is now a professor of urban planning at Berkeley, examines the correlation between power plants' stack emissions and pollution allowances holdings with racial and income characteristics of the populations surrounding the plants. He looks at data from the first three years of the program and concludes that the program "does not appear to have been concentrating SO_2 pollution disproportionately for the poor and racial minority populations." (Coburn, 2001). Ten years later, Evan Ringquist conducted a similar study using data that covered more sources, across a larger geographic area and longer time period.[3] Using this expanded dataset, Ringquist also failed to find that allowance holdings were concentrated in Black or Hispanic communities. (Ringquist, 2011). Notably, however, Ringquist

1. The relevant studies use varied parameters to identify communities of interest in exploring the distributional impacts of trading. Some look at the impacts on different income and racial groups, while others, including the more recent studies of the California cap-and-trade program, use the CalEnviroScreen Index, which incorporates a mix of social and economic criteria, to identify "disadvantaged" communities of interest. Here, we generically refer to the communities of interest as "disadvantaged;" however, throughout the remainder of this appendix, we specify how the communities of interest were defined in each study when reviewing the findings.

2. The marginal abatement cost is the cost of reducing one more unit of pollution. In general, marginal abatement costs increase as firms pursue deeper emissions reductions.

3. The Acid Rain Trading program was introduced in two phases. As Ringquist described, "Phase I of the ATP...ran from 1995 through 1999 and included only 110 electric generating facilities east of the Mississippi River. By contrast, Phase II of the ATP (2000–2010) covered nearly 2,000 polluting facilities nationwide." Ringquist, 2011.

did find that emissions were reallocated towards poorly educated communities throughout the course of the trading program. Based on these findings, Ringquist suggests that:

> "There is no inherent tradeoff between efficiency and equity when using market-based instruments for pollution control. Policymakers, however, might make an effort to design and implement future emissions trading programs in a manner that reduces the monitoring costs of tracking emissions trading. By reducing monitoring costs, policy- makers may prevent the concentration of emissions in poorly educated communities while preserving the efficiency benefits of these instruments." (Ringquist, 2011).

RECLAIM:
There have been at least three in-depth economic analyses of the distributional impacts of RECLAIM. The first of these studies, published by Meredith Fowlie et al. in 2012, compared emissions at facilities regulated by RECLAIM with similar facilities in nonattainment areas in other parts of California. These matched facilities were subject to command-and-control regulation during the study period, which provides a comparison group that can be used to compare the observed emissions at facilities regulated under RECLAIM to what would have been had command-and-control been maintained throughout the state. (This approach is referred to elsewhere in this appendix as a "counter-factual matching approach.") Fowlie et al. used the "ring approach" to correlate emissions concentrations with demographic criteria, whereby they determined the racial and income characteristics of the populations surrounding regulated facilities. Using this methodological approach, they "observed changes in emissions do not vary significantly with neighborhood demographic characteristics." (Fowlie et al., 2012).

In 2018, Corbett Grainger and Thanicha Ruangmas published a second counterfactual examination of RECLAIM's distributional impacts that used a pollution dispersion model instead of the ring approach to measure the affected populations. With this new methodology, Grainger & Ruangmas found that higher income groups received larger reductions in pollution exposure than lower-income groups. (Grainger & Ruangmas, 2018). However, they found conflicted evidence on the impact of race. Specifically, they stated that "conditional on income (or poverty rates), we find that Blacks benefit while Hispanics lose relative to whites under RECLAIM." (Ibid). They do not offer any hypothesis for why the program would have had opposite impacts on these two different racial minorities.

Notably, however, in a very recent counterfactual study that again used the ring approach to define affected populations, Erin Mansur & Glenn Sheriff found a similarly divergent racial impact. In particular, they find that Black communities experienced relatively larger reductions than white communities under RECLAIM while Hispanic communities experienced relatively smaller reductions. (Mansur & Sheriff, 2019). Importantly, however, unlike Grainger & Raungmas, Mansur & Sheriff did not find evidence that trading led to a reallocation of emissions towards low-income populations. To the contrary, they find that "distributions of exposures for whites and individuals from house-holds above twice the poverty line are worse than the distributions for all other demographic groups." (Ibid). They also note that while there was a "shift in relative positions across groups [with Blacks having the most favorable exposure distribution and Hispanics the least desirable exposure], each individual group is better off under RECLAIM than at baseline or command and control." (Ibid).

AB 32:
At least four recent studies have examined the distributional effects of California's Cap-and-Trade Program. One of these studies found an increase in pollution in disadvantaged communities following implementation of the trading regime (although, as described below, this study has been criticized for not properly analyzing causation). The other three studies either found that the policy had no statistically significant distributional impacts or that it decreased the relative pollution burden imposed upon disadvantaged communities.

The first major study of the distributional impacts of California's Cap-and-Trade Program was published by Lara Cushing et al. in 2018. In this study, the authors examine the location of facilities regulated under California's carbon trading program and whether changes in the emissions profiles of such facilities between 2013 and 2015 (the first three years after the trading regime commenced) correlated with income or race. They found that regulated facilities are "disproportionately located in economically disadvantaged neighborhoods with higher proportions of residents of color….Moreover, the majority (52%) of regulated facilities reported higher annual average local (in-state) GHG emissions since the initiation of trading." (Cushing et al., 2018). They further find that "[n]eighborhoods that experienced increased in annual average GHG and co-pollutant emissions from regulated facilities nearby after trading began had higher proportions of people of color and poor, less educated, and linguistically isolated residents, compared to neighborhoods that experienced decreases in GHGs." (Cushing et al., 2018).

Importantly, in a subsequent study, the economist Ryan Walch wrote the following critique of the Cushing et al. study:

"The most simplistic approach to answering the research question posed in this paper would be to compare the mean emissions before and after the program. Many of the EJ groups concerned about cap-and-trade in California implicitly make such an argument and cite research such as Cushing et al. (2016) that follows this method. If I were to replicate this approach with my data, I would find a statistically insignificant decrease of 10.2 tons a year in NO_x and a statistically significant increase of 0.62 tons per year for SO_x. However, there are major concerns about the validity of this approach. It is impossible to separate the effect of the program from changes in co-pollutant levels that would have occurred anyway. To get proper estimates of the program's *causal* impact, we need to find a proper control group that would allow us to estimate what would have happened at the California plants under the no-program counterfactual." (Walch, 2018).

Meredith Fowlie's work provides further reason to question Cushing et al.'s conclusions. Among other things, Fowlie has shown that California experienced economic growth that was higher than the national average in the years after cap-and-trade program was established, which suggests Cushing et al.'s results may not be due to AB-32, but instead other correlated factors, including economic growth and historical disparities in the distribution of pollution. (Fowlie, 2016).

There are also substantial variations between the trading program developed under the AB-32 program and that which may be implemented under LL97. To begin with, the California program regulates a wide variety of sectors and Cushing et al. found substantial inter-sectoral variation in emissions trends, with a few particular sectors such as the cement industry, appearing to account for a substantial amount of the emissions increases they observed. This is quite a distinctive context from the situation under

LL97 in which many of the major emitters (i.e. power plants) are excluded from the regulatory ambit, leaving primarily commercial and residential buildings within the law's reach. Finally, as Cushing et al. observe, in the early years of AB-32, the required emissions reductions could be entirely met through offsets, including those out of state.[4] This is another material difference from LL97, which permits facilities to only use offsets to meet 10% of their obligations.

As noted above, the other three studies of which we are aware that have investigated the distributional impacts of California' Cap-and-Trade Program have failed to find evidence that it has exacerbated the pollution burden in EJCs. In one such study, Ryan Walch used a difference-in-difference approach to estimate the extent to which California's Cap-and-Trade Program has caused a change in the distribution of NO_x and SO_x in California. To do so, he matches power plants within California that are regulated under AB 32 with similar plants outside of California that are regulated under command-and-control programs alone and compares changes in the magnitude and direction of emissions in the years following the introduction of AB 32. The plants outside of California serve as a control group. Using this approach, Walch found that "average co-pollutant emissions at plants located in low-income or minority communities covered by the program have not gone up relative to co-pollutant emissions at plants in similar communities outside of California." (Walch, 2018).

Danae Hernandez-Cortes and Kyle Meng also failed to find a negative impact on EJ communities in a very recent study of co-pollutant emissions; to the contrary, they found that California's Cap-and-Trade Program has produced relatively *more* benefit for disadvantaged communities. Using a difference-and-differences approach to examine changes in exposure to air pollution from regulated facilities following implementation of the carbon trading regime, the authors examined whether the gap in emissions exposure increased or decreased following introduction of trading. Notably, to estimate pollution exposure impacts, this study used a complicated air pollution dispersion model which tracked the movement of pollution plumes from regulated sources as opposed to simply drawing a ring around regulated sources to approximate pollution exposure. Using this methodology, Hernandez-Cortes & Meng find that trading "reduced inequality in local air pollution exposure between disadvantaged and other communities." (Hernandez-Cortes & Meng, 2020).

Hernandez-Cortes & Meng's findings are consistent with an earlier study by Meng. In that study, Meng compared the change in emissions in disadvantaged communities and other communities relative to the year prior to the start of trading (2012) to see whether the two types of communities experienced different emissions trends. As he explains, "a greater drop in emissions for disadvantaged communities compared to other communities would suggest that cap-and-trade had caused emission differences to narrow across the two groups." (Meng, 2019). This analysis indicated that disadvantaged and other communities experienced similar declines in emissions following the start of trading (disadvantaged communities actually experienced a slightly larger decline but this difference did not rise to the level of statistical significance). (Ibid). Based on these findings, Meng concludes that his analysis finds no evidence to suggest that cap-and-trade has increased environmental injustice. To the contrary, Meng states that "[i]f anything, the evidence suggests that disadvantaged communities may have experienced on average a greater decline in emissions since the start of the cap-and-trade program than other communities." (Ibid).

4. The authors state: "Thus, by design, the 3%–3.5% annual reduction in GHG emissions set by the decreasing cap can be achieved entirely via offset projects. Cutbacks in the use of more carbon intensive energy sources imported from outside the state (such as electricity generated from coal-fired rather than natural gas power plants) can also be used by regulated entities to meet emission reduction goals in lieu of in-state reductions." Cushing et al., 2018, p. 5. Note, however, that a recent study that specifically examined the distributional impacts of offsets found that the use of offsets has not tended to lead to a shift in pollution from wealthy/white areas towards low-income communities of color. Shapiro & Reed, 2021.

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APPENDIX B—Modeling Inputs, Assumptions, and Methodology

Model Inputs and Assumptions

The Study's key inputs and assumptions are documented below. While all data sources identified have certain limitations, we believe these are the best sources available and are sufficient for the Study's overarching purpose, which is to measure the difference between a baseline model focused on LL97 compliance only and models that permit trading.

Property Segments

The Study defined 202 property segments to understand owner decision making. It is assumed that each property within a segment will make the same decision, as it faces the same modeled conditions, constraints, costs, and benefits.

The 202 unique property segments, listed in the table below, are based on:

Real estate characteristics such as ownership type (condo/coop[1] vs. rental), occupancy type (such as residential or office), building class/quality (such as office building class and rental market tier), residential affordability.

Physical and energy characteristics such as building size and age, energy characteristics such as heating type, current emissions intensity.

Regulation-driven characteristics that affect a segment's regulatory coverage under LL97, such as building use and rent-regulation status.

The NYC PLUTO database served as the baseline dataset off of which we summarized properties and their use, building area, year built, number of floors, and other building attributes. On top of this dataset, we joined data from the CoStar property database, LL84 benchmarking data, LL87 audit data, and data on rent-regulated and subsidized properties supplied by the NYU Furman Center.

We grouped properties into 4 broad occupancy categories: residential, commercial (which includes office, hospitality and retail), industrial, and institutional. A complete list of the 202 segments that fell within these 4 broad categories is provided in the follow pages.

Residential and office buildings comprise the largest number of covered buildings. As such, it may be helpful to note some of key attributes of the segments in these sectors:

Key attributes of select residential segments

3 stories or less: Residential construction code, more outdoor space for heat pumps, almost no common area loads.

Four to seven stories: Some elevators and common area spaces. Typically outer borough and high fuel use for space heating and domestic hot water (DHW).

Eight stories and taller: Different steam system layouts, older Manhattan market rate buildings and newer tall buildings with more elevator and pumping loads.

1. Defined as properties with building class beginning in R (condominium), or with building class C6, C8, D0, or D5 (cooperatives).

Post 1980: More hydronic and forced air/heat pump. Buildings have insulation and more functional ventilation systems. More mixed-use buildings with amenities and ground-floor retail.

Pre 1980: Steam and hydronic, mass walls with no real insulation.

Electrically heated: These are multifamily buildings with electric space heating. Reductions as a percent of baseline use are modified for these types of buildings, and fuel end use savings are not applicable.

Key attributes of select office segments

7 stories or less: Primarily on-site heating plants, decentralized cooling. Tenants own and operate most of their own ventilation and cooling systems.

500,000+ SF, non-district steam cooling: Primarily district steam for heating with either electric chillers or floor-by-floor packaged units owned and operated by the base building. Tenants will have supplemental cooling for data closets. Electrifying heating for these buildings poses a challenge.

500,000+ SF, steam-driven cooling: Primarily district steam heating and steam-driven chillers. The base building owns and operates the majority of the cooling and ventilation equipment, although tenants will have supplemental cooling for data closets. Electrifying heating and cooling for these buildings poses a challenge.

Mid-size (8+ stories, up to 500,000 SF) pre-war: Primarily on-site boilers with decentralized cooling. Tenants primarily responsible for cooling and ventilation equipment.

Mid-size (8+ stories, up to 500,000 SF) post-war: The majority of buildings in this typology have district steam instead of on-site heating plants, and there is a slight bias towards central cooling plants vs. decentralized cooling. Because of the reliance on district steam for heating, electrifying these buildings poses a challenge.

Table 1. List of detailed property segments.

Key

Residential

Commercial—Office

Commercial—Other

Industrial

Institutional

1	Multifamily Electrically Heated—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
2	Multifamily Electrically Heated—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
3	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Condo/Coop
4	Multifamily 1980 and after, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
5	Multifamily 1980 and after, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
6	Multifamily 1980 and after, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
7	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
8	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
9	Multifamily 1980 and after, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
10	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
11	Multifamily 1980 and after, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
12	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
13	Multifamily Pre-1980, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
14	Multifamily Pre-1980, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
15	Multifamily Pre-1980, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
16	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
17	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
18	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
19	Multifamily Pre-1980, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Condo/Coop
20	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Condo/Coop
21	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Condo/Coop
22	Multifamily Electrically Heated—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 1
23	Multifamily Electrically Heated—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
24	Multifamily Electrically Heated—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
25	Multifamily Electrically Heated—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2
26	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 1
27	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
28	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 3

29	Multifamily 1980 and after, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
30	Multifamily 1980 and after, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
31	Multifamily 1980 and after, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
32	Multifamily 1980 and after, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 3
33	Multifamily 1980 and after, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
34	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 1
35	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
36	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
37	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
38	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2
39	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 3
40	Multifamily 1980 and after, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 1
41	Multifamily 1980 and after, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
42	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 1
43	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
44	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
45	Multifamily 1980 and after, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
46	Multifamily 1980 and after, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2
47	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 1
48	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
49	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 3
50	Multifamily Pre-1980, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
51	Multifamily Pre-1980, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
52	Multifamily Pre-1980, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
53	Multifamily Pre-1980, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

54	Multifamily Pre-1980, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
55	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 1
56	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 2
57	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
58	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
59	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2
60	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 3
61	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 1
62	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
63	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 3
64	Multifamily Pre-1980, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 1
65	Multifamily Pre-1980, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Market-Rate Rental, Tier 3
66	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 1
67	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 2
68	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Market-Rate Rental, Tier 3
69	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 1
70	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 2
71	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Market-Rate Rental, Tier 3
72	Multifamily Electrically Heated—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
73	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
74	Multifamily 1980 and after, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
75	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental <35% rent-regulated
76	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
77	Multifamily 1980 and after, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
78	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental <35% rent-regulated

79	Multifamily 1980 and after, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
80	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
81	Multifamily Pre-1980, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
82	Multifamily Pre-1980, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
83	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental <35% rent-regulated
84	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
85	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
86	Multifamily Pre-1980, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental <35% rent-regulated
87	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental <35% rent-regulated
88	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental <35% rent-regulated
89	Multifamily Electrically Heated—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
90	Multifamily Electrically Heated—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
91	Multifamily Electrically Heated—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
92	Multifamily 1980 and after, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
93	Multifamily 1980 and after, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
94	Multifamily 1980 and after, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
95	Multifamily 1980 and after, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
96	Multifamily 1980 and after, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
97	Multifamily 1980 and after, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
98	Multifamily 1980 and after, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
99	Multifamily 1980 and after, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
100	Multifamily 1980 and after, 8+ floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
101	Multifamily Pre-1980, 1 to 3 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
102	Multifamily Pre-1980, 1 to 3 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
103	Multifamily Pre-1980, 1 to 3 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

104	Multifamily Pre-1980, 4 to 7 floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
105	Multifamily Pre-1980, 4 to 7 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
106	Multifamily Pre-1980, 4 to 7 floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
107	Multifamily Pre-1980, 8+ floors—High Emitters (not yet compliant with 2024 limits)—Affordable Rental >35% rent-regulated
108	Multifamily Pre-1980, 8+ floors—Medium Emitters (compliant with 2024 limits but not 2030)—Affordable Rental >35% rent-regulated
109	Multifamily Pre-1980, 8+ floors—Low Emitters (already compliant with 2030 limits)—Affordable Rental >35% rent-regulated
110	Office <8 floors—High Emitters (not yet compliant with 2024 limits)—Class A
111	Office <8 floors—High Emitters (not yet compliant with 2024 limits)—Class B
112	Office <8 floors—High Emitters (not yet compliant with 2024 limits)—Class C
113	Office <8 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Class A
114	Office <8 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Class B
115	Office <8 floors—Medium Emitters (compliant with 2024 limits but not 2030)—Class C
116	Office <8 floors—Low Emitters (already compliant with 2030 limits)—Class A
117	Office <8 floors—Low Emitters (already compliant with 2030 limits)—Class B
118	Office <8 floors—Low Emitters (already compliant with 2030 limits)—Class C
119	Office Very Large (>500K square feet), non-steam cooling—High Emitters (not yet compliant with 2024 limits)—Class A
120	Office Very Large (>500K square feet), non-steam cooling—High Emitters (not yet compliant with 2024 limits)—Class B
121	Office Very Large (>500K square feet), non-steam cooling—Medium Emitters (compliant with 2024 limits but not 2030)—Class A
122	Office Very Large (>500K square feet), non-steam cooling—Medium Emitters (compliant with 2024 limits but not 2030)—Class B
123	Office Very Large (>500K square feet), non-steam cooling—Medium Emitters (compliant with 2024 limits but not 2030)—Class C
124	Office Very Large (>500K square feet), non-steam cooling—Low Emitters (already compliant with 2030 limits)—Class A
125	Office Very Large (>500K square feet), non-steam cooling—Low Emitters (already compliant with 2030 limits)—Class B
126	Office Very Large (>500K square feet), non-steam cooling—Low Emitters (already compliant with 2030 limits)—Class C
127	Office Very Large (>500K square feet), steam cooled—High Emitters (not yet compliant with 2024 limits)—Class A
128	Office Very Large (>500K square feet), steam cooled—Medium Emitters (compliant with 2024 limits but not 2030)—Class A
129	Office Very Large (>500K square feet), steam cooled—Medium Emitters (compliant with 2024 limits but not 2030)—Class B
130	Office Very Large (>500K square feet), steam cooled—Medium Emitters (compliant with 2024 limits but not 2030)—Class C
131	Office Very Large (>500K square feet), steam cooled—Low Emitters (already compliant with 2030 limits)—Class A

132	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class A
133	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class B
134	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class C
135	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class A
136	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class B
137	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class C
138	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class A
139	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class B
140	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class C
141	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class A
142	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class B
143	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—High Emitters (not yet compliant with 2024 limits)—Class C
144	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class A
145	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class B
146	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Medium Emitters (compliant with 2024 limits but not 2030)—Class C
147	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class A
148	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class B
149	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Low Emitters (already compliant with 2030 limits)—Class C
150	Education—Higher Education
151	Education—K-12, Non-Public
152	Food Service
153	Health care Inpatient—For-Profit
154	Health care Outpatient—For-Profit
155	Hotel and Dorm
156	Industrial, Lab, Data Center
157	Public Assembly
158	Public Service
159	Repair, gas stations, dealerships
160	Retail and miscellaneous business

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

161	Supermarkets
162	Warehouse and storage
163	Multifamily Electrically Heated—Condo/Coop—Highest Emitter
164	Multifamily 1980 and after, 1 to 3 floors—Condo/Coop—Highest Emitter
165	Multifamily 1980 and after, 8+ floors—Condo/Coop—Highest Emitter
166	Multifamily Pre-1980, 1 to 3 floors—Condo/Coop—Highest Emitter
167	Multifamily Pre-1980, 4 to 7 floors—Condo/Coop—Highest Emitter
168	Multifamily Pre-1980, 8+ floors—Condo/Coop—Highest Emitter
169	Multifamily Electrically Heated—Market-Rate Rental, Tier 3—Highest Emitter
170	Multifamily 1980 and after, 4 to 7 floors—Market-Rate Rental, Tier 3—Highest Emitter
171	Multifamily Pre-1980, 4 to 7 floors—Market-Rate Rental, Tier 1—Highest Emitter
172	Multifamily Pre-1980, 4 to 7 floors—Market-Rate Rental, Tier 2—Highest Emitter
173	Multifamily Pre-1980, 4 to 7 floors—Market-Rate Rental, Tier 3—Highest Emitter
174	Multifamily Pre-1980, 8+ floors—Market-Rate Rental, Tier 3—Highest Emitter
175	Multifamily Pre-1980, 4 to 7 floors—Affordable Rental <35% rent-regulated—Highest Emitter
176	Multifamily Pre-1980, 8+ floors—Affordable Rental <35% rent-regulated—Highest Emitter
177	Multifamily 1980 and after, 4 to 7 floors—Affordable Rental >35% rent-regulated—Highest Emitter
178	Multifamily 1980 and after, 8+ floors—Affordable Rental >35% rent-regulated—Highest Emitter
179	Multifamily Pre-1980, 1 to 3 floors—Affordable Rental >35% rent-regulated—Highest Emitter
180	Multifamily Pre-1980, 4 to 7 floors—Affordable Rental >35% rent-regulated—Highest Emitter
181	Multifamily Pre-1980, 8+ floors—Affordable Rental >35% rent-regulated—Highest Emitter
182	Office <8 floors—Class A—Highest Emitter
183	Office <8 floors—Class B—Highest Emitter
184	Office <8 floors—Class C—Highest Emitter
185	Office Very Large (>500K square feet), steam cooled—Class C—Highest Emitter
186	Office Post-1947, Mid-Size (over 8 floors, up to 500K square feet)——Highest Emitter
187	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Highest Emitter
188	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Highest Emitter
189	Office Pre-1947, Mid-Size (over 8 floors, up to 500K square feet)—Highest Emitter
190	Education—Higher Education—Highest Emitter
191	Food Service—Highest Emitter
192	Health care Outpatient—For-Profit—Highest Emitter
193	Hotel and Dorm—Highest Emitter
194	Industrial, Lab, Data Center—Highest Emitter
195	Public Assembly—Highest Emitter
196	Repair, gas stations, dealerships—Highest Emitter

197	Retail and miscellaneous business—Highest Emitter
198	Supermarkets—Highest Emitter
199	Warehouse and storage—Highest Emitter
200	Health care Inpatient—Non-Profit
201	Health care Outpatient—Non-Profit
202	NYCHA

Key

- Residential
- Commercial—Office
- Commercial—Other
- Industrial
- Institutional

Abatement Measures

Abatement measures were identified as those that would reduce reliance on on-site combustion and result in long-term building sustainability. The Study targeted measures that have not yet been implemented at scale and are likely required to be implemented in order to reach the City's sustainability goals. These measures do not depend on behavior modification by tenants and assume that home and business electricity and thermal loads will remain unchanged throughout the study period, other than through the specified retrofit measures that, in many cases, reset building systems.

Abatement measures include:[2]

Energy Efficiency (any fuel type):
- boiler and distribution optimization
- exterior insulation and air sealing
- water submetering

Energy Efficiency (electricity):
- appliance and plug load efficiency
- lighting power reduction
- building management system

Electrification:
- electrify cooking appliances
- electrify cooling
- convert space heating to heat pumps
- convert domestic hot water to heat pumps
- convert domestic hot water to point-of-use

Fuel Switching:
- switching from fuel oil #4 to fuel oil #2
- switching from fuel oil#4 to natural gas

Abatement measures can be combined in an additive way, except for the following combinations (which represent options mutually exclusive of the defined measures):

Electrification of space heating—a fuel switch measure—combined with added envelope insulation—a load reduction measure

Electrification of domestic hot water—a fuel switch measure—combined with water submetering—a load reduction measure

We assume that electrification is pursued without retaining fuel backup, as current technology has no need for fuel backup. Keeping gas infrastructure in place after electrification could be a more difficult retrofit, and requires maintenance of two systems, doubling maintenance work. Unlike dual-fuel systems of today, electrified systems and fuel-based systems have very little overlap in central plant or distribution infrastructure, so maintaining both systems would be burdensome to building operators.

Data sources: NYC Building TWG study for energy efficiency measures and NYC specific end uses summarized from LL87 data, CNCA Existing Building Performance Standards for energy end uses and savings estimates for electrification measures, BE-Ex Pursuing Passive for NYC specific space heating electrification measure details.

Costs and Benefits of Abatement Measures

The Study calculated costs as an installation cost per square foot of floor area. Where costs were given normalized per energy unit, such as in the CNCA study, the baseline energy use intensity of the different building segments was used to develop a cost per floor area.

The team calculated benefits by approximating energy end uses via a combination of the NYC TWG / LL87 data sets, and where supplementation was needed, from CBECS for certain building segments. These end uses then had energy use reductions applied to them for each applicable abatement measure to develop an energy savings estimate per energy type—electricity or fuel. The energy savings estimate was then applied as a percent reduction to the applicable fuel when the abatement measure was selected by the model.

2. Some of these abatement measures apply only to certain property segments and were assigned based on aspects of the segment, such as fuel type and building use. See Table 2 for more information on abatement measures by segment.

Costs and benefits remain the same throughout the study period as there is too much uncertainty to measure whether metrics will increase or decrease over time.

Data sources: NYC LL84 for baseline fuel intensities, EIA CBECS as well as the above data sources for end uses and energy savings estimates

Table 2. Summary table of abatement measures.

Type	Abatement Measure	Applicable segments	Install Cost/SF	Nominal Energy Savings*	Applicable Fuel
Energy Eff.	Heating energy efficiency	All (except for electrically heated)	$1.7	13%	Gas/Oil/Stm
Energy Eff.	Multifamily electric plug load energy efficiency	Multifamily	$0.6	8%	Electric
Energy Eff.	Commercial electric plug load energy efficiency	Commercial	$0.2	5%	Electric
Energy Eff.	Lighting	Commercial	$0.2	3%	Electric
Energy Eff.	Energy management system	Commercial	$0.4	7%	All
Energy Eff.	Water submetering	Multifamily	$0.5	4%	Gas/Oil/Stm
Energy Eff.	Wall insulation	Multifamily Low-Rise	$25.0	13%	Gas/Oil/Stm
Electrification	Cooking electrification	Multifamily	$2.5	4%	Gas/Oil/Stm
Electrification	Convert space heating to air source heat pumps	All	$18.0	67%	Gas/Oil/Stm
Electrification	Convert hot water to air source heat pumps	Multifamily	$6.0	28%	Gas/Oil/Stm
Electrification	Convert hot water to point of use	Commercial	$0.2	10%	Gas/Oil/Stm
Electrification	Partially Electrify Cooling	Commercial	$2.4	5%	Gas/Oil/Stm
Electrification	Fully Electrify Cooling	Commercial	$18.0	50%	Gas/Oil/Stm
Fuel Switching	Conversion from FO4 to NG for dual-fuel buildings	All	$40K / building	15%	Gas/Oil/Stm
Fuel Switching	Conversion from FO4 to FO2 for primary FO4 buildings	All	$3.0	85%	Gas/Oil/Stm
Combo	DHW ASHP + submetering	Multifamily	$6.5	28%	Gas/Oil/Stm
Combo	Heating ASHPs + wall insulation	Multifamily Low-Rise	$47.0	67%	Gas/Oil/Stm

*The highest GHG emitting buildings in the MF and office categories have a higher energy savings percentage for EE measures. Electrification measures assume an added electricity use in a ratio taken from the CNCA study page 21.

Table 3. Energy modeling results of a typical multifamily building from the NYC TWG study.

MF-Postwar >7 stories (a typology representative of most multifamily buildings)	Site EUI (kBTU/SF)		
	Baseline	TWG Model Path 1 (optimization of existing systems)	Measure
Lighting	3.3	1.7	Reduce lighting W/SF from 0.5 to 0.25
Equipment Electric	6.6	5.2	Reduce plug load W/SF from 0.65 to 0.51
Conveyance	1.8	1.2	Reduce energy use by 30%
Total	11.7	8.1 (30% reduction)	

Detailed Notes on Abatement Measures

To calculate energy savings, we found the median total site EUI and the typical electricity vs non-electricity energy split for each segment, and used that as a basis for determining the impact of energy use reductions. The 50th percentile gas user may be a very different building than the 50th percentile oil user. We therefore aggregated gas, oil, and steam as a combined thermal energy source to develop estimated savings for each measure. While a median value was used to calculate per-segment savings, the baseline energy use for each segment is conveyed as the total energy use of each fuel type within the segment.

Given the abatement measures chosen for this analysis, which produce deeper level of savings than measures listed in LL87 audits, the Study used the TWG, CNCA, and BE-Ex studies rather than directly using LL87 data to determine costs and savings potentials. That said, LL87 data has been utilized to calculate baseline energy end uses and serves as a primary input in other studies (i.e., the NYC Building TWG study) that are key sources used by the Study.

Heating energy efficiency: Reduce space heating by 20% through distribution balancing and temperature control. Estimated installation cost is $1.70 / SF.[3] Heating distribution savings are generally achieved with a similar scope of measures including indoor temperature feedback, proper venting and room-by-room thermostatic control of the heaters. Higher energy users are assigned a 30% savings. This measure is mutually exclusive with the savings projection for electrifying space heating.

Multifamily and commercial plug load reduction: Reduces plug loads by 30% for 1/3 of the building-wide electricity load through common area savings from smart plugs, appliance upgrades, lighting controls and lighting wattage reductions. The NYC TWG energy modeling of multifamily buildings had a similar result shown in Table 3.

Installation cost of this measure is approximately $0.20 / SF for lighting[4] + $0.40 / SF for common area and tenant area appliance upgrades.[5] Conveyance upgrades could be replaced by tenant education programs reducing energy waste in apartments, making up that same 5–10% savings without incurring much cost. Total cost for measure is $0.60 / SF.

3. This cost estimate comes from the TWG report; comprehensive steam upgrade is estimated at $1.25/SF; right size steam boilers at end of useful life: $0.45/SF. Total is $1.70/SF. See TWG Report, at 55 and 65.

4. TWG Report, at 47.

5. TWG Report, at 48, summing the cost of all measures less than $0.25/SF.

For typologies such as tenant-controlled offices that cannot achieve a 30% electrical consumption reduction through this measure, savings are modeled assuming a 15% reduction in plug loads and a lighting power density reduction from the LPD allowed in the 2014 NYC Energy Conservation Code to the LPD proposed in the 2020 NYC Energy Conservation Code. Lighting consumption savings for both of the "Very Large Office" typologies were de-rated by 20%, which accounts for upgrades that have already occurred in common areas and back-of-house spaces. Lighting savings opportunities for these buildings are assumed to be limited to tenant spaces only.

Building Management System: Reduce whole building electricity and fuel use in commercial buildings through use of a centralized system that optimizes to reduce energy use, such as by understanding tenant behaviors and feedback through sensors. Based on assumptions developed for an Energy Management System in the NYSERDA Commercial Baseline study, this measure yields 22% savings, is feasible in 70% of buildings, and is applicable to 46% of whole building electricity use and 90% of whole building fuel use. This yields an overall segment savings of 7% in electricity savings and 14% in fuel savings. The cost of the BMS is $1.39 per kWh saved, so the cost varies by segment.

Cooking electrification: Convert gas cooking stoves to electric, eliminating cooking gas usage. Electric stoves are 39% more efficient than gas, so electricity increase is 0.61 * existing cooking gas usage.[6] Installation cost is difficult because electric stoves require more amperage but may also relieve a building of gas riser replacement and testing. Equipment costs are roughly estimated as $0.72 / kBTU of cooking gas usage.[7] For a typical multifamily building that uses 3 kBTU/SF for cooking gas, this comes out to 3 kBTU/SF *$0.72 $/kBTU = $2.16 / SF. Note there are significant benefits to converting away from gas stoves including indoor air quality and gas riser replacement cost reduction.

Heating air source heat pumps: Convert space heating to heat pumps, eliminating space heating non-electricity use. Electric heat pumps eliminate steam or hot water distribution problems, so the heating load of the building is reduced, and this measure has an estimated 30% heating load reduction. Assuming a boiler efficiency of 80% and a heat pump efficiency of 250%, new electricity use is calculated (in kBTU) as 80%/250% * (1-30%) * space heating use.[8] Installation cost is roughly $0.40 per kBTU converted, resulting in a median building cost of $18/SF. Cost data is highly variable in general for this level of retrofit. Non-energy benefits of this measure include the addition of space cooling, as most buildings with central heating systems do not have central cooling systems serving every room. Since heat pumps can provide heating and cooling, every space served by the heat pumps will have cooling in addition to heating, where previously only heating was available.

For typologies where district steam heating is prevalent, the steam savings and electric consumption values shown are hypothetical and do not consider the possibility of delivering sufficient electrical service to the building. The installation cost for these buildings is greater than the installation cost in buildings with on-site heating to account for the lost rentable square footage required to house the heating equipment.

6.Steven Winter Associates, Carbon Neutral Cities Alliance, Performance Standards for Existing Buildings, Performance Targets and Metrics, Final Report, tb. 18 (March 2020), *available at* http://carbonneutralcities.org/wp-content/uploads/2020/03/CNCA-Existing-Building-Perf-Standards-Targets-and-Metrics-Memo-Final-March2020.pdf (last visited June 15, 2021).

7. Ibid. "Cooking" incremental cost is 95% of BAU if only considering equipment. All other equipment costs from same table.

8. Ibid.

Domestic hot water, heat pumps: Convert DHW to heat pumps. Eliminates DHW non-electricity usage. Heat pumps are assumed 59% more efficient than gas (gas efficiency: 82%, heat pump efficiency: 200%), so new electricity use is (1–59%) * non-electricity usage. Installation cost is 2.2x BAU or $0.33 per kBTU converted, or around $6/SF in typical multifamily buildings.

Domestic hot water, point of use: For building types with small water use loads, a point of use electric resistance water heater measure can be used. The end energy use of this measure may be similar to a central heat pump measure, with an approximately equal first cost.

Apartment water submetering. Saves 20% of DHW usage through a reduction in apartment water use. Cost assumed to be ~$0.50 / SF for water meters and low flow fixtures in apartments.

Partially electrify cooling: This measure applies to the "Very Large Office, Steam Cooling" typology only. These buildings currently use district steam to power central cooling plants, avoiding summertime peak electric demand charges. The savings assume that the building will install an electric chiller sized for 30% of the building's cooling load and will operate that chiller whenever the building's cooling load is 30% or less outside of the summertime peak demand window. Approximately 10% of the steam usage for cooling can be offset by electricity using this measure. Steam energy for cooling was converted to electricity assuming a steam chiller at with an efficiency of 16 lbs/ton and an electric chiller with an efficiency of 0.6 kW/ton. No peak demand impact would be associated with this measure, as it only affects mild weather chiller operation.

Fully electrify cooling: This measure applies to the "Very Large Office, Steam Cooling" typology only. It is advantageous for these buildings to continue using steam to power cooling equipment because using steam for cooling avoids high summertime electric demand charges. The steam savings and electric consumption increase shown are hypothetical and do not take into account the possibility of delivering sufficient electrical service to the building. Steam energy for cooling was converted to electricity assuming a steam chiller with an efficiency of 16 lbs/ton and an electric chiller with an efficiency of 0.6 kW/ton.

Fuel oil #4 conversion: This measure is included to account for a #4 fuel oil phaseout by 2030. Buildings can use #4 oil in two ways, either as the primary fuel or as part of a dual fuel system that can use natural gas or #2 oil.

For dual fuel buildings, the cost to convert is zero since the building has all the hardware to burn natural gas and just needs to call the utility company to switch their service class. The assumption is that all of those buildings will choose this least-cost option, which removes 100% of fuel oil #4 and rolls this energy use into the next option (gas or #2 oil).

For buildings that use only #4 oil, there are two conversion options:

- Switch some hardware so that the building can use #2 oil instead. Our rough estimate is that this would cost a minimum of around $40,000 per building to modify oil tanks and piping in the boiler room.
- Convert the burner, chimney, and piping to use natural gas only. This cost is more dependent on the size of the building, and we estimate of $3/SF in buildings that are converting based on sample projects.

Building Owner Behaviors

Owner Investment Time Horizon

Given frequent asset turnover, most building owners have short investment timelines to ensure they will see returns for building investments. As a result, the Study assumes:

- Commercial, multifamily, retail, industrial, and hotel building owners make investment decisions based on a 5-year investment time horizon (e.g. the model weighs upfront costs vs. the net present value of ongoing costs and benefits over a 5-year period);
- Education, health care, public assembly, and public service building owners make investment decisions based on a 10-year investment timeline (these real estate segments tend to be held for longer periods of time). The affected segments are 150, 151, 153, 154, 157, 158, 190, 192, 195, 200, 201, 202 from the list above.

Data sources: interviews with the real estate industry

Expected Savings

To address concerns from the real estate industry regarding energy savings potential, savings are based on achieved savings as reported in LL87 data and other New York City-focused resources for the chosen abatement measures, and these savings have then been discounted to 85% for the first two compliance periods. The 15% discount, broadly applied as a rough estimate, draws from a study based in California that found an 85% realized savings rate for abatement measures installed through investor-owned utility energy efficiency programs compared to projected savings.[9]

As abatement measures are implemented and benchmarks of energy savings are established, building owner perception of expected savings will increase to 100% of quoted savings.

9. Kaufman, N., & Palmer, K. (2010). Energy-Efficiency Program Evaluations: Opportunities for Learning and Inputs to Incentive Mechanisms, Resources for the Future, 14. http://dx.doi.org/10.2139/ssrn.1589673.

Data sources: interviews with the real estate industry, "Energy-Efficiency Program Evaluations: Opportunities for Learning and Inputs to Incentive Mechanisms" (Resources for the Future)

Owner/Tenant Dynamics

Owner Share of Capital Costs

The baseline model conservatively assumes that owners cannot pass capital costs to tenants.

Data sources: interviews with the real estate industry

Execution Costs

We took an approach to estimate additional per-square-foot costs as a measure of labor hours required of a building manager (separate from the contractor) for each measure. This metric conveniently correlates with the disruptiveness of measures to tenant spaces, as where building managers are required to spend significant time, it is typically to coordinate and monitor measures that require entering a tenant space. This calculation assumes a per-hour labor cost of $50 (including base wages and benefits).

Data sources: input from SWA engineers on time and intensity of implementation

Owner Share of Energy Costs

Energy cost impacts may entail (1) energy cost savings from reduced fuel, gas, and electricity use, and (2) increased electricity costs where electrification measures increase electricity use.

The model assumes that owners of condo and coop buildings (i.e., the homeowner association) cover and receive 100% of energy cost impacts.

For all other segments, the model assumes:

- Owners cannot pass costs of fuel to tenants if implementing a base building measure
- Owners can pass through the proportion of fuel costs equivalent to the average tenant space in a building if implementing tenant level measures

- For electrification measures, fuel-cost savings accrue to the owner, while electricity cost increases are passed to the tenant.

Data sources: interviews with the real estate industry

Growth In Segment Demand

The model assumes an annual growth in the square footage of the building stock for each segment based on each segment's historical 10-year CAGR, capped at 5%. At a citywide level, the square footage of the building stock is expected to grow by 0.75% year over year based on historical growth.

Data source: PLUTO

Energy Prices

Wholesale electricity costs are derived from the NYISO Grid in Transition Study assuming the Clean Leadership and Community Protection Act (CLCPA) mandates are met.

Electricity delivery costs are derived from utility documents with forecasted escalation prices.

Renewable Energy Credit (REC) supply and price are derived by estimating Tier 4 REC supply and prices, based on resource costs and forecasted energy and capacity prices provided in NYSERDA's recent white paper. Resources eligible are assumed to be energy provided along the Champlain Hudson Power Express, energy provided along Empire State Connector, and offshore wind connecting into NYISO Zone J.

Other fuel prices are derived using NYMEX Futures pricing, EIA Energy Outlook forecasts, and estimations of delivery costs based on historical utility and delivered-price information.

Data sources: NYISO Grid in Transition Study, NYMEX Futures pricing, EIA Energy Outlook forecasts, Consolidated Edison Tariffs

Grid Decarbonization

The baseline model assumes that the electricity grid decarbonizes according to CLCPA; we have also run the baseline model using an assumption that the CLCPA targets for grid decarbonization are delayed by 10 years.

The Study derives Zone J specific emissions rates from the NYISO Grid in Transition Study modeling results, assuming the State itself meets CLCPA.

Data sources: NYISO Grid in Transition Study, CLCPA

Modeling Methodology

Simulation of the LL97 cap and trade market was performed using The Brattle Group's Decarbonization, Electrification & Economic Planning (DEEP) Model. DEEP captures the interactions among emissions, technology adoption, and costs for serving primary energy demand across all carbon-intensive economic sectors. DEEP helps policymakers assess the roles of efficiency, electrification, and fuel-switching in a multi-sector strategy to a decarbonized energy economy. The model can run in both planning and optimization modes, the latter of which was used in this study.

In the context of LL97, New York City owners of buildings with area 25,000 square feet and above must limit the metric tons of CO_2 equivalent (tCO_2e) they emit to levels below those specified in the law. If they cannot meet this emissions limit, they must pay a penalty on any excesses; when trading is introduced, building owners have the opportunity to sell excess allowances into or buy allowances from a cap-and-trade market. The Brattle model simulates private decision-making of individual entities within this broader market. It determines an optimal least-cost mix of emissions abatement measures that would be implemented by the owners of each building segment to ensure individual and citywide compliance with LL97 requirements.

For the purposes of modeling decision-making, the costs of each compliance measure (less any offsetting benefits) are those *faced by building owners* who must comply with LL97. Building owners will act as private decision-makers choosing the least-cost means of compliance when considering the up-front and ongoing costs (and offsetting benefits) of each $CO2_e$ abatement measure, as compared to the costs of paying a penalty or purchasing allowances from the market. Building owners will also rationally choose to over-comply if the revenues from selling excess allowances exceed the private costs of available abatement measures.

Table 4 and Table 5 summarizes the model's primary inputs and outputs, respectively. The model operates in real dollar terms (i.e., real 2020$).

Table 4: Brattle carbon market model key inputs.

Inputs

Building Characteristics: Set of building types or segments to be modeled (both covered and non-covered buildings that are regulated under Section 321 of LL97 or owned/operated by the New York City Housing Authority). Characteristics of each building segment for each study year under a "no policy" scenario before compliance measure implementation include:

- Building typologies (class and segmentation signifiers) that have policy or study relevance (e.g. residential, in an environmental justice area, rent controlled, location, etc.), as described in section above
- Aggregate segment emissions limit (summation of individual limits of buildings in that segment)[10]
- Total building energy usage by source (electricity, natural gas, fuel oils, and district steam) for all study years & prior to implementing measures

Abatement Measure Price and Quantity: For each building segment, CO_2e abatement measures are available to meet LL97 compliance (see full list in previous section). Measures are treated as distinct. The units of compliance options can differ (e.g. MWh of RECs, kWh of EE, kWh of electrification), and may be designated as mutually exclusive or otherwise inter-dependent, but they must be able to translate into the following units:

- Investment ($) and ongoing costs ($/year)
- Quantity of CO_2e abated (tCO_2e/year) and/or energy use changes (% of original use)
- Measure life (years, or time schedule of % original tCO_2e/year)
- Benefits accrued to the building owner by the measure (time schedule of $ in received benefits over the measure life)
- Differences in the above values over time, to the extent that parameters differ depending on implementation year

10. LL97 does not set caps for building emissions limits for individual types of buildings for 2035–2050. Instead, it instructs the DOB to issue rules by January 1, 2023 that specify limits for the periods between 2035–2039 and 2040–2049. However, the law says that the average carbon intensity for all covered buildings during these years should be 0.014 tCO_2e/sf/yr or less by 2050. For the purposes of this study, MOC&S provided a set of interim emissions limit assumptions for the years between 2034 and 2049. MOC&S instructed the study team to assume that the emissions limits for 2035–2039 would be the same as those listed in LL97 for 2030–2034. For the 2040–2049, MOC&S calculated an indicative emissions limit as follows: 1) they found the variance of each of the occupancy group targets from the average overall GHGI in 2030; 2) these variances were applied to the 2050 average GHGI included in the text of LL97; and 3) the half-way point between the 2030 and 2050 targets were determined and assigned to the 2040–2049 compliance period.

Inputs

Offset Price and Quantity: Modeled offset costs are roughly over \$3–\$4/metric ton CO_2, assuming international offsets from any source are eligible. These costs are based on recent historical offset costs from voluntary carbon markets. See Donofrio et al., 2020.

Economic and Market Parameters: Various other parameters will be inputs to the model, including at a minimum:

- After-tax weighted average cost of capital (ATWACC), as faced by the majority of building owners
- Electricity and energy prices and emissions rates

Policy Parameters and Choices: These inputs may differ across modeled scenarios and are determined on an ongoing basis. These may include:

- Maximum emissions rate imposed on each building segment[11]
- Penalty rate for exceeding the emissions cap
- Whether trading is allowed
- Other policy parameters (e.g. banking, restrictions on trade, cost containment reserve, etc.)
- Opt-in rules

Building Owner Behaviors: As described in the section above, owners are assumed to discount expected savings by 15%, have a planning horizon of 5 to 10 years, pass some energy costs and savings on to tenants, and do not pass capital costs on to tenants.

11. For the purposes of this study, MOC&S provided at a set of interim emissions limit assumptions for the years after 2034 in consultation with DOB. These interim limits assumed that the 2035–2039 limits are the same as those for 2030–2035 period. The limits become more stringent in 2040 and these limits are in place until 2050, at which point the limits become even more stringent. As such, there are effectively four periods and the cap gets tighter in each period: 2024–2029; 2030–2039; 2040–49; 2050 and on.

Inputs

Electricity System Costs and Emissions: We derive customer electricity costs and emissions for the study period 2020–2050 in part using results from New York Independent System Operator (NYISO) Grid in Transition Study ("Grid Study").[12] The Grid Study determines the cost-optimal electricity grid capacity expansion to meet the 70% clean energy by 2030 and 100% clean energy by 2040 mandates set in the Climate Leadership and Community Protection Act (CLCPA). This study provides data on future resource mix, electricity generation by resource type, and the costs of each technology by location, but does not explicitly report anticipated wholesale or retail prices consistent with that mix.

To derive customer electricity commodity costs, we translate the resource mix and generation data provided in the Grid Study for 2024, 2030, and 2040 into customer costs by calculating the total costs required to sustain the electricity generators in those years.[13] This method does not separately calculate wholesale energy costs and other program costs, such as renewable energy credit (REC) payments, but rather assumes that the total commodity costs paid by customers is equal to the summation of all the cost components required to sustain the electricity system.[14]

12. The Grid Study's results were calculated using Brattle's Grid Scenario Impact Model (GridSIM), which is a capacity expansion and planning model designed for analysis of highly decarbonized electric systems. GridSIM evaluates grid reliability at an hourly granularity, market prices and revenues for resource adequacy, and ultimately provides optimal resource investment and retirement portfolios over a multi-decade time horizon such that total investment and production costs are minimized and reliability and environmental mandates are achieved. Leuken et al., New York's Evolution to a Zero Emission Power System: Modeling Operations and Investment Through 2040. May 18, 2020; Leuken et al., NYISO Grid in Transition Study: Detailed Assumptions and Modeling Description. March 30, 2020.

13. Electricity commodity costs for years in between 2024, 2030, and 2040 are interpolated linearly. Costs are assumed to stay constant post 2040 in real dollars, once the electricity grid has entirely decarbonized.

14. It is likely that the addition of renewable energy in New York State in the future will result in more of customers' electricity commodity costs shifting away from wholesale energy costs, as wholesale market prices decline. This will shift customer bill costs towards higher program costs that will be needed to rise to make up for revenue declines in the wholesale markets. However, regardless of the proportion of customer bills that pays for each component, the sum of all the components that are part of customers' energy commodity charges will reflect the revenues required to pay for the annual system costs.

Outputs

Chosen Measures: LL97 compliance options chosen by each building segment over time. These can be aggregated to relevant groups of building segments (e.g. buildings in environmental justice communities) or to the citywide level.

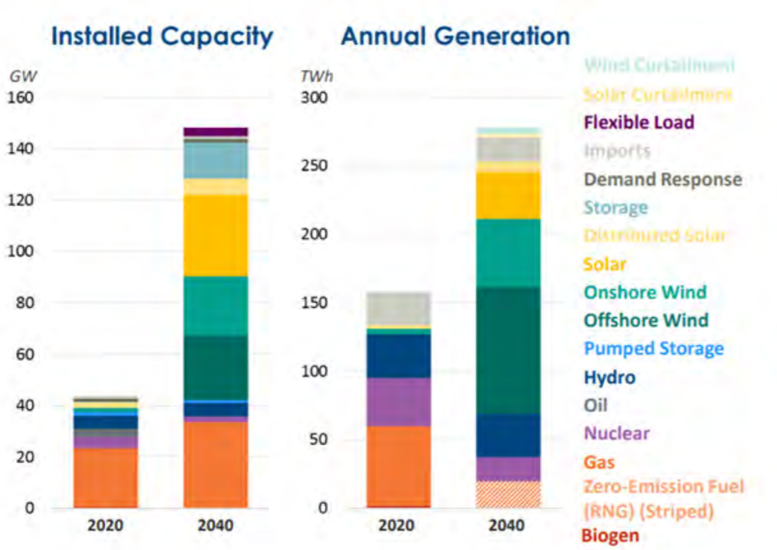
Costs and Benefits: Building-segment-specific and citywide results for each modeled year, including:

- CO_2e and local pollutant emissions
- Building owner implementation costs and benefits collected over time (by segment and aggregated) for covered buildings
- For non-covered buildings, implementation costs, allowance sales revenues, and other private costs/benefits (these entities will only uptake measures if provided some incentive, such as City funding or the creation of credits for sale)
- Total social costs and benefits can be determined via post-processing to the extent these differ from the private costs and benefits (e.g. by accounting for the social cost of carbon emissions, or cost/benefits accrued to entities *other than the building owners*), and to compare various cap-and-trade program designs

Carbon Market Outcomes: Carbon market results would be produced for each modeled study year (intervening years will be estimated via interpolation). Most parameters can be reported at the citywide level and disaggregated to the individual building segment level:

- Carbon price
- Penalties incurred for emissions exceeding LL97 caps (in both tCO_2e and $)
- Net purchase and sale volumes of credits
- Other market outcomes relevant to a particular policy (e.g. banking volumes by year)

Figure 1. Installed Capacity and Annual Generation in 2020 and 2040.



Source: Lueken et al. New York's Evolution to a Zero Emission Power System: Modeling Operations and Investment Through 2040. May 18, 2020.

Electricity Prices and Emissions

Electricity delivery rates and surcharges are estimated using Consolidated Edison average monthly New York City bills.[15] These reports estimate Consolidated Edison electricity delivery rates by customer type, including bill surcharges.[16] We use flat delivery rates for each building segment, based on segment building type and monthly unit and/or building electricity usage.[17]

Fossil fuel prices are forecast based on a blend of NYMEX Futures pricing and EIA Energy Outlook forecasts. NYMEX future prices are useful to estimate near-term fuel prices, as they represent the current expectations of fuel prices in the short-term.[18] However, futures pricing is limited to a few years into the future before it begins to lose resolution, as prices begin to reflect long-term trends rather than near-term expectations. Projected long-term price changes for fossil fuels are provided from the EIA 2020 Energy Outlook.[19] To estimate fuel prices for this study, we blend NYMEX and EIA price information to develop near-term and long-term estimates respectively. Average natural gas delivery and surcharge costs are estimated for each building segment according to their annual consumption and customer type using Consolidated Edison average customer bill reports.[20] Information regarding delivered fuel oil pricing in New York City is not readily available. Therefore, we use historical NYMEX day-ahead prices and New York City heating oil delivered prices to estimate a fuel-delivery adder for all buildings in New York City.[21]

LL97 directly establishes GHG coefficients for the first compliance period (2024–2029) for grid-tied electricity and several types of fossil fuels that can be burned onsite (natural gas, fuel oil #2, fuel oil #4, and district steam). The law instructs DOB to establish coefficients for grid-tied electricity for the post-2029 period by rule. For modeling purposes, this Study assumed that the grid would fully decarbonize by 2040 in accordance with the targets set by the CLCLA, and that the carbon intensity of coefficients for grid-tied electricity would reflect this pace. For non-CO_2 pollutant emissions, MOC&S has provided values for all fuel types.

15. As defined in Consolidated Edison documents, delivery charges include a customer charge, delivery charges, monthly adjustment clause and adjustment, processing charges, delivery revenue surcharges, revenue decoupling mechanism adjustments, dynamic load management surcharge, and applicable metering charges. We also include additional surcharges listed, such as systems benefits charges, clean energy standard delivery surcharges, and other tax surcharges.

16. Consolidated Edison, Average Monthly Bills, available at https://www.coned.com/-/media/files/coned/documents/save-energy-money/using-private-generation/historical-average-full-service-electric-rates.pdf?la=en (accessed June 6th, 2020); Edison Electric Institute, Typical Bills and Average Rates Report Winter 2019; Edison Electric Institute, Typical Bills and Average Rates Report Summer 2019.

17. We use a flat rate because abatement measures considered in this study are primarily measures aimed at reducing energy consumption, rather than peak load shifting. In addition, data granularity is not sufficient to match the complexity of tariff structures and there remains much uncertainty regarding how hourly demand profiles will evolve, how abatement measures will impact hourly demand, and the changes in rate component pricing.

18. NYMEX Futures pricing was collected on May 22nd, 2020.

19. Energy Information Agency, Annual Energy Outlook 2020, January 2020, available at https://www.eia.gov/outlooks/aeo/ (accessed June 14, 2021).

20. Ibid. Delivery charges include base rate charges, processing charges, delivery revenue surcharges, revenue decoupling mechanism adjustments, commodity surcharges, and monthly rate adjustments.

21. New York State Energy Research & Development Authority, Monthly Average Home Heating Oil Prices, available at https://www.nyserda.ny.gov/researchers-and-policymakers/energy-prices/home-heating-oil/monthly-average-home-heating-oil-prices (accessed May 29, 2020).

APPENDIX C—Detailed Results of Initial Model Runs

The color scales in the detailed tables below show relative values across ***each row*** of the table: the darkest green is the highest value in that row, the darkest red is the lowest value in that row. Where there is a dotted line around several rows, the color scale shows relative values for all rows that are outlined. As a general rule of thumb, **green = good, darkest green = best. Orange = bad, darkest orange = worst. All monetary values are in 2020$ USD and 2020 NPV.**

None of these scenarios includes the transfer payments from an auction.

I. Benefits Overview

	SIMPLE TRADING	PRICE FLOOR			BANKING				EJC POLICIES		
		$25	$50	75	Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
Overall Net Benefits	$1,280	$3,015	$4,443	$6,341	$1,155	$1,372	$1,994	$2,748	$1,602	$1,975	$1,821
Owners	$395	$849	$1,219	$1,930	$907	$424	$922	$1,101	$433	$485	$445
Tenants	$49	$78	$106	$217	$89	$62	$96	$109	$25	$44	$21
Penalties to City	-$153	-$177	-$178	-$178	-$224	-$167	-$167	-$224	-$176	-$175	-$176
Change in GHGs	$18	$354	$398	$462	$202	$12	$1	$278	$29	$80	$38
Avoided Deaths (Low)	$971	$1,911	$2,898	$3,910	$181	$1,041	$1,142	$1,484	$1,291	$1,541	$1,493
Avoided Deaths (High)	$2,346	$4,553	$6,986	$9,355	$460	$2,487	$2,692	$3,615	$3,279	$3,920	$3,680
EJC Net Benefits PSF ($/Sqft)											
Overall	$1.80	$3.80	$5.30	$7.20	$0.50	$1.90	$1.90	$2.60	$0.90	$1.10	$1.50
Owners	$0.10	$0.30	$0.50	$0.70	$0.40	$0.10	$0.30	$0.40	$0.10	$0.10	$0.20
Tenants	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Lower GHG	$0.00	$0.20	$0.20	$0.30	$0.10	$0.00	-$0.10	$0.10	$0.00	$0.00	$0.10
Avoided Deaths	$1.70	$3.20	$4.60	$6.20	$0.10	$1.80	$1.60	$2.10	$0.90	$1.00	$1.20
Non-EJC Net Benefits PSF ($/Sqft)											
Overall	$0.80	$1.70	$2.60	$3.70	$1.10	$0.80	$1.40	$1.90	$0.60	$0.80	$0.40
Owners	$0.30	$0.70	$1.00	$1.50	$0.70	$0.30	$0.80	$0.90	$0.30	$0.30	$0.20
Tenants	$0.00	$0.10	$0.10	$0.20	$0.10	$0.10	$0.10	$0.10	$0.00	$0.00	$0.00
Lower GHG	$0.00	$0.30	$0.30	$0.30	$0.20	$0.00	$0.00	$0.20	$0.00	$0.00	$0.00
Avoided Deaths	$0.40	$0.70	$1.20	$1.60	$0.10	$0.40	$0.50	$0.70	$0.30	$0.40	$0.20

	SIMPLE TRADING	PRICE FLOOR				BANKING				EJC POLICIES		
		$25	$50	75		Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
Abatement, REC, and Offset Cost Savings ($/Sqft)												
EJC	$0.09	$0.12	$0.20	$0.26		$0.36	$0.12	$0.19	$0.32	$0.04	$0.02	$0.04
Non-EJC	$0.02	$0.02	$0.06	$0.04		$0.19	$0.06	$0.04	$0.09	$0.02	$0.00	$0.09
II. Investment												
Building Investments ($/Sqft)												
EJC	$0.12	$0.20	$0.23	$0.28		-$0.08	$0.11	$0.03	-$0.02	$0.06	$0.06	$0.13
Non-EJC	$0.12	$0.21	$0.29	$0.47		$0.06	$0.10	$0.14	$0.17	$0.10	$0.11	$0.00
Building Investments ($ million)												
EJC	$40	$69	$80	$95		-$29	$37	$9	-$8	$57	$60	$126
Non-EJC	$165	$306	$416	$674		$82	$139	$204	$245	$225	$249	-$9
III. Trade Revenue												
Net Trade Revenue ($ million)												
EJC	$47	$87	$121	$158		$65	$48	$41	$71	$67	$64	$110
Non-EJC	$105	$216	$339	$504		$208	$119	$126	$228	$110	$112	$66
IV. GHG Reductions												
GHG Reduction, by type, EJC (103 Metric Ton)												
EE	652	1123	1282	1475		-189	708	300	128	947	978	2810
Offset	-115	1180	1180	1180		1180	-115	-120	1180	-117	0	-120
REC	-403	-456	-523	-542		-589	-538	-589	-589	-391	-303	-364
GHG Reduction, by type, Non-EJC (103 Metric Ton)												
EE	1801	3118	4048	5443		1017	1795	2115	2461	1834	2065	195
Offset	-334	3857	3857	3857		3857	-334	-352	3857	-347	-2	-354
REC	-784	-888	-954	-1150		-1246	-942	-1246	-1246	-820	-579	-845
GHG Reduction, by type, EJC, PSF												
EE	1.9	3.3	3.7	4.3		-0.6	2.1	0.9	0.4	1.0	1.0	2.9
Offset	-0.3	3.4	3.4	3.4		3.4	-0.3	-0.4	3.4	-0.1	0.0	-0.1
REC	-1.2	-1.3	-1.5	-1.6		-1.7	-1.6	-1.7	-1.7	-0.4	-0.3	-0.4

	SIMPLE TRADING	PRICE FLOOR				BANKING				EJC POLICIES		
		$25	$50	75		Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
GHG Reduction, by type, non-EJC, PSF												
EE	1.7	2.9	3.7	5.0		0.9	1.6	1.9	2.3	1.4	1.5	0.1
Offset	-0.3	3.5	3.5	3.5		3.5	-0.3	-0.3	3.5	-0.3	0.0	-0.3
REC	-0.7	-0.8	-0.9	-1.1		-1.1	-0.9	-1.1	-1.1	-0.6	-0.4	-0.6
Aggregate Emissions Reductions GHG (PSF)												
EJC	0.40	5.40	5.70	6.20		1.20	0.20	-1.20	2.10	0.40	0.70	2.40
Non-EJC	0.60	5.60	6.40	7.50		3.30	0.50	0.50	4.60	0.50	1.10	-0.70
V. Co-Pollutant Emissions												
PM, Aggregate (Metric Ton)												
EJC	445	816	952	1092		-190	494	165	80	697	722	2246
Non-EJC	813	1515	2117	2793		-84	782	644	938	885	1042	-389
NO^x, Aggregate (Metric Ton)												
EJC	-42	-33	-23	4		-10	-43	-16	-7	-40	-22	28
Non-EJC	56	119	273	284		243	54	247	269	57	87	69
SO^x, Aggregate (Metric Ton)												
EJC	21	45	53	63		-12	26	9	4	37	39	144
Non-EJC	60	102	138	177		10	58	51	66	66	75	-7
Avoided Deaths ($ million) *Low*												
EJC	132	215	278	354		-25	123	79	88	192	204	248
Non-EJC	88	154	223	291		-2	75	78	97	98	114	63
Avoided Deaths ($ million) *High*												
EJC	312	499	654	828		-58	291	182	203	471	505	598
Non-EJC	214	379	550	712		-4	180	186	249	259	299	166

	SIMPLE TRADING	PRICE FLOOR				BANKING				EJC POLICIES		
		$25	$50	75		Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
Pollutant Reductions by Period (Metric Ton)												
PM, by period, EJC												
2024–2029	-74	50	152	220		123	-74	144	188	-74	-2	79
2030–2034	19	67	78	118		-43	99	-26	-2	23	5	227
2035–2039	27	82	96	132		-38	113	-4	5	34	14	278
2040–2050	477	619	622	612		-235	359	47	-122	716	704	1646
PM, by period, non-EJC												
2024–2029	-89	169	546	789		396	-92	443	625	-88	49	-88
2030–2034	56	119	214	409		8	295	84	205	36	49	-140
2035–2039	72	161	267	451		37	335	178	233	52	63	-137
2040–2050	774	1070	1083	1128		-527	242	-62	-143	883	881	-26
NO_x, by period, EJC												
2024–2029	-45	-36	-27	-1		-4	-46	-11	-3	-45	-24	5
2030–2034	0	0	0	0		0	0	0	0	0	0	2
2035–2039	0	0	0	0		0	0	0	0	0	0	5
2040–2050	2	11	11	11		0	0	0	0	11	11	19
NO_x, by period, non-EJC												
2024–2029	37	106	261	276		248	35	245	269	37	71	59
2030–2034	0	0	0	5		0	5	0	0	0	0	0
2035–2039	0	1	2	5		0	5	0	2	0	0	0
2040–2050	10	11	11	11		-4	0	0	-1	11	11	0
SO_x, by period, EJC												
2024–2029	-6	3	7	13		6	-6	7	12	-6	0	6
2030–2034	0	5	5	5		-5	5	0	0	0	0	15
2035–2039	0	5	5	6		0	5	0	0	0	0	19
2040–2050	27	34	34	34		-13	22	0	-11	44	44	102
SO_x, by period, non-EJC												
2024–2029	-2	14	38	51		29	-2	32	43	-2	6	1
2030–2034	5	10	15	25		4	20	7	14	5	5	-5
2035–2039	5	12	17	30		5	22	13	15	5	5	-5
2040–2050	50	66	67	72		-25	19	-3	-3	57	57	-2

	SIMPLE TRADING	PRICE FLOOR				BANKING				EJC POLICIES		
		$25	$50	75		Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
VI. Energy Use Reduction												
Building Investments ($/Sqft)												
Electricity (GWh)	-309	1,593	2,792	9,556		2,476	-1,129	3,024	3,495	-207	-6,548	-1,330
Natural Gas (GBtu)	25,641	44,395	53,723	68,164		-7,603	26,341	12,464	14,783	32,162	85,946	40,822
Fuel Oil #2 (GBtu)	1,809	4,525	6,961	9,174		-2,855	1,668	296	1,459	2,342	18,403	-618
Fuel Oil #4 (GBtu)	-9,165	490	1,758	1,995		1,913	-21	1,811	2,035	5	205	634
District Steam (GBtu)	19,775	23,525	27,400	28,977		19,731	21,780	22,914	22,578	18,052	19,502	17,603
VII. Participation												
Participation, in non-EJCs (% Share of Eligible SF Participating in Trading)												
Covered	86%	100%	100%	100%		100%	83%	82%	100%	86%	88%	92%
Opt-in	0%	0	0	0		0	0	0	0	24%	0%	22%
Participation, in EJCs (% Share of Eligible SF Participating in Trading)												
Covered	84	100	100	100		100	83	81	100	83	TBD	TBD
Opt-in	0	0	0	0		0	0	0	0	34	TBD	TBD

	SIMPLE TRADING	**PRICE FLOOR**				**BANKING**				**EJC POLICIES**		
		$25	$50	75		Simple	Delayed	No Offsets	+ $25PF	Opt-In	Delay to 2030 (+Opt-In)	20% EJC Subsidy (+Opt-In)
VIII. Carbon Price ($/metric ton)												
2024	3	25	50	75		32	3	37	25	3	0	0
2025	0	25	50	75		34	0	40	27	0	0	0
2026	0	25	50	75		35	0	42	28	0	0	0
2027	0	25	50	75		37	0	44	30	0	0	0
2028	0	25	50	75		39	0	46	32	0	0	0
2029	0	25	50	75		42	0	49	33	0	0	0
2030	99	74	50	75		44	99	52	35	99	99	99
2031	98	73	50	75		46	98	55	37	98	98	98
2032	96	71	50	75		49	96	58	39	96	96	96
2033	102	77	50	75		52	70	61	41	102	102	102
2034	108	25	50	75		54	74	64	44	58	23	0
2035	0	25	50	75		57	78	68	46	0	0	0
2036	0	25	50	75		61	82	71	48	0	0	0
2037	0	25	50	75		64	87	75	51	0	0	0
2038	0	25	50	75		67	92	79	54	0	0	0
2039	0	25	50	75		71	97	84	57	0	0	0
2040	173	173	173	173		75	102	88	60	173	173	173
2041	170	170	170	170		79	108	93	63	170	170	170
2042	166	166	166	166		84	114	98	67	166	166	166
2043	162	162	162	162		88	120	104	70	162	162	162
2044	159	159	159	75		93	127	109	74	159	159	159
2045	156	156	156	75		98	133	115	78	156	156	156
2046	152	152	152	75		104	141	122	83	152	152	125
2047	149	149	149	75		109	149	128	87	149	149	0
2048	146	146	146	75		115	146	136	92	146	146	0
2049	143	143	143	75		122	143	143	97	110	143	0
2050	140	140	140	140		128	140	140	102	140	140	140

APPENDIX D—Detailed Evaluation Tables of the Two Illustrative Trading Proposals

The Study analyzed Proposals #1 and #2 against eight categories of metrics. This appendix reports the results of this analysis. Unless otherwise noted, the results are reported for the entire study period (2024–2050).

1. Cost-Benefit Analyses

1.1. Metric: Cumulative benefits and costs of illustrative trading proposals compared to LL97 base case without trading during the study period

Objective: The higher the positive difference between monetized benefits and costs, the better. As we are analyzing the potential benefits and costs of a trading program, all costs and benefits are the incremental costs and benefits compared to the LL97 base case without trading.

TOTAL

(2020 NPV in millions of dollars):

Group	Proposal 1	Proposal 2
All	4547	3015

Breakdown		
Property owners	304	854
City Agencies and Offices	450	-251
Tenants	98	107
Society: GHG emissions	100	20
Society: Avoided deaths	3595	2285

(2020 NPV dollar by square footage):

Group	Proposal 1	Proposal 2
All	1.9	1.3

Breakdown		
Property owners	0.1	0.4
City Agencies and Offices	0.2	-0.1
Tenants	0	0
Society: GHG emissions	0	0
Society: Avoided deaths	1.5	1

BREAKDOWN BY EJC STATUS AND GROUP

EJCs (2020 NPV in millions of dollars):

Group	Proposal 1	Proposal 2
All EJC groups	3323	1790
Property owners	427	208
Tenants	3	3
Society: GHG emissions	115	-5
Society: Avoided deaths	2778	1584

EJCs (2020 NPV dollar by square footage):

Group	Proposal 1	Proposal 2
All EJC groups	3.4	1.8
Property owners	0.2	0.1
Tenants	0	0
Society: GHG emissions	0.1	0
Society: Avoided deaths	2.8	1.6

Non-EJCs (2020 NPV in millions of dollars):

Group	Proposal 1	Proposal 2
All non-EJC groups	773	1476
Property owners	-123	646
Tenants	95	104
Society: GHG emissions	-16	25
Society: Avoided deaths	817	701

Non-EJCs (2020 NPV dollar by square footage):

Group	Proposal 1	Proposal 2
All non-EJC groups	0.6	1.1
Property owners	-0.1	0.3
Tenants	0.1	0.1
Society: GHG emissions	0	0
Society: Avoided deaths	0.6	0.5

2. Overall Emission Reductions

2.1. Metric: Reductions in GHG emissions compared to the LL97 base case without trading (in thousand metric tons)

Objective: The higher, the better. Higher relative reductions in emissions compared to a no-trading scenario indicate that the trading program incentivizes additional reduction in emissions.

Proposal 1	Proposal 2
2695	828

2.2. Metric: Reductions in GHG emissions compared to the LL97 base case without trading by compliance measure (in thousand metric tons)

Objective: This metric indicates how properties are choosing to comply, and whether the trading program results in lasting investments leading to emissions reductions.

By abatement measure:

Abatement Measure	Proposal 1	Proposal 2
DG	0	0
EEE	5777	3768
Offset	-884	-884
REC	-2199	-2055

By property type:

Property type	Proposal 1	Proposal 2
Hotel	386	551
Industrial	-806	-800
Institutional	2580	1072
Office	1824	1605
Resi Condo	-1205	-1576
Resi Market-Rate	-485	-594
Retail	-365	-470
Affordable Housing	767	1042
NYCHA	0	0

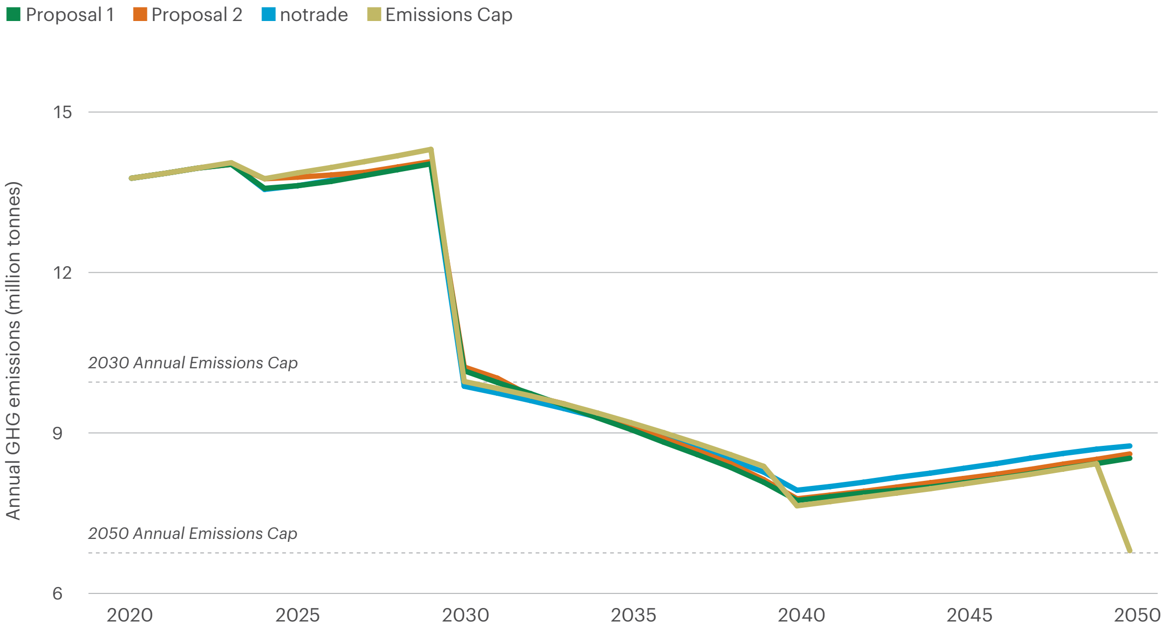
2.3. Metric: Reductions in local air pollutants ($PM_{2.5}$, NO_x, SO_x) compared to the LL97 base case without trading (in metric tons)

Objective: The higher, the better. Higher relative reductions in emissions compared to a no-trading scenario indicate that the trading program incentivizes additional reduction in emissions of local air pollutants.

Pollutant	Proposal 1	Proposal 2
$PM_{2.5}$	3427	2403
NO_x	380	702
SO_x	257	223

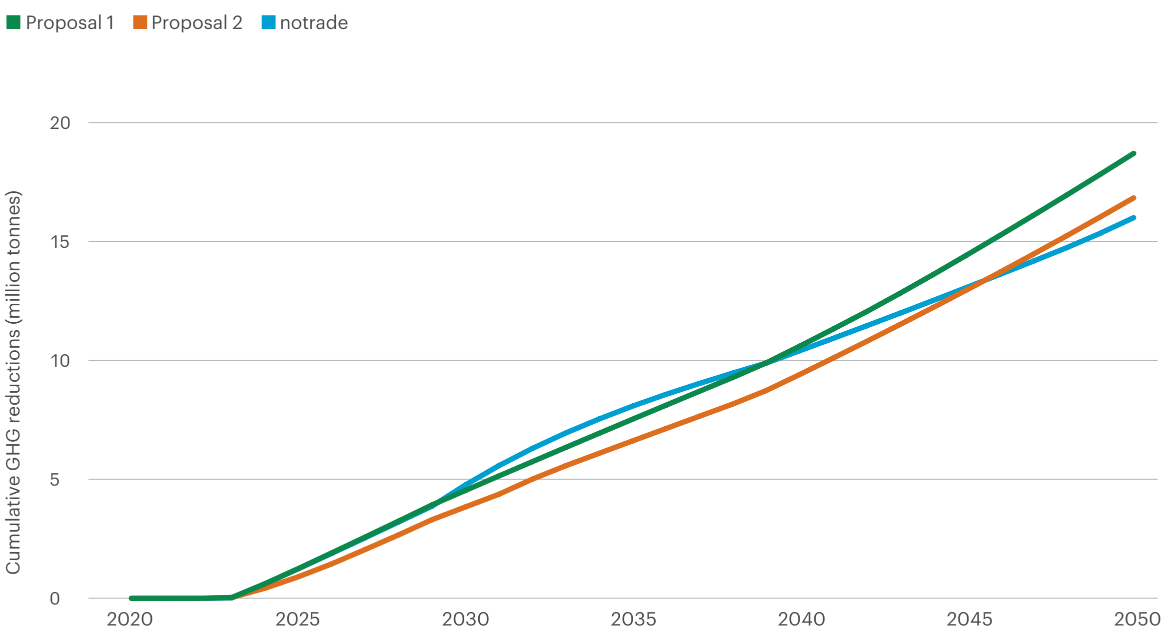
3. Timing

3.1 Metric: Annual greenhouse gas emissions compared to LL97 base case with no trading



3.2 Metric: Cumulative reductions in greenhouse gas emissions

Objective: The higher the cumulative reductions in early years, the sooner the emissions reductions take place.



3.3 Metric: Reductions in greenhouse gas emissions while the emissions cap is non-binding (2024–2029) for properties covered under LL97 compared to LL97 base case with no trading (in thousand metric tons)

Objective: The higher, the better. This metric keeps track of early action in LL97-covered properties.

Property type	Proposal 1	Proposal 2
All except Affordable Housing and NYCHA	484	-135
Affordable Housing and NYCHA	-447	-448

4. Environmental Justice

4.1 Metric: Aggregated investment by square footage by EJC status compared to the LL97 base case without trading (in 2020 NPV dollars per square footage)

Objective: The higher, the better. A comparison of investment in EJCs versus non-EJCs is informative of equitable investment in EJCs.

	Proposal 1	Proposal 2
Non-EJCs	0.08	0.12
EJCs	0.37	0.07

4.2. Metric: Additional investments by properties subject to prescriptive measures or non-covered properties by EJC status (in 2020 NPV dollars/sqft)

Objective: The higher, the better. This metric shows how a trading program might encourage additional investment from properties that are not covered or currently subject to prescriptive measures.

	Property type	Proposal 1	Proposal 2
Non-EJCs	All except Affordable Housing and NYCHA	0.08	0.1
	Affordable Housing and NYCHA	0.04	0.22
EJCs	All except Affordable Housing and NYCHA	0.8	0.05
	Affordable Housing and NYCHA	0.13	0.09

4.3. Metric: Square footage participating in trading, by coverage and EJC status (in percentage terms)

Objective: The higher, the better. This metric measures if properties find it beneficial to go beyond their baseline—i.e. "participate"—under a given policy scenario. It indicates how much additional investment a policy could encourage from opt-in buildings.

	Property Type	Proposal 1	Proposal 2
Non-EJCs	All except Affordable Housing and NYCHA	79%	84%
	Affordable Housing and NYCHA	18%	49%
EJCs	All except Affordable Housing and NYCHA	81%	81%
	Affordable Housing and NYCHA	21%	60%

4.4. Metric: Net trade revenue compared to the LL97 base case without trading, by EJC status

Objective: The higher, the better. This metric measures how much trade revenue flows into EJCs. It includes trade revenues and costs, penalties paid, and auction costs.

In 2020 NPV dollars per square footage:

	Proposal 1	Proposal 2
Non-EJCs	-0.62	0.09
EJCs	0.28	0.26

In 2020 NPV million dollars total square feet:

	Proposal 1	Proposal 2
Non-EJCs	-848	117
EJCs	273	253

4.5. Metric: Reductions in owners' net costs by EJC status compared to LL97 base case without trading

Objective: The higher, the better. This metric shows how a trading program reduces costs for property owners in EJCs and non-EJCs. It includes trade revenues and costs, costs of compliance measures, and associated savings in energy costs.

In 2020 NPV dollars per square footage

	Proposal 1	Proposal 2
Non-EJCs	-0.09	0.47
EJCs	0.43	0.21

In 2020 NPV million dollars

	Proposal 1	Proposal 2
Non-EJCs	-123	646
EJCs	427	208

4.6. Metric: GHG emissions abated by compliance measure by EJC status compared to LL97 base case without trading

Objective: Reductions in GHG with trading should be at least as large as with no-trading. A trading program should not incentivize increases in emissions originating in EJCs compared to a no-trading scenario. This metric indicates how properties are choosing to comply in EJCs and non-EJCs, and whether the trading program results in lasting investments leading to emissions reductions.

In metric tons:

Non-EJCs:

Abatement Measure	Proposal 1	Proposal 2
ALL	-348	742
DG	0	0
EEE	1467	2454
Offset	-441	-441
REC	-1374	-1271

EJCs:

Abatement Measure	Proposal 1	Proposal 2
ALL	3045	88
DG	0	0
EEE	4311	1314
Offset	-442	-442
REC	-824	-784

In metric tons by thousand square feet:

Non-EJCs:

Abatement Measure	Proposal 1	Proposal 2
ALL	-0.3	0.5
DG	0	0
EEE	1.08	1.8
Offset	-0.32	-0.32
REC	-1.01	-0.93

EJCs:

Abatement Measure	Proposal 1	Proposal 2
ALL	3.1	0.1
DG	0	0
EEE	4.4	1.3
Offset	-0.4	-0.4
REC	-0.8	-0.8

4.7 Metric: Change in local pollutants abated compared to LL97 base case without trading by EJC status

Objective: A trading program should not incentivize increases in local pollutant emissions originating in EJCs compared to a no-trading scenario. Under this metric, a higher number is better because it signals more pollutant reductions.

In metric tons:

$PM_{2.5}$:

	Proposal 1	Proposal 2
Non-EJCs	234	1176
EJCs	3197	1226

NO_x:

	Proposal 1	Proposal 2
Non-EJCs	340	445
EJCs	40	259

SO_x:

	Proposal 1	Proposal 2
Non-EJCs	43	117
EJCs	216	104

In grams per square footage:

$PM_{2.5}$:

	Proposal 1	Proposal 2
Non-EJCs	0.17	0.86
EJCs	3.25	1.25

NO_x:

	Proposal 1	Proposal 2
Non-EJCs	0.25	0.33
EJCs	0.04	0.26

SO_x:

	Proposal 1	Proposal 2
Non-EJCs	0.03	0.09
EJCs	0.22	0.11

4.8. Metric: Projected $PM_{2.5}$-related mortality impacts compared to LL97 base case without trading by EJC status (in averted premature deaths associated with primary and secondary $PM_{2.5}$ during the 2024–2050 period)

Objective: A trading program should not lead to worse air quality health impacts compared to the LL97 base case without trading.

Avoided premature deaths:

	Proposal 1	Proposal 2
Non-EJCs	119	110
EJCs	485	270

4.9. Metric: Projected reductions in energy consumption costs compared to LL97 base case without trading by EJC status

Objective: This metric is informative about the potential reductions in energy costs in EJCs with a trading program compared to a no-trading scenario.

In 2020 NPV million dollars:

Owners:

	Proposal 1	Proposal 2
Non-EJCs	753	623
EJCs	345	-17

Tenants:

	Proposal 1	Proposal 2
Non-EJCs	95	104
EJCs	2	3

In 2020 NPV dollars per square footage:

Owners:

	Proposal 1	Proposal 2
Non-EJCs	0.55	0.46
EJCs	0.35	-0.02

Tenants:

	Proposal 1	Proposal 2
Non-EJCs	0.07	0.08
EJCs	0	0

5. Owners' Net Costs

Metric: Net reductions in owners' net costs compared to LL97 base case without trading

Objective: The higher, the better. Large reductions in costs compared to a scenario with no trading is indicative of trading providing flexibility to property owners to comply with LL97 in a cost-effective manner. It includes trade revenues and costs, costs of compliance measures, and associated savings in energy costs, net of savings passed on to tenants. A comparison of savings across property types is indicative of which property types are accruing the most/least savings.

In millions of dollars (2020 NPV):

Property type	Proposal 1	Proposal 2
ALL	305	853
Affordable Housing	-6	-61
Hotel	24	104
Industrial	61	59
Institutional	58	127
NYCHA	3	2
Office	328	515
Resi Condo	-4	132
Resi Market-Rate	-30	48
Retail	-129	-73

In dollars (2020 NPV) by square footage:

Property type	Proposal 1	Proposal 2
ALL	0.13	0.364
Affordable Housing	-0.009	-0.09
Hotel	0.221	0.965
Industrial	0.429	0.412
Institutional	0.385	0.847
NYCHA	0.017	0.015
Office	0.747	1.174
Resi Condo	-0.011	0.341
Resi Market-Rate	-0.168	0.27
Retail	-1.218	-0.691

6. Simplicity of Use

Qualitative indicator: Assessment of complexity of implementation from the point of view of property owners, compared to LL97 base case without trading

Objective: The less complex, the better.

	Proposal 1	Proposal 2
Simplicity of Use	High	Medium

Rubric:

Low: Requires *no* additional action, behavior change, or capacity-building among participating building owners.

Medium: Requires *some* level of capacity-building or existing sophistication from building owners that choose to engage with the specific policy design element (e.g. banking, opt in).

High: Requires either *substantially greater* capacity-building or existing sophistication from most building owners.

7. Implementation Complexity

7.1. Qualitative indicator: Assessment of the complexity of administering the program

Objective: The less complex, the better. This metric assesses how complex it would be for the City to administer the trading proposals after the initial establishment of a trading program.

	Proposal 1	Proposal 2
Regulatory Complexity	Medium	Medium
Institutional Complexity	High/Medium	Medium
Monitoring Complexity	High/Medium	Medium

Rubric:

A. Regulatory complexity

Low: Regulations, once designed, do not require updates.

Medium: Regulations, once designed, require periodic updates.

High: Regulations require frequent upgrades to adjust parameters.

B. Institutional complexity

Low: Does not require substantial additional institutional capacity.

Medium: Requires some, but not substantial, additional institutional capacity.

High: Requires substantial additional institutional capacity.

C. Monitoring complexity

Low: Does not require substantial monitoring beyond basic compliance.

Medium: Requires some additional monitoring.

High: Requires substantial monitoring of multiple instruments.

7.2. Qualitative indicator: Assessment of the complexity of initially establishing the program based on whether it would require minor or substantially new City legislation, state legislation, etc.

Objective: The less complex, the better. This metric assesses the complexity for the City of initially establishing the trading program.

	Proposal 1	Proposal 2
Complexity of Establishing the Program	High	Medium

Rubric:

Low: Requires new city legislation, but does not require substantial rewriting of LL97 or state legislation.

Medium: Requires new city legislation and substantial rewriting of LL97, but not state legislation.

High: Requires new city legislation, substantial rewriting of LL97, and potentially state legislation.

8. Robustness

Qualitative indicator: Assessment of the sensitivity of outcomes to the costs of compliance options, energy prices, technology efficiencies, variabilities in weather, macroeconomic events (e.g. recessions.)

Objective: The more robust, the better. This metric focuses on qualitative results of the proposals rather than the variation in the numerical results. An increase or a decrease in the numerical results under different sensitivities does not necessarily mean that the results are undesirable, just that the magnitude of change is sensitive to external factors. For example, the additional greenhouse gas abatement might triple with one design under the optimistic scenario or be cut in half in another. However, as long as both the optimistic and the pessimistic scenarios show higher abatement for that design compared to the no-trade base case, the qualitative results do not change and we would classify that result as robust.

	Proposal 1	Proposal 2
Overall Robustness	Medium	Medium

Rubric:

Low: Multiple key metrics change qualitatively.

Medium: Some metrics change, but key metrics do not change qualitatively.

High: None of the key metrics change qualitatively.

Below are more detailed tables analyzing the results of the sensitivity scenario runs. For a given proposal, the "optimistic" and "pessimistic" columns show whether the metrics in those scenarios are higher or lower compared to the metrics in the base case scenario. The "Qualitative Change" column shows whether or not there is a directional change in the results compared to the base case scenario (i.e. whether the sign of a given metric changes compared to the base case scenario).

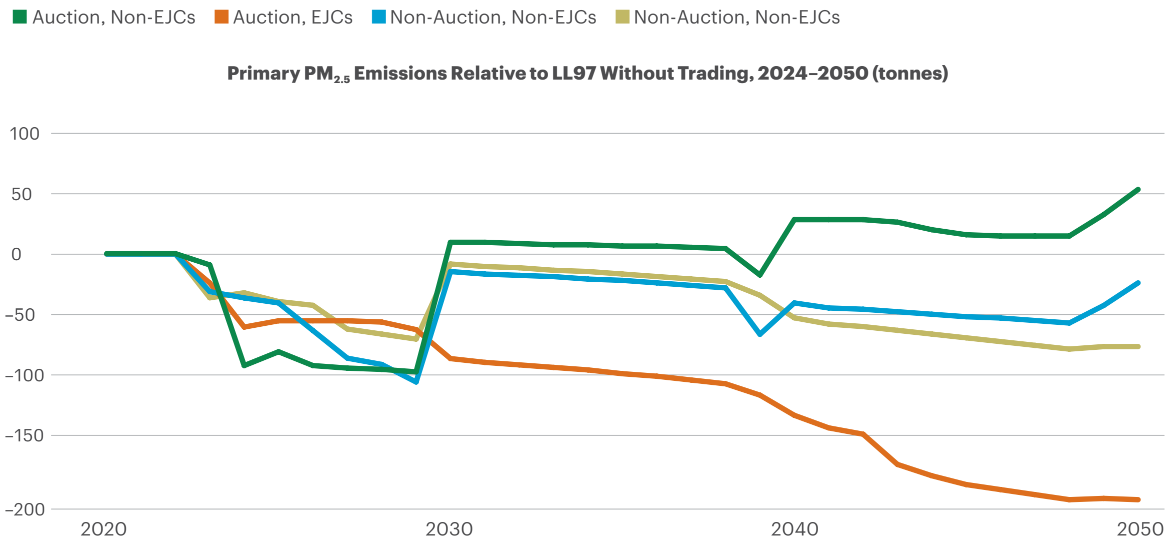
For example, assume that Proposal 1 scores as +10 on a given metric under the base case assumptions. If a sensitivity scenario changes the metric to be +12, it would be classified as "higher" and "no qualitative change." If a sensitivity scenario changes the metric to be +8, it would be classified as "lower" and "no qualitative change." However, if a sensitivity scenario changes the metric to be -2, it would be a qualitative change.

Proposal 1			
Metric	**Optimistic**	**Pessimistic**	**Qualitative Change**
1.1	Higher	Lower	No
2.1	Higher	Lower	No
2.2	Higher	Lower	No
2.3 - $PM_{2.5}$	Higher	Higher	No
2.3 - SO_x	Higher	Higher	No
2.3 - NO_x	Lower	Lower	No
3.1	Higher	Similar	No
3.2	Higher	Similar	No
4.1	Higher	Higher	No
4.2	Higher	Higher	No
4.3	Higher	Lower	No
4.4	Lower	Higher	Yes
4.5	Higher	Higher	Yes
4.6	Higher	Higher	Yes
4.7 - $PM_{2.5}$	Higher	Higher	Yes
4.7 - SO_x	Higher	Higher	Yes
4.7 - NO_x	Lower	Lower	Yes
4.8	Higher	Higher	Yes
4.9	Lower	Lower	Yes
5.1	Higher	Higher	No

Proposal 2			
Metric	**Optimistic**	**Pessimistic**	**Qualitative Change**
1.1	Lower	Higher	No
2.1	Higher	Lower	No
2.2	Higher	Lower	No
2.3 - $PM_{2.5}$	Higher	Higher	Yes
2.3 - SO_x	Higher	Higher	No
2.3 - NO_x	Higher	Higher	Yes
3.1	Higher	Similar	No
3.2	Lower	Similar	No
4.1	Higher	Higher	No
4.2	Lower	Higher	No
4.3	Higher	Higher	No
4.4	Lower	Lower	Yes
4.5	Higher	Lower	No
4.6	Higher	Higher	No
4.7 - $PM_{2.5}$	Higher	Higher	Yes
4.7 - SO_x	Higher	Higher	Yes
4.7 - NO_x	Higher	Higher	Yes
4.8	Lower	Higher	Yes
4.9	Lower	Higher	Yes
5.1	Lower	Higher	No

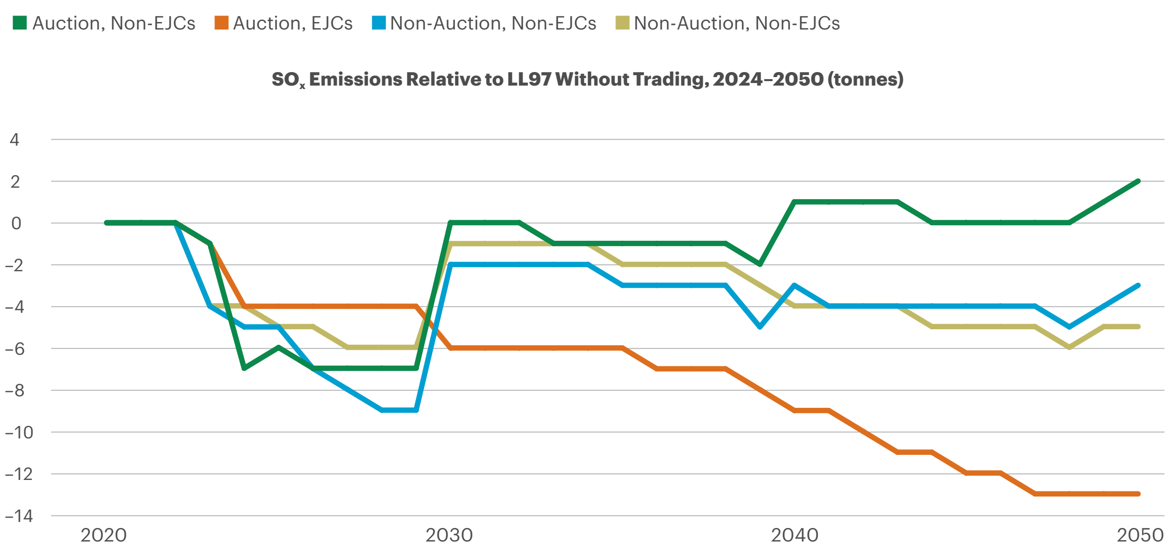
APPENDIX E—Changes in GHG and Local Air Pollution Over Time under Illustrative Proposals

Primary $PM_{2.5}$ emissions are lower in all years, *except* within non-EJCs under the auction design, due to a shift in building investment towards EJCs.



Note that the x-axis represents LL97 without trading. Emissions under no-trade are not constant but are set as the baseline for comparison.

SO_x emissions are lower in all years, *except* within non-EJCs under the auction design, due to a shift in building investment towards EJCs.

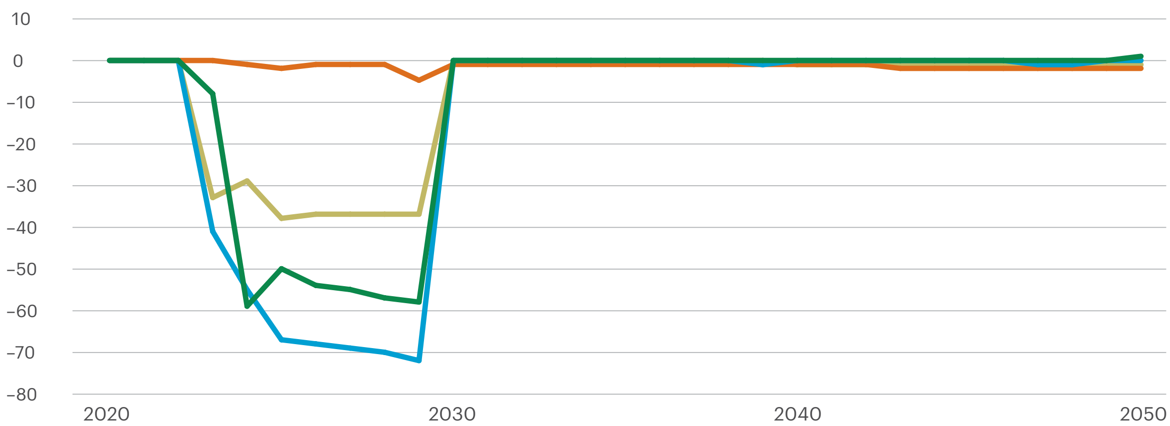


Note that the x-axis represents LL97 without trading. Emissions under no-trade are not constant but are set as the baseline for comparison.

NO_x emissions are lower for both designs in all years, in both EJCs and non-EJCs.

■ Auction, Non-EJCs ■ Auction, EJCs ■ Non-Auction, Non-EJCs ■ Non-Auction, Non-EJCs

NO_x Emissions Relative to LL97 Without Trading, 2024–2050 (tonnes)

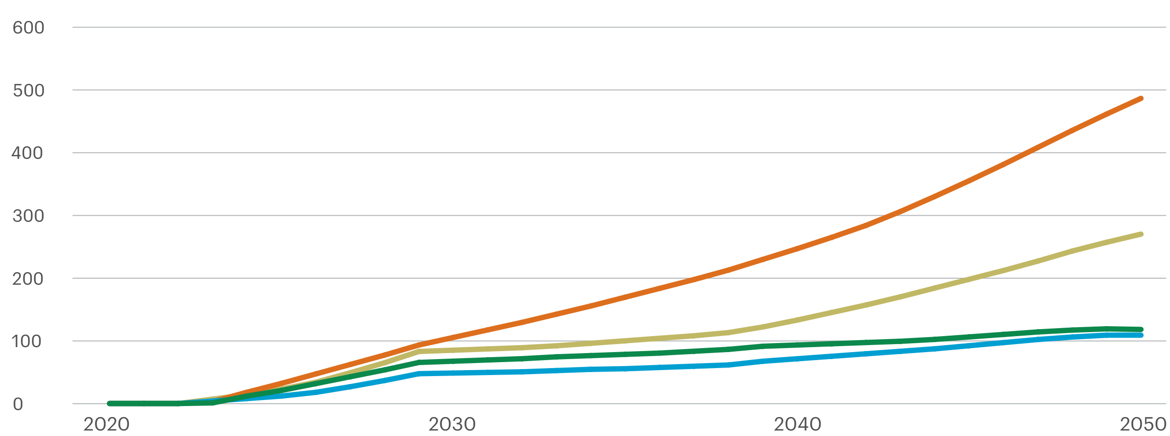


Note that the x-axis represents LL97 without trading. Emissions under no-trade are not constant but are set as the baseline for comparison.

Due to reduced local pollutants, all designs avoid premature deaths in EJCs and non-EJCs. The auction design saves more lives in EJCs and non-EJCs.

■ Auction, Non-EJCs ■ Auction, EJCs ■ Non-Auction, Non-EJCs ■ Non-Auction, Non-EJCs

Cumulative Additional Avoided Deaths vs. LL97 Without Trading, 2024–2050



Note that the x-axis represents LL97 without trading.

APPENDIX F—Stakeholder Group Participants

Throughout the study process, the team consulted extensively with two stakeholder groups. The Mayor's Office of Climate and Sustainability convened one of the groups and the Urban Green Council convened the other. We list the members of the groups below to express gratitude for their service. Importantly, not all members of the group support the idea of carbon trading and they have not reviewed this final report.

Urban Green Council Stakeholder Group

Edward Amador, New York City Council

Ronnie Black, Marex Spectron

Austen Brandford, New York City Council

Carlos Castell Croke, NYLCV

Dickson C. Chin, Jones Day

Costa Constantinides, New York City Council

Cecil Corbin-Mark, WE ACT for Environmental Justice (*in memoriam*)

Molly Dee, Jaros, Baum & Bolles

Donna De Costanzo, Natural Resources Defense Council

Daniel Egan, Vornado Realty

Adriana Espinoza, Mayor's Office of Climate Policy and Programs

Jonathan Flaherty, Tishman Speyer

Phoebe Flaherty, ALIGN

Dirk Forrister, International Emissions Trading Association

Adam Freed, Bloomberg Associates

Ean Fullerton, New York City Council

Carlos Garcia, NYC Environmental Justice Alliance

John Gilbert, Rudin Management Co.

Jeff Gracer, Sive Paget Riesel

Crissy Haley, JLL

Chris Halfnight, Urban Green Council

Sam Hoffer, Verra

Carl Hum, Real Estate Board of New York

Sonal Jessel, WE ACT for Environmental Justice

Aaron Jones, SEIU 32BJ

Dr. Noah Kaufman, Center on Global Energy Policy, Columbia University

Vlada Kenniff, New York City Housing Authority

Laurie Kerr, LK POLICY LAB

John Mandyck, Urban Green Council

Danielle Manley, Urban Green Council

Andrew McKeon, Regional Greenhouse Gas Initiative, Inc. (RGGI)

David Miller, C40

Yuko Nishida, Renewable Energy Institute (formerly Tokyo Cap-and-Trade Program)

Evan Preminger, Cozen O'Connor

Frank Ricci, Rent Stabilization Association

Mary Ann Rothman, CNYC

Alec Saltikoff, JPMorgan Chase & Co.

Peggy Shepard, WE ACT for Environmental Justice

Pete Sikora, New York Communities for Change

Maritza Silva-Farrell, ALIGN: The Alliance for a Greater New York

Zachary Steinberg, Real Estate Board of New York

Amy Sugimori, 32BJ SEIU

Julie Tighe, NYLCV

Amy Turner, Sabin Center for Climate Change Law, Columbia University

Michael Wara, Stanford Woods Institute for the Environment

Nicholas Widzowski, Office of Council Member

Dr. Peter Wilcoxen, Syracuse University Maxwell School of Citizenship & Public Affair

Ellen Zielinski, New York City Housing Authority

Mayor's Office of Sustainability, Technical Advisory Committee

Christine Appah, New York Lawyers for the Public Interest

Eddie Bautista, New York City Environmental Justice Alliance

Brodie Boland, McKinsey

Gina Bocra, New York City Dept. of Buildings

Francesco Brindisi, New York City Office of Management & Budget

Steve Caputo, New York City Dept. of Citywide Administrative Services

Kim Darga, Housing Preservation and Development

Luke Falk, Related Companies Inc.

Carl Mas, New York State Energy Research & Development Authority

Curtis Probst, New York City Energy Efficiency Corp.

Cecil Scheib, New York University

Dana Schneider, Empire State Realty Trust

Jared Rodriguez, Lefrak Realty Group

Mark Rauch, Environmental Defense Fund

Samantha Wilt, Natural Resources Defense Council

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